Renewable Thermal Energy Alternatives for an Indigenous-led Aquaponic Greenhouse in the Alberta Boreal Forest Natural Region, Canada

A value-sensitive integrative analysis

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by

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Executive Summary

This thesis explores the potential to power an Indigenous-led Aquaponic Greenhouse in the Alberta Boreal Forest Natural Region with renewable thermal energy. In collaboration with LANDMARC and Fort McKay First Nation (FMFN), the research aims to bridge the perspectives of systems engineering and Traditional Ecological Knowledge (TEK) to propose a feasible and culturally aligned greenhouse design supplied by renewable heating alternatives.

The main objective of this study is to examine and develop the most critical areas of the Aquaponic Greenhouse project to get a better understanding of the problems that need solving. Focusing on the techno-economics of the renewable heating supply sets a clear guideline and remains a critical factor for project success. The main purpose of the research is to support the FMFN project developer in decision-making by evaluating the technical-, economic-, social-, and environmental performance of suitable renewable heating alternatives for the greenhouse. The main research question is put forward as follows:

What are potential renewable energy alternatives to sustainably meet the thermal demand of an Indigeonus-led community-scale Aquaponic Greenhouse in the Alberta boreal forest?

Following a broad literature review and a theoretical grounding in the value sensitive design, design science research, and systems thinking, the study develops an integrative framework to capture socio-technical, economic, and ecological aspects within the project. Stakeholder values are systematically identified and translated into technical design requirements and key performance indicators. The outcome presents a conceptual Aquaponic Greenhouse design that balances traditional practices, community preferences, and efficient growing methods with a combination of nutrient-film technique and soil-based growing beds. A techno-economic analysis is conducted to compare three renewable heating technologies (biomass boilers, biodigester system with biogas, and ground source heat pumps (GSHP) and two hybrid configurations in comparison to a natural gas boiler. The analysis considers an operational life cycle of 20 years for the greenhouse and its heating system. A multi-criteria integration is carried out using the Best-Worst Method in which the project developer assigns weights to performance indicators in the domains of technical, environmental, social, and economic criteria. The project is in its conceptualization phase before implementation.

The findings indicate that while natural gas remains difficult to compete with in financial terms, it fails to align with social and environmental values. By contrast, hybrid systems score highest according to a multi-criteria assessment. Importantly, the study underscores that a passive solar greenhouse design, featuring south-facing glazing, night curtains, and thermal energy storage, is crucial in reducing the thermal demand by up to 47 % on average. Such energy-saving measures mitigate overall costs, reduce reliance on fossil fuels, and pave the way for more ambitious renewable solutions. Furthermore, the analysis reveals that scaling up the greenhouse size improves financial viability, although a pilot approach is recommended to manage risks and maintain system reliability.

Potential renewable heating alternatives to sustainably meet the thermal demand of an Indigenous-led community-scale Aquaponic Greenhouse in the Alberta boreal forest are first of all passive solar utilization within the building design with a combined use of night curtains and thermal storage elements. In addition to that, a hybrid solution with biodigester (biogas) for base loads and grid-connected natural gas provision for flexible peak demand is recommended if the biodigester solution can be scaled and improved by different measures to move away from fossil-powered energy over time. The second potential renewable heating alternative is the combination of GSHP as a base and biomass boilers for peaks. This hybrid option demonstrates advantages in cooling capabilities for summer and improved scalability opportunities than natural gas. The heat pump can initially be powered from grid electricity but replaced over time by partial or full renewable electricity from solar photovoltaic which is conceivable with Alberta's high solar potential. The first hybrid option is more cost-effective, scalable, and flexible but environmentally more harmful. The second option requires higher upfront costs but can be

seen as cleaner and demonstrates greater opportunities of becoming completely off-grid in the future but can only be scaled on the biomass boiler side. Standalone technologies that can be eligible in certain contexts are biomass boiler systems for smaller greenhouse sizes in which a constant resource flow is secured, or ground source heat pumps for exceptionally large greenhouses when high capital investments can be provided easily.

Overall, the thesis concludes that an Indigenous-led Aquaponic Greenhouse project in Fort McKay can be both economically viable and culturally appropriate, provided that the design process integrates TEK, embraces community engagement, and systematically evaluates renewable heating technologies. The proposed framework and model can serve as a replicable guiding strategy for similar socio-technical initiatives aiming to strengthen food sovereignty, reduce greenhouse gas emissions, and promote Indigenous self-determination.

The holistic and integrative nature of this study introduces several limitations. While the research aims to address the technical, economic, social, and environmental dimensions of the project, time constraints required compromises in the depth of analysis. Key areas such as the techno-economic analysis and value-sensitive design were prioritized, but a comprehensive exploration of the policy landscape including financial subsidies or regulatory frameworks for clean energy projects was beyond the scope of this thesis. The early stage of the project was another limiting factor. The analysis is an initial approximation of understanding broad connections where many aspects were uncertain and could change quickly.

This study advanced academic discourse by demonstrating how Traditional Ecological Knowledge can be meaningfully incorporated into conventional engineering frameworks, supported by Value Sensitive Design (VSD), systems engineering approaches, and multi-criteria decision-making (MCDM). The research process itself was transparent about its challenges and successes, shedding light on how integrating values into engineering can yield novel insights and practical applications, but also expose methodological gaps. Although certain plans like a participatory BWM community survey was canceled due to time constraints, the attempt underlined the importance of inclusive, community-oriented approaches and opened avenues for future exploration. By highlighting the synergies among TEK, VSD, and MCDM, the work underscores the potential for holistic, value-driven innovations in socio-technical systems. Ultimately, the study's interdisciplinary nature including cultural values, social challenges, ecological relationships, and advanced engineering methods demonstrates how complex, uncertain contexts can foster both meaningful collaboration and methodological evolution.

The research discovered a majority of topics to be explored from very specific identified gaps regarding the project to more broad and conceptual ideas that might be applicable to various other fields. The nature of the holistic and integrative framework provided a creative space to investigate multiple challenges from different perspectives and yielded valuable insights that can be further developed and analyzed.

Acknowledgements

This master thesis has been a long and stormy journey with ups and downs, both challenging and rewarding. As Henry Ford wisely stated, *"When everything seems to be going against you, remember that the airplane takes off against the wind, not with it"*. Fortunately, I did not have to go this journey alone and had more support than I could ever have asked for to lift me up.

I would like to begin by expressing my sincere gratitude to my thesis committee which supported and guided me throughout the course of this research and whose valuable insights and critical feedback significantly refined the quality of my work.

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Benjamin Iemhényi Hankó
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Nomenclature

Abbreviations

AFN	Assembly of First Nations
AG	Aquaponic Greenhouse
AHP	Analytic Hierarchy Process
BWM	Best-Worst Method
CAPEX	Capital Expenditure
CEA	Controlled-environment Agriculture
CHP	Combined Heat and Power
COE	Cost of Energy
CO_2	Carbon Dioxide
DWC	Deep Water Culture
ECCC	Environment and Climate Change Canada
EU	European Union
FMFN	Fort McKay First Nation
GHG	Greenhouse Gas
GSHP	Ground Source Heat Pump
HDD	Heating Degree Days
IA	Indoor Agriculture
IPO	Input-Process-Output
IPLC	Indigenous Peoples and Local Communities
ISC	Indigenous Services Canada
KPI	Key Performance Indicator
LANDMARC	Land Use Based Mitigation for Resilient Climate Pathways
MMR	Mixed Methods Research
MOU	Memorandum of Understanding
NFT	Nutrient Film Technique
NPC	Net Present Cost
NPV	Net Present Value
NRCan	Natural Resources Canada
OPEX	Operational Expense
PI	Power-Interest
PV	Photovoltaic
PVE	Participatory Value Evaluation
RAS	Recirculating Aquaculture System
RHT	Renewable Heating Technology
RQ	Research Question
SE	Systems Engineering
SQ	Sub-Question
STC	Solar Thermal Collector
STE	Solar Thermal Energy
TEA	Techno-Economic Analysis
TEK	Traditional Ecological Knowledge
TES	Thermal Energy Storage
TR	Transdisciplinary Research
UNDRIP	United Nations Declaration on the Rights of Indigenous Peoples
VSD	Value Sensitive Design

Symbols

V	Volume of the fish tank	[l]
SD	Stocking density	[kg/l]
FFR	Fish Feed Ratio	[% body weight]
WG	Weight gain per fish	[kg/year]
AY_{fish}	Annual fish yield	[kg]
N_{fish}	Number of fish	[amount]
FF	Fish feed requirement	[kg/day]
FRR	Feed Rate Ratio for NFT	[g/(m^2)]
PD	Plant density	[plants/m^2]
HC	Harvesting cycle	[days]
Y	Yield	[kg/m^2]
A	Planting area	[m^2]
N_{basil}	Number of basil plants	[amount]
AY_{basil}	Annual yield of basil	[kg]
AY_{lettuce}	Annual yield of lettuce	[kg]
UA_{total}	Total heat transfer coefficient	[W/$^\circ$C]
U	U-value	[W/(m^2 $\cdot$ $^\circ$C)]
$A_{\text{component}}$	Surface area of component	[m^2]
Q_{heating}	Thermal energy demand	[kWh/month]
HDD	Heating Degree Days	[$^\circ$C-day]
D_h	Daytime hours ratio	
I_{solar}	Daily solar radiation	[kWh/(m^2/day)]
τ	Solar transmittance	[%]
α	Solar absorptance	
SF	Shading factor	[%]
$Q_{\text{solar-gains}}$	Immediate solar gains	[kWh/month]
$Q_{\text{heating,supply}}$	Required heating supply	[kWh/month]
η	Thermal efficiency	
CV	Calorific value	[kWh/m^3
C_{m}	Maintenance cost	[$ CAD/kWh]
Sz	Sizing factor	[l/kW]
EF_{CO2}	Emissions factor	[kg CO$_2$/fuel-unit]
P_{min}	Minimum power requirement	[kW]
$V_{\text{min,buffer}}$	Minimum buffer tank volume	[l]
Q_{gas}	Required natural gas	[m^3/month]
Q_{biomass}	Required biomass	[t/month]
$\dot{V}_{\text{organic-waste}}$	Required organic waste	[l/month]
$\dot{V}_{\text{water}}$	Required water	[l/month]
E	Electrical energy requirement	[kWh]
t_{lifespan}	Project lifespan	[years]
r	Discount rate	[%]
P_{gas}	Natural gas price	[$ CAD/kWh]
$P_{\text{electricity}}$	Electricity rate	[$ CAD/kWh]
$C_{\text{fish-feed}}$	Fish feed cost	[$ CAD/kg]
P_{fish}	Sales price of fish	[$ CAD/kg]
P_{basil}	Sales price of basil	[$ CAD/kg]
P_{lettuce}	Sales price of lettuce	[$ CAD/kg]
$CAPEX$	Capital expenditures	[$ CAD]
$OPEX$	Operating expenses	[$ CAD]
NPC	Net Present Cost	[$ CAD]
NPV	Net Present Value	[$ CAD]
CO_2	Carbon dioxide emissions	[t CO$_2$]
S_{waste}	Waste management savings	[$ CAD]

P_{offset}	Carbon offset price	[$ CAD/t]

1 Introduction

"It is the craziest thing in human history. We've built the greatest society that mankind has ever known - a global society. We communicate across continents, we think nothing of jumping on an airliner for a meeting in Zurich or Seattle or Shanghai. And yet all of this, everything we have created, rests upon a finite fluid resource that we're busy burning away. Did you ever think about this?"

(John Ironmonger, Not Forgetting the Whale)

1.1. Problem statement

"Humanity is conducting an unintended, uncontrolled, globally pervasive experiment whose ultimate consequences could be second only to a global nuclear war (...) Far-reaching impacts will be caused by global warming and sea-level rise, which are becoming increasingly evident (...) The best predictions available indicate potentially severe economic and social dislocation for present and future generations (...) It is imperative to act now." (World Conference on the Changing Atmosphere, Toronto 1988 [54])

Climate change relates to global shifts in temperatures and weather, induced by human activities through the burning of fossil fuels, that generate greenhouse gas emissions (GHG), trapping the sun's heat and thereby contributing to global warming [81]. Consequences of climate change involve severe droughts, water scarcity, wildfires, rising sea levels, flooding, melting polar ice caps, and catastrophic storms among others [81]. Global food systems are in crisis, threatening the food security of a quarter of humanity while another quarter experiences unhealthy over-consumption [19]. At the same time, the impacts of industrial agriculture are pressuring terrestrial ecosystems, and biodiversity is facing mass extinction around the globe [19]. Solutions to address the three colliding global crises of climate change, dysfunctional food systems, and biodiversity degradation are described as the "trilemma of land use" [19], illustrated in Figure 1.1. Demands on land use for climate protection, food security, and biodiversity conservation are strongly competitive and one can seemingly only be resolved at the expense of the other two [19].

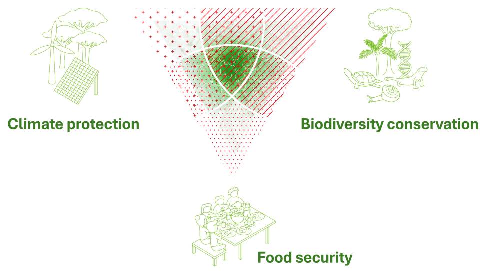

Figure 1.1: Trilemma of land use [19]

The biggest contributors of global CO_2 emissions, historically (1751 to 2017), are North America and China, each counting 29% of global cumulative emissions, followed by the European Union (EU) with 22% [72]. Canada ranked among the second highest emitting countries or regions per capita in 2021 [32]. While there is an ongoing debate about how to correctly measure CO_2 emissions to fairly assign responsibilities and blame, certainly the least responsible actors are the most negatively affected by the outcomes.

Fischer et al. [19] present global political strategies to policymakers for *sustainable land stewardship*, which acts as a guiding principle to solve the trilemma of land use [19]. ”Humankind must accept and assume its responsibility for land in order to mitigate climate change, conserve biodiversity, and safeguard food security. [...] The focus should be on halting the destruction of terrestrial ecosystems and on investing massively in their conservation and restoration” [19].

Paradoxically, the people who have been sustainable land stewards for millennia, practicing all the solutions asked for before climate change, are Indigenous Peoples and Local Communities (IPLC) whose rights were revoked. Concurrently, IPLCs such as First Nations in Canada, face all major identified crises of climate change, dysfunctional food systems, and mass extinction of biodiversity within their traditional land, to a disproportionally high degree [74]. Despite Canada’s abundance of land, only 7 % of the total land is used for agricultural practices due to reduced soil quality and unsuitable climate and terrain [90]. Climate impacts related to food security, are particularly present in northern and Indigenous communities, where effects of reduced thickness of ice, thawing permafrost, and unpredictable and extreme weather events are threatening food safety [74]. Climate-related disruptions across the food system are complex and impact critical dimensions of food security as entire ecosystems are altered on which traditional supply patterns have relied on [74]. In the case of the Fort McKay First Nation (FMFN) community, the entire ecosystem of their traditional land was (and is) altered, not only because of climate impacts but also oil sands mining.

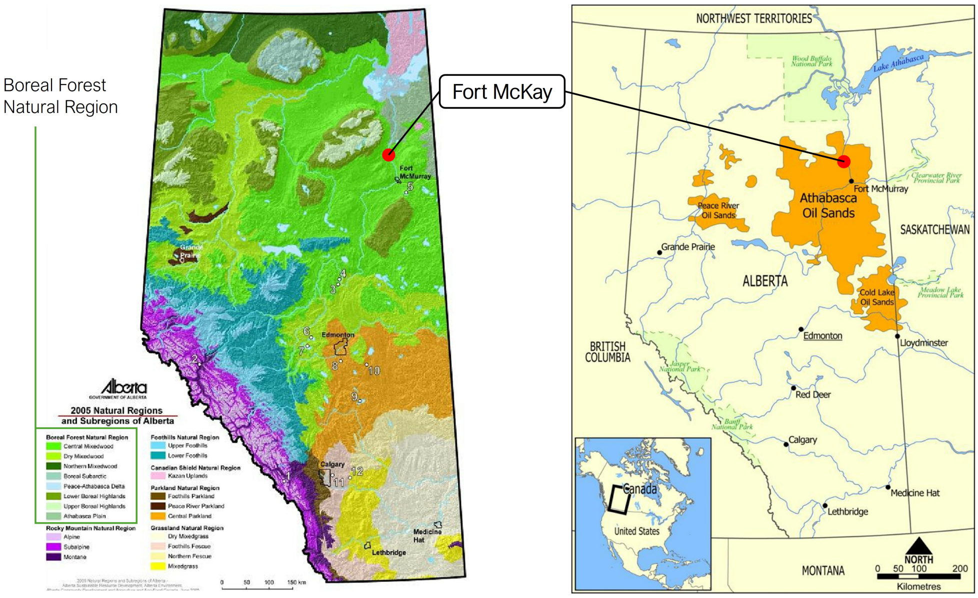

Figure 1.2: Fort McKay: Geographical context [56, 58]

Fort McKay is located in northern Alberta alongside the Athabasca River and the FMFN community is inhabited by 800 members of Dene, Cree, and Métis, sharing a border with the Fort McKay Métis Community [22]. The community lies in the center of both the Boreal Forest Natural Region and the large-scale Athabasca oil sands extraction area as shown in Figure 1.2.

Boreal forests are found in high-latitude environments interwoven by low-lying wetlands in which freezing temperatures occur for around half a year and trees are able to reach a minimum height of 5 m [1]. Boreal forests are considered the single largest pool of living biomass on the earth’s surface, therefore being critically important in global carbon dynamics and estimated to sequester around 20 % of total carbon generated by global forests [43, 27]. 28 % of the world's boreal zone (552 million hectares) is found in Canada which stores carbon, purifies air and water, and regulates the climate not only for the country but the globe [30].

The vast disturbance of the land due to mining operations has had ecological, social, and cultural impacts on the community, receiving criticism from members. Environmental concerns include dust development, rise in volatile organic compounds levels in the air, contaminated reclaimed land, water salinity levels, and insufficient topsoil, preventing the successful growth of plants and gardening efforts [14]. Additional concerns involve cultural loss due to limited access to the land and degradation of traditional supply patterns such as hunting, trapping, fishing, growing, and collecting plants for medicinal purposes [14]. Nevertheless, FMFN signed a Memorandum of Understanding on a prospective oil sands lease development together with Suncor, the second largest oil producer in Canada [21]. The agreement ensures that the First Nation will be in charge of governing oil sands activity on the reserved land and provides the opportunity for the community to financially benefit from it [79]. The Fort McKay Sustainability Department seeks to preserve FMFN's way of life by maintaining its ability to exercise Treaty (Section 35) and inherent rights as well as traditional land use practices, in collaboration with industry and government for responsible resources [23].

The community has been an engaging partner in the Canadian case study of LANDMARC (Land Use Based Mitigation for Resilient Climate Pathways), which is a 4-years funded EU-funded project within HORIZON 2020 that assesses the potential of land-based negative emission solutions in land use sectors such as agriculture and forestry [48]. In cooperation with 17 international partners, areas explored jointly with FMFN include soil carbon sequestration, use of biochar, afforestation and wetland restoration, use of BECCS (Bioenergy with Carbon Capture and Storage), and controlled-environment agriculture (CEA) [48].

The challenging environmental conditions surrounding Fort McKay demand for adaptive and innovative ways of revitalizing traditional practices with the aim of having access to nutritious and culturally appropriate food and strengthening food sovereignty efforts [11]. One prime example and success story from a northern community is the Inuvik Community Greenhouse which is considered the most northern commercial and community greenhouse in North America that is capable of providing local and sustainable fresh produce during summer months north of the Arctic Circle [80]. Fort McKay First Nation aspires to revitalize and define their own sustainable local food production system. The vision is to develop a year-round growing community greenhouse that incorporates an aquaponic system and is powered by renewable energy. This aligns very well with the five multi-benefit strategies of sustainable land stewardship proposed by Fischer et al. [19]: (1) Expand efforts to restore terrestrial ecosystems massively; (2) Develop an interconnected system for protected areas; (3) Promote diversify-based agriculture; (4) Transform dietary habits; (5) Shape the bioeconomy with a focus on biomass.

1.2. Definition of key concepts

1.2.1. Traditional Ecological Knowledge and reciprocal restoration

Note: The following passages were left unchanged as it is not my place to explain or define Traditional Ecological Knowledge (TEK). Excerpts are shown from Kimmerer [45], who is "the founder and director of the Center for Native Peoples and the Environment, whose mission is to create programs which draw on the wisdom of both indigenous and scientific knowledge for our shared goals of sustainability" [46]:

The idea of reciprocity with land is fundamental to many indigenous belief systems. Indeed, such beliefs serve as the foundation for what have been described as "cultures of gratitude." In such cultures, people have a responsibility not only to be grateful for the gifts provided by Mother Earth, they are also responsible for playing a positive and active role in the well-being of the land. They are called not to be passive consumers, but to sustain the land that sustains them. Responsibilities to the more-than-human world are simultaneously material and spiritual, and, in fact, the two are inseparable. The traditional ecological knowledge of indigenous peoples is rich with prescriptions, both philosophical and pragmatic, for this practice of giving back to the land.

Among my Anishinaabe people, we share a teaching known as "the prophecy of the seventh fire." This teaching relates that, with the coming of strangers to our shores, many changes will befall our people.

It is said that the land will become fragmented, plants and animals will be lost, that the people will be scattered and divided from their homelands, and that the language spoken for millennia will nearly disappear. As we know, these things have come to pass. Our peoples live on tiny remnants of their original homelands, and our language and culture face many threats. The prophecy explains that the plants and animals will become diminished, the waters undrinkable, and the air itself changed. This, too, we know has come to pass. We are also taught that in the time of the seventh fire, there will be a fork in the road. The people remaining on Earth must make a choice either to continue on the path that leads to destruction of life as we know it or to choose a different future — one of renewal. It is said that should the remaining people choose the path toward life, they will turn back along the road from which they have come and begin to pick up the pieces that have been scattered along the road—remnants of language, the old stories and songs, seeds and ragged patches of plants, wandering animals and birds, and together they will begin to put the world back together again. The people will reclaim their responsibilities for taking care of the land, and thus heal the land and the people. The prophecy of the seventh fire speaks, I think, of *reciprocal restoration*.

Reciprocal restoration is the mutually reinforcing restoration of land and culture such that repair of ecosystem services contributes to cultural revitalization, and re- renewal of culture promotes restoration of ecological integrity. Based on the indigenous stewardship principle that "what we do to the land we do to ourselves," restoration of land and culture are inseparable. This approach arises from a creative symbiosis between traditional ecological knowledge and restoration science, which honors and uses the distinctive contributions of both intellectual traditions. Reciprocal restoration recognizes that it is not just the land that is broken, but our relationship to it. Reciprocal restoration encompasses repair of both ecosystem and cultural services while fostering renewed relationships of respect, responsibility, and reciprocity. All flourishing is mutual. Reciprocal restoration is grounded in the positive feedback relationship between cultural revitalization and land restoration. Revitalizing language and culture protects and disseminates TEK, and builds relationships of reciprocity and respect, all of which are good for the land. What's good for the land is good for the people. The fate of the land and the consequences for culture are much more strongly linked for Native peoples than for those in the dominant culture. Thus, ecological restoration in indigenous communities takes on a special depth and dimension.

In the dominant materialistic worldview, humans are understood as standing outside nature, as exogenous forces whose interactions with nature are generally considered negative. What is "new" to Western science often has antecedents in indigenous knowledge, articulated millennia ago.

1.2.2. Aquaponic Greenhouse

Greenhouses are a form of protected cultivation in which crops are grown inside of the structure, covered by transparent material that is permeable to sunlight but protects from unfavorable weather conditions and extreme climate while trapping heat [57]. They allow to control of the environment such as temperature, humidity, and ventilation to improve crop yields and can be classified into closed and semi-closed greenhouses [51]. A semi-closed greenhouse is a novel greenhouse that is highly efficient in hot and arid climates but not suited for cold climates. Closed greenhouses create a stable environment and protect plants from pests and diseases [51]. Agricultural greenhouses can be further classified based on their shape or other characteristics. Types of greenhouses found in colder climates include chinese-style, quonset, even span, passive solar, and gothic arch as displayed in Figure 1.3 [62].

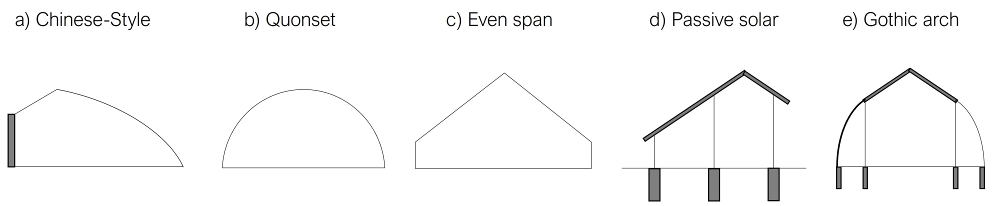

Figure 1.3: Types of greenhouses used in colder climates

Maraveas et al. [51] identify gothic arch greenhouses as particularly suitable for regions with heavy snowfall due to their efficient shedding of snow. Another related concept that is growing in popularity is CEA, a technology-based approach to food production that includes indoor agriculture and vertical farming [88]. Commonly applied techniques are hydroponics, aquaponics, aeroponics, soil-based and hybrid systems that can be applied in greenhouses [29].

Aquaponics is a combination of aquaculture and hydroponics and known as as an efficient method that solves wastewater problems in aquaculture and nutrient management issues in hydroponics by integrating both processes in a symbiotic way [2]. Hydroponics as part of aquaponics is a type of horticulture in which crops or medicinal plants are grown with water-based mineral nutrient solutions instead of soil. The three main types of hydroponics used in aquaponic systems are media-based growing beds, nutrient film technique (NFT), and deep water culture (DWC) as illustrated in Figure 1.4.

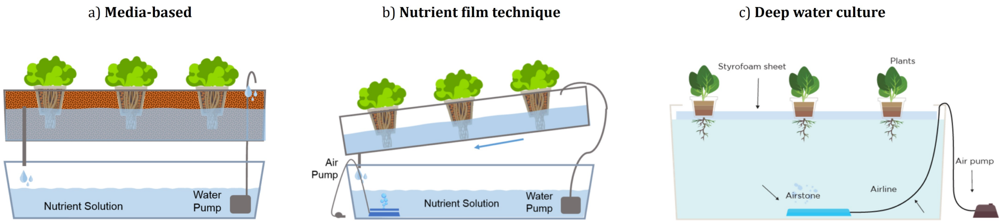

Figure 1.4: Main types of hydroponics used in aquaponic systems

All types of aquaponics require a fish tank or pond for aquaculture which has little influence on the functioning of the design setup [2]. The fish in the tank consume provided fish food and excrete excess nutrients into the water, which is pumped to the hydroponic system and is used as the nutrient source for plants [2]. The microorganisms in the biofilter play a crucial role in translating nutrients into receptive forms for the plant, and also reduce the nitrogenous compounds together with the plants before the water is redirected into the fish tank since high levels of nitrogen are toxic for the fish [2]. A functioning system balances the nutrient cycle between fish, plants, and microbes in a self-sustaining manner in which only fish food has to be provided as a food source to cultivate fish and plants, which all benefit mutually from each other. The design of aquaponics is categorized into coupled and decoupled systems as shown in Figure 1.5.

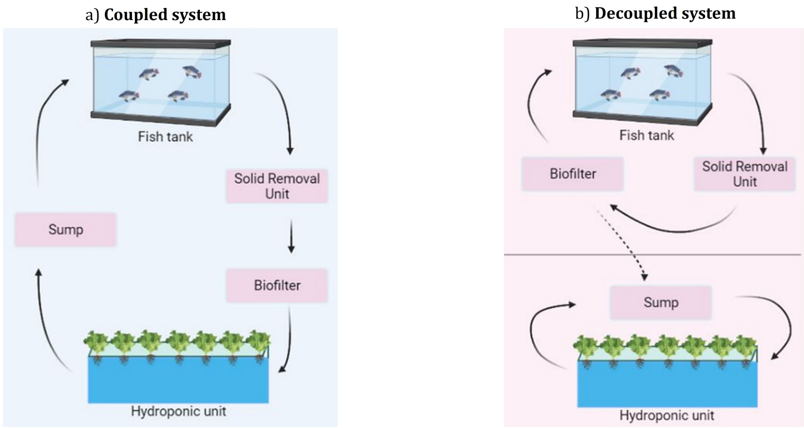

Figure 1.5: Coupled vs. decoupled aquaponics [2]

In coupled systems (1-circle loop systems), the water is pumped from the aquaculture unit into the hydroponic unit and back in a single closed loop [2]. This is the more simple form in which fish and plants grow in the same water quality which can impose stress on either fish or plants, resulting in lower yields. Those systems do not require an additional biofilter and sump tank and are commonly used in combination with media-based growing beds [2]. Decoupled systems consist of a recirculating aquaculture system (RAS) and a hydroponic unit which are separate from each other and only connected by a one-way valve to provide water to the plants [2]. They are commonly used with NFT or DWC which require an additional biofilter and sump tank but can fulfill different nutrient requirements and ideal water quality for the respective living organisms [2]. Such a system can improve yields and support intensive production of fish and plants which is preferred for larger-scale aquaponic farms but comes at higher costs. The combination of CEA with a decoupled RAS and hydroponic growing unit is defined as an Aquaponic Greenhouse (AG) in this study.

1.2.3. Renewable energy

Renewable energy is defined as natural energy resources that are replenished at a higher rate than they are consumed and can be classified into three general categories for the provision of final or useful energy [82, 44]. Geothermal heat, solar energy, and gravitational forces of planets are the three main categories of renewable energy as depicted in Figure 1.6.

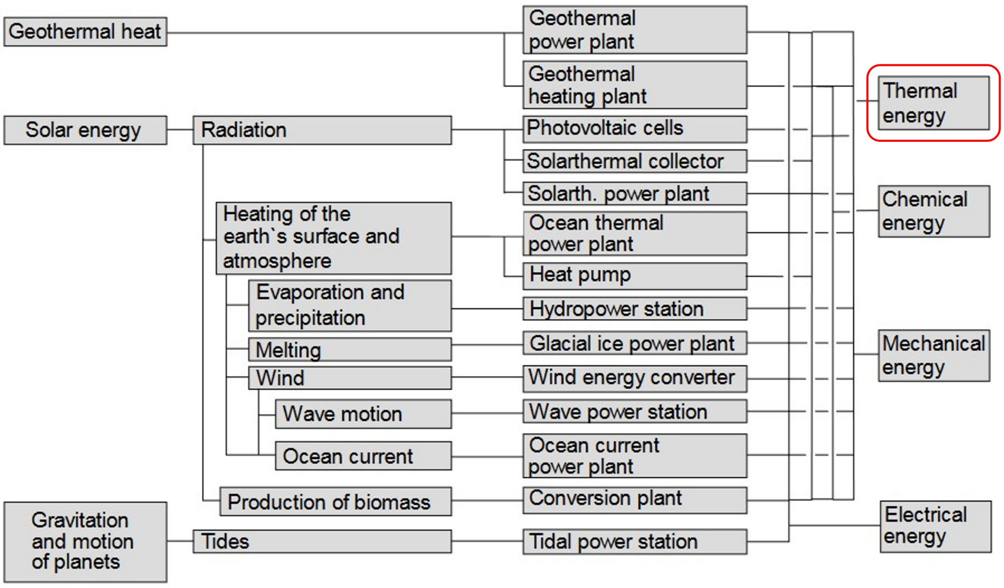

Figure 1.6: Renewable energy for the provision of useful thermal energy

Those three sources produce various energy flows in energy conversion processes found in nature [44]. Wind, hydropower, wave and ocean current, and biomass all result from the conversion of solar energy. Heat pumps are strictly not classified as geothermal energy as they use the heat of the earth's surface from solar radiation rather than from the earth's core. Solar heat provision by passive systems such as using solar radiation through architectural measures is also considered renewable energy [44]. For this research, solar energy is classified as energy conversion from direct solar radiation. Wind, hydropower, and biomass are named as such without referring to solar energy as an overarching theme. Geothermal heat pumps are nevertheless described as geothermal energy to avoid any confusion. All sources exhibit variations in energy density and require certain boundary conditions such as suitable locations. The type of final energy utilized can be thermal, chemical, mechanical, or electrical energy. This study focuses on thermal energy output, although other conversion processes may also be applicable.

1.3. Knowledge gaps

Exploring the practicability of a renewable-powered AG in this unique context remains highly uncertain. The vision of the FMFN's project developer of establishing a renewable-powered community-scale AG might seem technically manageable and straightforward to evaluate. However, from a systems thinking perspective in which relationships and interactions between organizations, ecosystems, social structures, and technicalities at hand are examined, the project becomes significantly more complex. The attempt to understand the interactions of all systems combined already proves to be a major challenge, particularly in this social context.

Historically, IPLC experienced Canadian-imposed colonial practices (systems of oppression induced by settlers towards Indigenous Peoples) that have caused severe social and material inequities and threatened their lives and health across many generations [75]. Efforts towards reconciliation and against systemic racism of Indigenous peoples have been progressing slowly. As recently as 2007, the Canadian Government voted against the United Nations Declaration on the Rights of Indigenous Peoples (UNDRIP) but adopted the UNDRIP into federal law in 2021 as one of the first countries around the world [66]. Furthermore, industrial oil sands mining activities are causing expansive land disturbances within the community but simultaneously generate income that is used for social services of its members, which also advances indirect dependencies on fossil fuels [20]. IPLC such as FMFN uphold worldviews and values that can be profoundly different from Western-centric ideals but the changing environment pushed such communities into adopting Western ways of living to preserve the social welfare of the community, often at the cost of cultural loss. The greenhouse project in Fort McKay represents more than a technical food production system and its renewable energy supply. It is an effort to regain control of shaping the community's future in line with their values.

Beyond the social complexities of the greenhouse project, there is also the challenge of bridging two different worldviews. TEK has not been integrated into engineering principles due to its limited acceptance as a theoretical method in Western science, as it follows a different rationale and its outcomes are not measurable by conventional scientific standards. The challenge lies in evaluating such intangible values from a fundamentally different perspective and integrating them into well-established engineering principles that rely on measurable data.

Even the technical aspects of renewable energy provision for this application reveal knowledge gaps. Established renewable energy projects are mostly located in the South of Canada where climate conditions are more favorable. Researchers from the University of Alberta have updated a mapping tool illustrating Canadian renewable energy projects greater than 1 megawatt, including Indigenous renewable energy projects which are shown separately in Figure 1.7 and Figure 1.8.

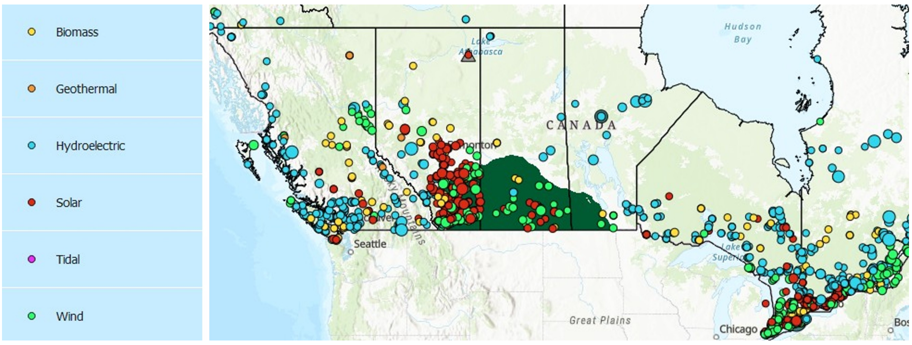

Figure 1.7: Canadian renewable energy projects [83]

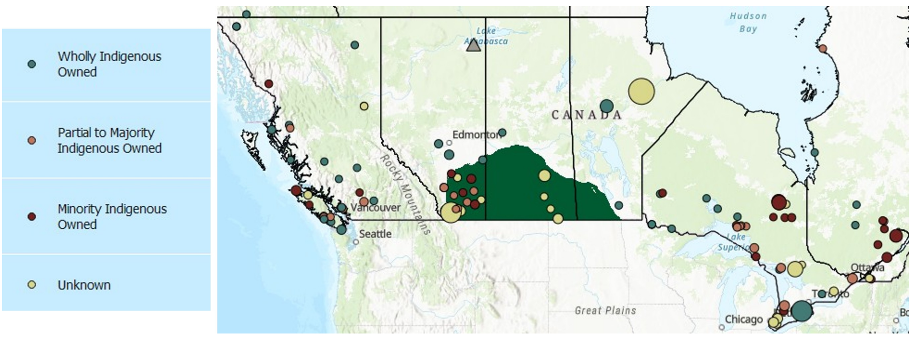

Figure 1.8: Canadian Indigenous renewable energy projects [83]

Incorporating an aquaponic system in a greenhouse makes it a 24/7 operation since it involves a natural process in which a nutrient cycle has to be perfectly balanced and cannot just be paused temporarily. The fish and plants require constant inside climatic conditions, especially regarding temperature. They are vulnerable to temperature fluctuations, which can lead to the mortality of both species and, consequently, the collapse of the entire system. Guaranteeing stable conditions with renewable energy in a climate where average temperatures drop to -20C° in winter, will be one of the most critical challenges in this project. Renewable energy is highly context-dependent, making it challenging to apply concepts from different geographical regions. Figure 1.7 demonstrates a general lack of renewable energy projects within the surrounding Northern region. Figure 1.8 shows an even greater gap for Indigenous-led renewable energy projects.

1.4. Objectives, scope, and research questions

The main objective of this study is to examine and develop the most critical areas of the AG project to get a better understanding of the problems that need solving. Focusing on the techno-economics of the renewable heating supply sets a clear guideline and remains a critical factor for project success. The main purpose of the research is to support the FMFN project developer in decision-making by evaluating the technical, economic, social, and environmental performance of suitable renewable heating alternatives for the greenhouse. A natural gas boiler serves as a benchmark for the comparison. Other major objectives and requirements are to create an initial value-sensitive design prototype of the AG and to estimate the thermal demand of it. The research does not include a detailed analysis of the various fields but aims to cover the broader picture holistically.

The study tries to integrate TEK and social values into the research design in an attempt to explore ways to exercise value-driven engineering. On an academic level, this means that ways of embedding (traditional) values into engineering principles are explored and tested. Approaches to transdisciplinarity are investigated by considering well-suited stakeholder engagement processes that can influence design decisions. Fundamentally, the study aims to facilitate a process in which recommendations can be drafted based on what community members perceive as important in their own understanding. As a researcher, I can select the tools and methods that allow for such considerations and conduct the analyses. In summary, the study attempts to produce research outputs that are beneficial to the community while adhering to standards expected from academic research. The main research question (RQ) is put forward as follows:

What are potential renewable energy alternatives to sustainably meet the thermal demand of an Indigeonus-led community-scale Aquaponic Greenhouse in the Alberta boreal forest?

The thesis focuses on evaluating the viability of renewable heating technologies to supply an indigenous-led aquaponic greenhouse within the Fort McKay community, located in the Natural Region of the Boreal Forest in northern Alberta, Canada. A techno-econnmic assessment is conducted in a value-sensitive and integrative manner that considers an operational life cycle of 20 years for the AG and its heating system. The project is in its conceptualization phase before implementation. The study only accounts for electrical energy demand that is linked to costs of the aquaponic system and greenhouse building, or cost-related to an input requirement of a reviewed heating technology. Renewable energy technologies that produce electricity and combined heat and power (CHP) are excluded. The design of the greenhouse is only covered at a surface level and related costs are a general approximation with an estimated deviation of around $\pm$ 10%. Only direct project stakeholders are considered for the analysis and direct stakeholder engagement is established with the project developer. Further stakeholder engagement is achieved via indirect sources.

The thesis is structured according to the research process flow and segmented by chapters that chronologically answer the sub-questions (SQs) in that given order. It starts with a literature review that creates the foundation for the study and also identifies topic coverage among academic literature, thus examining knowledge gaps. A theoretical background is provided on integrative problem-solving paradigms that guide the research methodology. In the methodology chapter, theories are applied to the study, and an integrative holistic framework is presented that was developed based on initial findings with a focus on contextual factors. Applied methods and tools are described after addressing data collection and protection. In the final section of chapter 3, limitations of the study are clarified. Chapter 4 is the starting point for the evaluation of the project and aims to answer sub-question 1:

SQ1: *How do the key values, needs, and preferences of project developers, designers, and stakeholders shape the greenhouse design, as well as technology- and Key Performance Indicator (KPI) selection for the renewable heating system?*

The chapter evaluates the FMFN community and its values linked to the project. A self-constructed process based on value sensitive design (VSD) is applied to identify project, designer, and stakeholder values. Narratives are developed to translate the values either into design implications or implications regarding technology- and KPI selection. A final selection of renewable heating technologies (RHTs) and KPIs for the performance evaluation are provided. Chapter 5 presents design artifacts of the AG to answer sub-question 2:

SQ2: *What embodies a value-sensitive and sustainable AG design, and what are its operational requirements and thermal energy demand?*

Design objectives and modeling concepts are described and presented to be incorporated in the techno-economic analysis (TEA). The TEA in Chapter 6 focuses on the thermal energy supply of renewable heating systems and addresses sub-question 3:

SQ3: *What are the selected renewable heating technologies' technical specifications and operational requirements compared to a natural gas boiler, and how do these influence their associated costs?*

The TEA is incorporated within the model, and costs are assigned to components and processes for thermal demand coverage by the selected RHTs. The model simulates a 20-year operational cycle, emphasizing the economic metric of Net Present Value (NPV). Model results are presented in Chapter 7 which are used for a multi-criteria integration in Chapter 8. The multi-criteria analysis allows for answering sub-question 4 by accounting for non-economic indicators:

SQ4: How do the heating technologies compare in terms of technical, environmental, social, and economic indicators, and how are these KPIs prioritized based on the project values?

The prioritization of KPIs by the project developer facilitates an aggregate ranking of technologies based on co-developed indicators. This multi-criteria ranking is compared to the NPV scoring of the TEA, to assess how the choice for a certain technology is influenced by incorporating other-than-economic values. All research results are synthesized and discussed in Chapter 9. The chapter reflects on the combined use of methods within the research framework and elaborates on limitations. The viability of renewable heating alternatives is deliberated to answer the main research question in Chapter 10. Key findings are first summarized based on posed sub-questions, and recommendations are provided for the FMFN project. Finally, the main research question is addressed more broadly before proposing future research based on the study outcomes.

2

Literature Review & Theory

“I’m still confused, but on a higher level.”
(Enrico Fermi)

2.1. Screening process and topic coverage

The selection process shows how the reviewed literature was selected. The main rationale of the search was to examine existing studies in the field of TEA or similar feasibility approaches for an Indigenous-led Aquaponic Greenhouse in the Alberta Boreal Forest Natural Region of Canada. Prompting for this specific area did not return any results in the TU Delft Library, ScienceDirect, and Google Scholar databases. The further search was split into three streams to find academic literature that covers relevant parts of the research topic, but in combination allows for valuable insights for an integrative analysis. 20 papers were included in the final selection as shown in Figure 2.1.

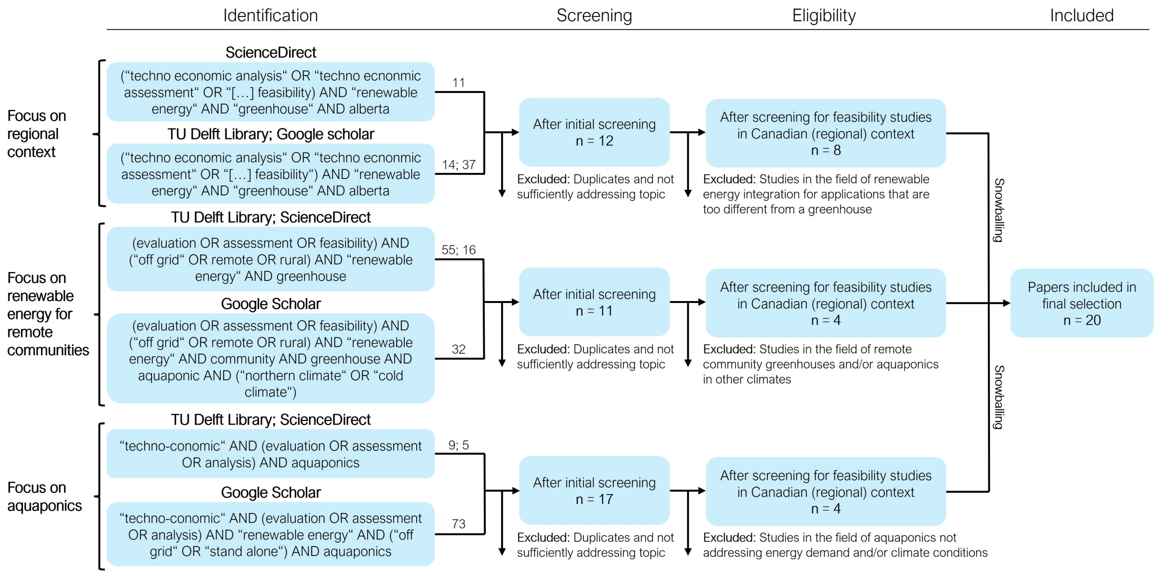

Figure 2.1: Screening process

The first stream focused on the regional context and more broadly on greenhouses and renewable energy. After screening for eligibility and excluding studies on renewable energy integration that did not apply to greenhouses, eight feasibility studies with either a Canadian or local context were selected. Secondly, assessments in the area of greenhouses and renewable energy for remote communities were scrutinized. The term ”Indigenous communities” was replaced by remote communities due to a lack of results and to keep the search more flexible and inclusive for other communities. Studies addressing profoundly different climate zones were excluded. The final focus was set on evaluations of renewable energy linked to aquaponics, in which literature was excluded that did not address energy demand or climate conditions. A final list of literature reviewed including title, year, authors, and journal is provided in Appendix A.1.

The topic coverage can be interpreted as initial findings and confirms knowledge gaps in academic literature. Table 2.1 shows TEAs and other studies conducted in Alberta or similar Canadian climate zones, whereas Table 2.2 lists TEA and relevant research in other regions. Both tables provide additional information about the exact location, the type of renewable energy assessed, and if the study is related to ’greenhouses’ (Gr.) or ’aquaponics’ (Aq.) and deals with aspects of ’community’ (Co.), ’rural’ (Ru.), and/or ’Indigenous’ (In.).

Table 2.1: Topic coverage of research in Alberta and similar Canadian climate zones

Nr.	Location	Renewable energy	Gr.	Aq.	Co.	Ru.	In.
Techno-economic analysis							
1	Community of Kuujjuaq (Nunavik, CA)	Geothermal energy systems	-	-	(Y)	(Y)	(Y)
2	Cochrane (Ontario, CA)	Bioenergy systems	-	-	(Y)	(Y)	-
3	Trout Lake First Nation (Northern Alberta, CA)	Solar PV, wind, hydrogen, Combined Heat and Power (CHP)	-	-	(Y)	(Y)	(Y)
4	Fort McMurray (Northern Alberta, CA)	Pilot dry batch anaerobic digestion	-	-	-	(Y)	-
5	Alberta, CA	Wind and geothermal energy	-	-	-	-	-
6	Alberta, CA	Thermal energy from solar radiation	(Y)	-	(Y)	(Y)	-
Other relevant research							
7	Community of Kuujjuaq (Nunavik, CA)	Deep geothermal energy source	-	-	(Y)	(Y)	(Y)
8	Edmonton (Alberta) & Northern Pine (Saskatchewan), CA	Agrivoltaics (solar PV)	(Y)	-	-	-	-
9	Northern and subarctic communities, CA	-	(Y)	-	(Y)	(Y)	(Y)
10	Northern communities, CA	Thermal energy storage system	(Y)	-	(Y)	(Y)	(Y)
11	Canadian landscape	Wind, hydro, solar, biomass, wave, tidal	-	-	-	-	-
12	Fort Albany First Nation (Ontario, CA)	-	-	(Y)	(Y)	(Y)	(Y)

Generally, it can be seen that only a few studies in Alberta and Canada (Table 2.1) deal with greenhouses, and only one covers aquaponics. The majority of studies refer to communities in rural or remote areas of which most can be identified as Indigenous communities. Within the category of TEA, only one study examines greenhouses, and two assessments are conducted for IPLC. The renewable energy sources evaluated in TEA include geothermal energy (2), bioenergy (2), solar photovoltaics (PV) (1), wind (2), and solar thermal energy (STE) (1). Additionally, non-TEA assessments include one geothermal energy, one solar PV, and one STE evaluation. The type of renewable energy assessed aligns well with findings of conducted research by Barrington-Leigh and Ouliaris [8] on estimating renewable energy potential for the region of Alberta.

Table 2.2 shows topic coverage in regions outside of Canada. Here, on the contrary, research could be found that dealt with greenhouses and aquaponics but fewer that address remote communities and none about IPLC. Two of the TEAs review multiple renewable energy alternatives for the application of an AG, whereas the remaining ones are TEAs solely about the AG without evaluating renewable energy supply. Noticeable is also that four out of all studies in other regions assess STE as a renewable energy option.

Table 2.2: Topic coverage of research in other regions

Nr.	Location	Renewable energy	Gr.	Aq.	Co.	Ru.	In.
Techno-economic analysis							
13	Himalayan region of Nepal	Wind, solar energy, geothermal aquifiers, TES, biogas	(Y)	(Y)	-	(Y)	-
14	La Paz (Baja California Sur, MX)	Solar energy	(Y)	(Y)	(Y)	(Y)	-
15	Ames (Iowa, US)	-	(Y)	(Y)	-	-	-
16	Ohio, US	-	(Y)	(Y)	-	-	-
17	Seville (Andalusia, ES)	-	(Y)	(Y)	(Y)	-	-
Other relevant research							
18	Global	Solar PV, wind, geothermal energy, biofuels, thermal storage systems	(Y)	(Y)	(Y)	-	-
19	Global	Solar greenhouse technologies	(Y)	-	-	-	-
20	Global	Hybrid renewable energy systems	-	-	(Y)	(Y)	-

2.2. Main findings

Canada has several unique geographical characteristics including abundant land area, and large inland and ocean water with some of the largest tidal ranges in the world, generating 60.8% of total electricity with hydropower [8, 41]. Wind power ranks second in renewable electricity sources with high potential sites generally more clustered in the southern regions of Alberta and Saskatchewan [8] Biomass is also utilized as a renewable energy source, particularly through forest products in the boreal forest region, and also by producing biofuels through organic waste [8]. However, the total Canadian energy supply is mainly provided by fossil fuels accounting for 75.5% (coal, oil, and natural gas) and the country also has an exceptionally high per capita consumption of energy of which 40% is used for heating [41, 8]. Alberta and Saskatchewan have by far the highest energy footprint per capita in the country, presumably due to their heavily resource-dependentlarge scale economies [8]. At the same time, Alberta holds extensive potential for utilizing solar energy since it ranks second in the amount of solar irradiation received among all provinces in Canada, particularly in winter [40]. Geothermal energy has not been harnessed at large-scale even though studies have shown its potential in satisfying a large portion of Canada's energy demand [8].

Piché et al. [62] reviewed greenhouses in North America and identified 8 community greenhouses in Canada. Growing sizes range from 30 - 810 m^2 and growing seasons are less than 6 months except for one in Invermere which is a Chinese-style greenhouse located in the south of Canada. It is also the only one that uses seasonal geothermal storage as heating. The remaining ones either have no heating at all, which explains the short growing seasons, and one uses gas heaters. Piché et al. [62] concludes that northern greenhouses are often not suited for cold climates because of their design, lacking thermal energy storage, and passive solar utilization which can maintain minimum temperatures inside the greenhouse above 10 °C. Imafidon, Ting, and Carriveau [40] identified that the heating demand of northern greenhouses accounts for 70 - 80 % of the total energy requirement and modeled the thermal energy of a passive Chinese-style greenhouse in Alberta which operates without any additional energy requirement but uses STE. As the name suggests, those can grow vegetables in northern China where temperatures fall below 10°C in winter. Due to Alberta's high solar potential, Imafidon, Ting, and Carriveau [40] concludes that the CSG is more economically viable than a traditional greenhouse and also other studies reported annual heat savings of 55 % compared to traditional greenhouses. [77] also found that greenhouse projects in the north of Canada are a possible way for communities to create local food production with additional social and cultural benefits.

The TEAs for aquaponics mostly assessed experimental setups with one type of fish and one type of vegetable with a growing area of less than 50 m^2. Xie and Rosentrater [89], Zappernick et al. [91], and Lobillo-Eguíbar et al. [50] made similar findings by identifying the greenhouse facility as the highest cost in initial investments while labor costs and vegetable market prices were the most sensitive parameters influencing profitability. Xie and Rosentrater [89] concluded in their evaluation of a tilapia-basil aquaponic system in Iowa that unit costs and environmental impacts decreased when the scale increased and indicated that a growing area of 75.6 m^2 was profitable with basil prices at 60 USD/kg. Zappernick et al. [91] and Wilkinson et al. [88] recommend diversifying vegetable production and integrating food production systems, for instance, aquaponics with soil-based production. Zhang et al. [92] conducted a comparative study of integrating renewable energy in aquaculture and found that airlift pumps can result in energy savings of up to 40 %. Solar technologies, particularly solar thermal energy, wind, biofuels, and geothermal heating are identified as promising technologies to reduce costs for the high energy demand. Geothermal energy can be restricted depending on the geological conditions of the region, and obtaining a constant biogas yield with anaerobic digestion remains challenging.

Goel and Sharma [28] analyzed the performance of different renewable energy scenarios for rural applications and concluded that rural electrification with renewables can reduce carbon dioxide (CO_2) emissions to 99 % but highlight that renewable-based electricity may not always be a cost-effective option unless supported by the government. Biomass energy is identified as being highly efficient and lowering the cost of energy while hybridization of energy sources is recommended to increase reliability. Priyanka et al. [64] demonstrate that building heating is among the most significant sources of diesel fuel consumption in North America in which only one-third of thermal capacity is converted into electricity resulting in high levels of waste heat. Their analysis concludes that the base case (fossil-fuel powered) provides the lowest cost of energy (COE) at 0.516 USD/kWh and net present cost (NPC) at 4.26 million USD to supply the Trout Lake community in northern Alberta. However, the hybrid system consisting of solar PV, wind, battery, and the fuel-cell system has the highest efficiency (93.5 % renewable fraction) with 0.6765 USD/kWh COE and 5.55 million USD NPC, therefore being the most economical and environmentally sustainable system to satisfy the total energy demand of the community. Gorjian et al. [29] come to the conclusion in their assessment of solar technologies for agricultural greenhouses, that the whole or partial energy demand of greenhouses can be provided by solar energy. The utilization of thermal energy storage (TES) (such as solar thermal collectors) for a solar greenhouse is essential and the combination benefits the long-term operation, particularly in regions with severe cold climates. Solar PV is recommended as a viable option to drive electrical components in the greenhouse.

Hayes et al. [37] performed a TEA of a digestion-compost process for remote oil sands mining camps in northern Alberta and found that renewable energy projects in Alberta are commonly supported via capital support, varying between 25-33 % for biogas projects. The study concludes that to achieve a simple payback of 4 years or less, waste disposal costs of 115 - 195 USD are required which is likely exceeded. Blair and Mabee [10] evaluated community-scale bioenergy systems for a forest-based community in Ontario and identified biomass boilers and CHP technologies as technologically mature and thus being competitive to traditional natural gas heating systems. They conclude that biomass heating systems are one of the lowest-cost ways to significantly reduce GHG in the short term.

There is a lack of papers examining geothermal energy potential, especially for a project like a community-scale AG. Miranda et al. [53], Rahmanifard and Plaksina [65], and Miranda, Raymond, and Dezayes [52] conducted studies to evaluate geothermal energy as a renewable source to supply arctic and sub-arctic off-grid communities that relate to large-scale geothermal power plants. For that, a minimum depth of 4 km needs to be reached to make it feasible. Rahmanifard and Plaksina [65] assessed the feasibility of using inactive wells for geothermal energy in the region which can reach down to 7 km in depth and found that the use of existing wells can reduce the cost of energy by 30-60 %.

Finally, Parajuli et al. [60] conducted a study that comes closest to this intended research by assessing potential renewable energy alternatives for an AG in the Himalayan Region of Nepal. They state that no research has focused on identifying viable renewable energy sources for an AG to fulfill energy requirements and site-specific practices in that region. The potential of lowering energy costs, reducing fossil-fuel consumption, and increasing profitability while addressing food-related challenges in diverse climate conditions was analyzed. The system design aligns well with recommendations from previous research and includes passive solar utilization with solar collectors, night insulation, and anaerobic digestion with biogas and geothermal aquifers. Wind energy and solar PV are used for electricity generation. Parajuli et al. [60] highlights that environmental parameters required inside depend upon cultivated species and plants which can be influenced according to climate conditions. Findings include that STE and insulation can significantly reduce heating requirements in a simple and efficient way and keep internal temperature 4-10 °C higher than external [60]. The use of geothermal energy can reduce costs by 35 % and anaerobic digestion to produce biogas is especially suitable for the socio-economic context characterized by livestock farming [60]. It was also found that a considerable amount of heat loss occurs during night which can be prevented by using night curtains. Generally, the energy modeling showed that heat loss was responsible for the high energy demand and results indicated that solar PV electrification for heating purposes seems to require extravagant financial and technical resources that cannot be met in that region. Passive solar heating is strongly recommended in combination with integrating locally available energy.

The literature review clearly demonstrates multiple gaps in existing research. Current community greenhouse projects in the region exhibit short growing seasons and are generally kept simple with most of them not using additional energy inputs, and if so, only from non-renewable energy sources. This works well with limited costs during operations but exclusively yields crops during summer when temperatures are suitable to grow plants. However, integrating an aquaponic system within the greenhouse makes it a continual operation with high energy demands that require a constant inside climatic environment. Table 2.1 and Table 2.2 showed that there is lacking research in identifying renewable energy alternatives for an AG in the context of the Alberta Boreal Forest Natural Region. Contextual factors are highly relevant and distinct contexts can require completely different solutions which makes it challenging to apply solutions from studies conducted elsewhere. Most studies even addressed other applications or experimental setups that do not reflect a community-scale AG. Most importantly, only a few studies included the social and cultural dimensions of Indigenous Peoples and mostly chose the type of cultivation based on profitability or resource availability. Aligning the needs, values, and traditional practices of IPLC with innovative solutions and assessing low-cost renewable energy options to supply such a community project, has not been done so far. High uncertainties remain regarding the technical and economic feasibility of meeting the thermal demand with renewable energy sources in this severe climate. The potential of passive solar heating systems, bioenergy, and geothermal energy has not been evaluated, despite their high suitability for the context and reduced initial investment costs compared to more common sources such as wind and solar PV. Notably, none of the studies used a holistic or transdisciplinary approach in their analysis that integrates socio-technical aspects.

2.3. Integrative problem-solving paradigms

2.3.1. Systems engineering

Systems engineering (SE) can be seen as a way to incorporate stakeholder needs and participation in managing sustainable and environmental systems and works both as a discipline and a process [18]. As a discipline, it adopts a holistic life-cycle perspective and continuously evolves to include relevant insights from other fields, wherein as a process, a transdisciplinary and integrative approach is offered to ensure the successful creation, deployment, and eventual retirement of engineered systems with regard to technological and social systems [18]. SE applies systems principles, concepts, scientific-, technological-, and management methods [76]. Engineering is used in the widest sense and systems can relate to people, products, services, information, processes, or natural elements that work together artfully for some purpose [76]. Transdisciplinarity refers to decision-making around shared objectives, collective understanding, and joint learning in real-world contexts and can be applied to system levels from straightforward to highly complex, but is especially crucial in unfamiliar and socio-technical scenarios [18]. In contrast, an integrative approach alone may suffice when a situation is less complex or has been encountered before, as a solution path can be more easily recognized although technical or other challenges may still arise [18]. Systems principles follow systems thinking and the systems sciences, forming the basis of SE including mental models, system archetypes, holistic thinking, separation of concerns, abstraction, modularity and encapsulation, causal loop diagrams, systemigrams, and systems mapping [18]. Figure 2.2 visualizes the framework of the systems engineering concept with emphasis on the systems engineering process model.

The methodology of systems engineering should be applied to complex problems that are difficult to understand, or significantly merged with the environment, but it is not meant to solve challenges where the mutual influence is already clear and doesn't require deeper examination or deliberation [36].

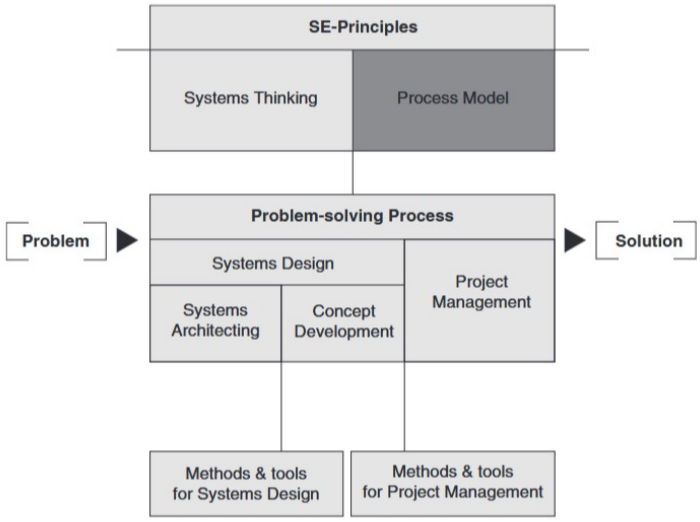

Figure 2.2: Framework of the systems engineering concept [36]

At the start of a project, the areas in need of development or definition may require closer examination or adjustments, and the main components of the problem need to be identified including factors that influence them as well as mutual dependencies [36]. From a systems thinking perspective such components are the system's elements and their relationships, but also relationships to environmental factors [36]. Only after a clear definition and structuring of the problem in agreement with both planners and client, should detailed qualitative and quantitative analyses be conducted to determine the scope of the design and systematically develop initial solution drafts [36]. This relates to the first basic principle of the SE process model, namely to proceed from the general to the detailed illustrated in Figure 2.3.

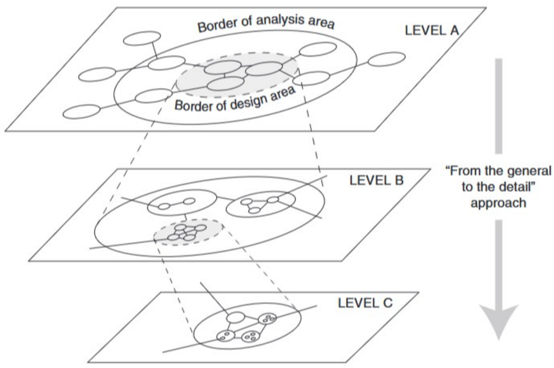

Figure 2.3: Narrowing the field of observation [36]

The second important SE guiding principle is ”variant creation” which relates to keeping the design solution space as broad as possible with regard to the level of consideration, and to not being convinced by the first solution that comes up as there are multiple solutions to any problem [36]. The third principle is an expansion of the above two and is about making a distinction between the solution (actual system's life cycle) and the project itself that realizes the solution both logically and temporal [36]. In systems engineering, multi-criteria decision-making (MCDM) is a widely used approach for choosing a solution among multiple alternatives within the design space.

MCDM is a discipline that navigates decision-making for selecting the best alternative from a set of defined potential solutions subject to multiple attributes or criteria [85]. Decision analysis is the systematic and quantitative approach and component of MCDM for evaluating alternatives when multiple conflicting criteria must be considered [85]. Stemming from this, multi-criteria decision analysis (MCDA) can be considered a theory itself that provides a stepwise process for solving decision problems with the advantage of not being limited to a single aspect or unit such as monetary considerations [85]. MCDA can be carried out for any kind of benefits and criteria depending on the formulated problem and objectives [85]. It highlights both positive and negative impacts of potential solutions, acknowledging trade-offs rather than an optimal solution [85]. The first step is to understand the exact nature of the problem which is part of the SE process. Secondly, objectives among the project or stakeholders need to be clarified as those are a guide to the result [85]. Defining criteria that are linked to the objectives is the next and particularly important step in MCDA [85]. The following steps involve developing a list of options, evaluating the options, calculating scores based on the data input, and finally documenting the results for monitoring and future use [85].

2.3.2. Design science research

Design Science Research (DSR) is rooted in engineering and learning science and aims to advance human knowledge by creating innovation artifacts such as constructs, models, and methods for solving practical problems [86]. Artifacts are applied to a certain context to improve that context in terms of a utility that the system, the people, and implemented methodologies together determine whether the goal is achieved [38]. DSR produces knowledge of how things should be designed by human agency, so-called Design Knowledge. DSR generates new ideas for adapting successfully to a dynamic environment. Such innovative ideas are communicated to the related community and academia as knowledge that provides the base for implementation and areas of future research [38]. Figure 2.4 illustrates the conceptual DSR framework in which the environment represents the core problem space [86].

The environment consists of people, organizations, and existing or planned technologies, along with the goals, tasks, issues, and opportunities perceived by stakeholders, which help define the needs that DSR addresses [86]. Those needs should be interpreted given strategies, structures, culture, and working processes of an organization or community, and together they establish the research problem from the researcher's perspective, ensuring that research activities remain relevant to stakeholder concerns [86]. A strong knowledge base that comprises theories, frameworks, tools, constructs, models, and methods is essential to be applied in the construction phase to establish potential solutions [86]. Methodologies guide the evaluation phase, ensuring the use of methods from social sciences such as interviews, surveys, focus groups, or others to assess outcomes [86].

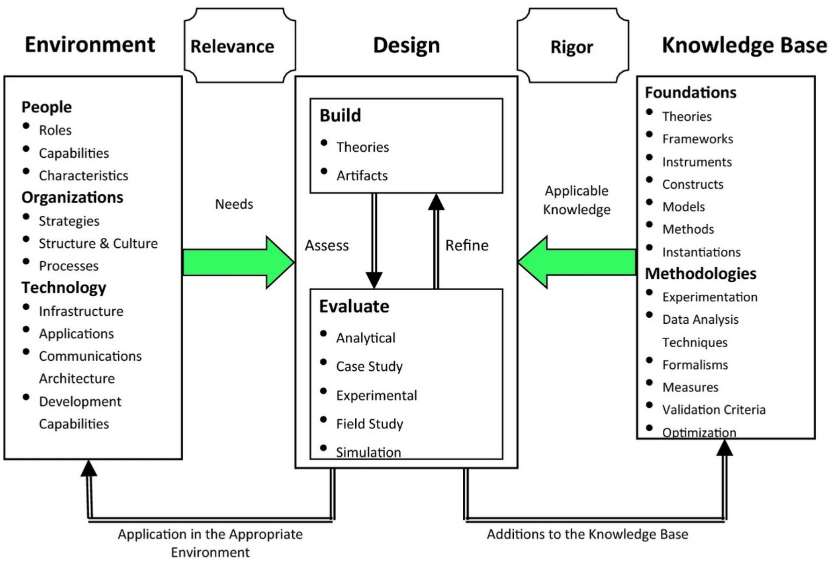

Figure 2.4: Design science research framework [86]

DSR's main focus is solving real-world problems within various application domains in which researchers identify a concrete need by analyzing the environment and by relying on existing studies, to check if sufficient DK is available [86]. Only if gaps exist, DSR is applied to develop innovative solutions by integrating, revising, or extending existing knowledge through iterative build and assessment cycles until they meet stakeholder needs [86].

2.3.3. Value sensitive design

DSR and value sensitive design are both approaches for creating or developing artifacts like technologies, systems, and processes but they address different areas in the design and research process. VSD is a more human-centered approach that guides the being with technology with moral values and positions researchers, designers, engineers, policymakers, and anyone working within socio-technical systems in ways that prioritize the well-being of humans and the natural world [25]. The provision of theory, methods, and practical approaches to systematically incorporate human values into technical design in a systematic is the key objective to drive technological innovation [25]. VSD processes are fluid and responsive to the context while offering an interactional way forward with an emphasis on well-being, dignity, and justice [25]. Within VSD human values are defined as: *"What is important to people in their lives, with a focus on ethics and morality"* [25]. Value sensitive design is used to shape situations and processes in design theory by acknowledging the highly interactive relationship between technology and human values [25]. Theoretical methods include the analysis of stakeholders; Differentiation between designer, project, and stakeholder values; Individual, group, and societal layered analysis; Integrative and iterative conceptual, technical, and empirical assessments; co-evolution of technology and social structures; and a guiding principle of committing to the progress and not for perfection [25]. The methods are thought of to be combined with other existing technical tools, and ultimately, VSD promotes human flourishing by broadening goals and adopting new ways and criteria to judge the quality of technological design [25]. VSD highlights the following:

1. "Proactive orientation toward influencing design. Value sensitive design is oriented toward influencing the design of technology early in and throughout the design process" [25].
2. "Carrying critical analyses of human values into the design and engineering process. Value sensitive design is committed to design and engineering methodologies that bring critical analyses of human values into the design process" [25].
3. "Enlarging the scope of human values. Value sensitive design embraces a broad spectrum of human values that arise in the human context" [25].
4. "Broadening and deepening methodological approaches. Value sensitive design's emergent methods draw on anthropology, design, human-computer interaction, organizational studies, psychology, philosophy, sociology, software engineering, and others" [25].

3
Research Methodology

"We need to manage holistically, embracing all of our science and traditional knowledge - all sources of knowledge. We can do that from the household to government to international relations."
(Allan Savory)

3.1. Research approach

The research follows a systems design thinking approach as part of systems engineering, that aims to incorporate systems thinking into design, by approaching complex socio-technical challenges in a holistic, human-centered, and iterative way. Buchanan [13] define a system as being "[...] a relationship of parts that work together in an organized manner to accomplish a common purpose". Systems thinkers try to understand and solve complexity by examining the relationships between parts of a system, and by looking at the system as a whole rather than breaking it down into isolated components [13]. Relationships refer to human relationships with each other but also their relationships with artifacts and nature [13]. Systems thinking methods emerged from the recognition of social systems and the importance of actively engaging stakeholders in early stages to capture their vision, ideas, needs, and values [63]. Integrating systems thinking into design principles can support designers in achieving more sustainable designs by better understanding the dynamic surrounding environment [63]. This is done by encouraging stakeholders within a system to shape the design and plan for themselves [63]. Anyone who plans, manages, organizes, or designs with social systems should embrace systems thinking [63]. Figure 3.1 introduces the socio-technical system under consideration.

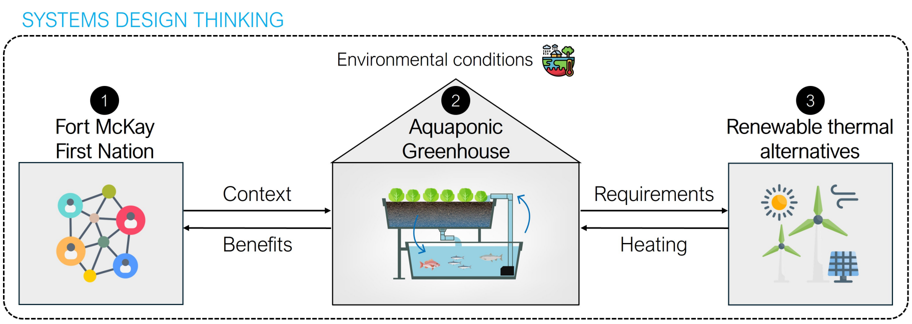

Figure 3.1: Systems Design Thinking Approach

In this research, the social system refers to the FMFN community, where the project developer envisions building an aquaponic greenhouse to enhance sustainable development and address various economic, social, and environmental challenges. The AG can be seen as a technical system that serves a social purpose and is directly linked to the technical renewable heating system. The environmental conditions, particularly climate impacts, interact strongly with all three presented systems. The primary focus of this study is to assess the viability of renewable energy options for the project by comparing heating alternatives to a natural gas scenario through a techno-economic analysis. A conventional engineering approach might involve estimating the thermal demand, selecting feasible solutions based on predefined criteria, and conducting a precise techno-economic analysis using well-established performance metrics for System 3. However, this approach may not fully align with the preferences of an Indigenous community. If the thermal demand does not correspond to a building design that the community finds acceptable, or if the selected heating technologies are not culturally adopted due to performance metrics that do not reflect community priorities, the feasibility of the solution may be compromised.

To avoid such a narrow focus within engineering, a transdisciplinary approach is applied. Transdisciplinary researchers engage with actors outside of academia in addition to working interdisciplinary to bring together academic objectives for learning and research with societal objectives arising from stakeholder needs [61]. Transdisciplinary research (TR) deals with complex and real-world challenges that require joint problem framing (JPF) between stakeholders inside and outside of academia where both scientific and practical needs exist and in which the integration of knowledge and values from various perspectives are necessary [61]. One way of conducting TR is by employing participatory research such as co-development, co-design, co-research, and knowledge co-production. Such collaborative concepts have gained increased attention within global sustainability and are increasingly adopted for complex socio-ecological systems [73]. Collaboration and co-development are vital in projects where concrete implementation of a solution is a key objective that community members are closely engaged with, and impacted by the scientific question at hand [73]. In this research, co-development relates to collaborating with the project developer and incorporating community values into the design processes of the AG and renewable heating system. The study seeks to create space for FMFN to participate in decision-making processes in community-engaged research.

Collaborating with Indigenous communities in a research context requires careful thought about how the research is conducted and needs to deal with the skepticism of many Indigenous Peoples towards researchers. There is an Alaska Native saying: ”Researchers are like mosquitoes; they suck your blood and leave” [16]. Unfortunately, research on Indigenous Peoples was historically used by colonial powers to extend political control over communities, such as the ”classifying and labeling” of Aboriginal Australians in an attempt to ”manage” them in the early years of Australian colonization [16]. Even today, research related to IPLC continues to be inappropriate, by using culturally insensitive research methodologies that neglect the needs and cultural norms of IPLC, or by presenting the research's goal as benefiting the community's well-being when its primary purpose appears to serve academic objectives instead [16]. Collaboration between academia and IPLC must clearly point out what and for whom expected benefits are to be, the values of research participants need to be acknowledged, and researchers need to understand the power of integrating Indigenous methods into research design [16]. However, using Western rational science to interpret TEK can be problematic itself and tends to misrepresent reality which will be further addressed in Section 3.4.

As a result, this study seeks to merge suitable and appropriate methods for the stated context. Mixed methods research (MMR) is applied to integrate rather than separate all means of data which also relates to the type of implementation process, integration in certain stages, theoretical perspectives, and methodological approaches such as quantitative and qualitative research. [17]. MMR design requires multiple methodologies, interdisciplinary approaches, and various philosophical perspectives for different parts of the research to generate more comprehensive and meaningful results [17]. An integrative research framework was established to fill the gap of lacking transdisciplinary studies that integrate socio-technical dimensions in their analysis with a holistic framework.

3.2. Integrative research framework

With the TEA as the central objective, a reverse engineering rationale could be applied to identify required data from the previous step: To conduct the TEA, the thermal demand is required, for which a greenhouse design artifact is needed, for which again community values need to be identified. The concept of bricolage was very useful in supporting decision-making for the ”right” methods to fill the toolbox, but also because the view is aligned with the Indigenous research methods of storytelling and personal reflection. Bricolage sees research methods actively in which processes and narratives are shaped by bringing our own understanding of the research context together with previous experiences and methods applied [9]. "The bricoleur is aware of deep social structures and the complex ways they play out in everyday life, the importance of social, cultural, and historical analysis, the consciousness of the researcher, the complex dimensions of what we mean when we talk about understanding" [9]. Bricoleurs reject and counter deterministic views of social reality and monological reductionism by accounting for relationships between the scientific and the moral, the quantitative and qualitative, and by embracing uncertainty and disorder [9]. Being aware of the assumptions and purpose of the researcher finding its way into the research and influencing what knowledge is produced, and that empirical data can yield fundamentally different interpretations based on who is looking at it from what perspective, are key characteristics [9]. It is important to acknowledge ongoing power relations and dominant discourses shaping the research process and regulating what kind of knowledge is produced and validated, and whose voices are legitimized [9]. The initial step in searching for methods, induced by the concept, was to brainstorm and ask a multiplicity of questions about the research and assign them to paradigms or methods (see Figure A.1 in Appendix A). Step-by-step a comprehensive integrative research framework was built illustrated in Figure 3.2.

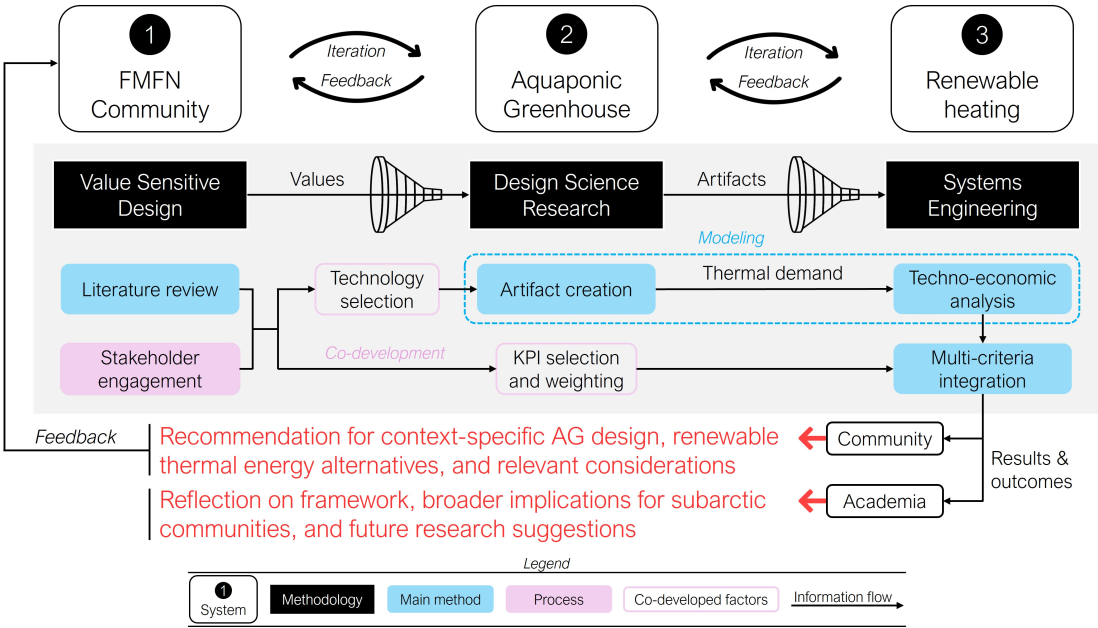

Figure 3.2: Integrative holistic research framework

Generally, the research study transitions from a broad perspective to a more focused scope, and simultaneously from a human-centered evaluation to a technology-centered analysis, according to a funnel approach (or "from the general to the detail" approach [36]). The framework is divided into three systems of which each is guided by an overarching integrative problem-solving paradigm that utilizes various methods. Only the most relevant methods or processes are shown in the visual framework. In reality, the systems, processes, and methods have a greater degree of overlap and interaction with each other in constant feedback loops and iterations. The literature review served as a first way of topic exploration within content analysis. It was used for scoping, establishing the framework, and feeding relevant information and findings to different parts of the study. The methodological framework is described according to the research flow process and explains how methods and tools are applied within the study. It clarifies how results are generated and further used within research paradigms and systems.

Multiple methods from VSD were applied in Chapter 4 *Community-Centric Evaluation*. A broad stakeholder analysis was conducted by mapping indirect and direct stakeholders of the project on a Quadruple Helix Stakeholder Map. Direct stakeholders were plotted on a Power-Interest Grid to prioritize stakeholders for further analysis. In line with VSD, stakeholders were classified into the value domains of project developer, designer, and other direct stakeholders, emphasizing roles rather than entities [25]. Including the designer (myself) allows for personal reflection and identifying influences towards the research. A process framework was established for identifying community values based on VSD methods, facilitated by direct engagement with stakeholders through qualitative data gathering to understand the diverse perspectives. Project values were identified within LANDMARC meetings of the FMFN sustainability working group. Designer values were identified by reflecting upon my role and positionality as a researcher to the subject, participants, and broader context of the work. Finally, stakeholder values were derived from literature about FMFN and LANDMARC interviews with elders from the community about gardening practices. Two iterations of the process were developed. First, a broader elicitation using value source analysis, qualitative coding, value tensions, and value scenarios was carried out for the Aquaponic Greenhouse in Section 4.3. Secondly, an adjusted process was applied for the renewable heating system in Section 4.4 with a more specified focus on technology- and KPI selection for the TEA. Figure 3.3 visualizes the first process iteration.

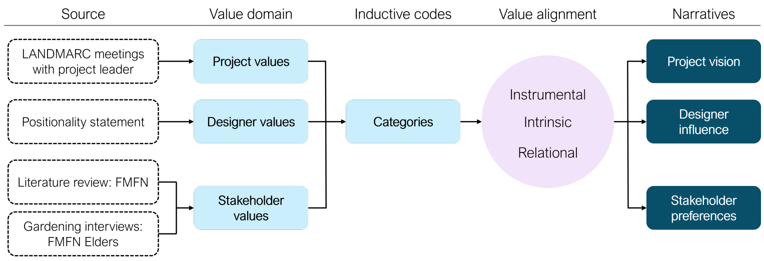

Figure 3.3: Process framework AG: From values to narratives

The value source analysis aims to make values from stakeholder sources of each value domain transparent to acknowledge Indigenous values and integrate TEK. This was done by inductively codifying articulated values into categories and deductively assigning a type of value to them. A quantitative comparison of value categories and value types between the project developer, designer, and stakeholders facilitated an assessment of value alignment (or value tension) [25]. Value tensions require mitigation strategies within the project [25]. In the final step, value-based narratives (value scenarios) were developed, reflecting project vision, designer influence, and stakeholder preferences. Narratives can capture contextualized insights into lived experiences engagingly. This makes narrative inquiry especially useful for socio-technical environments as they allow for complexity [25]. Furthermore, narratives are closely linked to the Indigenous method of storytelling which is an act of presenting a narrative, making it strongly compatible in this research. The narrative intends to summarize and translate the articulated values, thus giving design implications for chapter 5. To account for a more neutral interpretation of the value sources, AI was applied to create the narratives. This avoids biased choices of what I regard as important, particularly as my own values are included. A language model identifies text without placing any meaning to it. The data input provided was the full latex code of Chapter 4. The advanced reasoning model of ChatGPT o1 was applied in a temporary chat that is not saved to the history, not memorized by the AI, and not used for its training models to ensure data protection [59]. The following prompt was given:

Prompt 1 for the AG design narrative: "Develop a value-based narrative (or value scenario in Value Sensitive Design language) out of the entire value source analysis with regard to the Aquaponic Greenhouse and its design, that reflects the project vision, the designer influence, and the stakeholder needs and preferences."

The second iteration focused specifically on renewable heating systems in which deductive coding was applied for renewable heating technologies and KPIs as guiding categories. The objective was to derive a final selection of heating technologies to be assessed in the techno-economic analysis in Chapter 6 and to select measurable KPIs to evaluate the performance of the technologies. Here, the value identification supported a co-development process of selecting context-specific and appropriate technologies to review and KPIs as performance metrics. Figure 3.4 demonstrates the process for the second iteration.

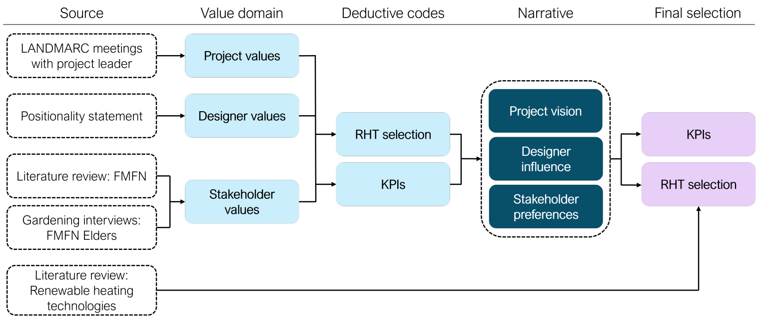

Figure 3.4: Process framework RHTs and KPIs: From values to selection

Value alignment was unnecessary since the values all relate to the specific categories of technology- and KPI selection where a solution was explored that includes the articulated values. Again, a value-based narrative was developed out of the results. In this case, the narrative provided implications for technology and KPI selection. An adjusted prompt was applied using the same Chat GPT o1 model:

Prompt 2 for the renewable heating system narrative: "Develop a value-based narrative out of the entire value source analysis with regard to the renewable heating system, particularly regarding technology selection and KPI selection. It should reflect the project vision, the designer's influence, and the stakeholder needs and preferences."

A final selection of technologies and KPIs is provided at the end of Chapter 4 in Section 4.4.3 based on combined findings from the literature review and outcomes of the value analysis. The narratives as well as technology- and KPI selection are outputs used for the following parts of the research as demonstrated in Figure 3.2.

For the Aquaponic Greenhouse design in Chapter 5, DSR principles were employed and various artifacts were developed. A general input-process-output (IPO) diagram was first created to understand the physical system in place which is shown in Appendix B.1. Constraints were listed based on the project developers' input. A requirements elicitation process was applied in which objectives were categorized into functional and non-functional related to the AG design and the renewable heating system based on the literature review and narratives. The narratives had the important functions of translating the values and preparing the data to be useful for the following methods. A major component of this study was the development of a comprehensive and integrated techno-economic systems design model implemented in Microsoft Excel. The first part handles the system sizing of the AG to determine the greenhouse size. A second artifact creation process was to translate the ground area of the building into a 3D model which was carried out with the software Autodesk Fusion 360. The rendering shows an initial value-sensitive AG design of the greenhouse and validates the system spacing inside. With a 3D design at hand, the external surfaces could be defined to estimate the heating demand. The thermal requirements were calculated within the Excel model based on monthly averages using the heating degree day calculation method. Climate data was obtained from Clean Energy Management Software developed by the Canadian government. The locations of Mildred Lake and Fort McMurray Airport provided NASA weather data which were used to represent Fort McKay.

The focus of the thesis was set on the renewable heating system for which more conventional engineering methods were applied. A techno-economic analysis (Chapter 6) and multi-criteria integration (Chapter 8 were incorporated within the Excel model. The community-centric evaluation established the foundation for integrating values and TEK into the design. The preliminary AG design ensured that thermal demand requirements could be more accurately calculated. To link the thermal demand to the heating supply, relevant operational parameters were defined and calculated. A base case was first established that focuses on assigning relevant capital expenditures (CAPEX) and operating expenses (OPEX) to the greenhouse building, RAS, and growing systems to model food and fish production. Parameter values were validated by experimental studies. The heating supply for the base case assumes a natural gas boiler system that serves as a benchmark for comparing the thermal performance to renewable heating alternatives. Monthly figures were extrapolated for an entire year. Cash flow statements within the model calculate NPC and NPV among others over a lifecycle of 20 years. Based on the base case, the model was adjusted step-by-step to reflect each renewable heating technology in a separate sheet. The single input variable allows for variation of the fish tank volume, facilitating outputs for different aquaponic system sizes which is proportional to the greenhouse size and thermal demand. Variables and parameters are therefore strongly connected and dependent on each other. A sensitivity analysis was performed for the AG without considering the heating supply and was only then carried out for each renewable heating option accounting for the whole system. The general separation of heating and non-heating-related costs was important to better understand the cost breakdown during operation.

While the AG narrative gave design implications for the greenhouse, the second narrative supported technology and KPI selection for the renewable heating system. The TEA was conducted for the selected technologies and built in a way that the co-developed KPIs can be measured. With this, the first five steps of an MCDA process were already given. The problem was formulated, objectives and stakeholder needs were identified, criteria were defined that are linked to the objectives, and a list of renewable heating options was provided and evaluated [85]. The use of MCDA in the multi-criteria integration enabled the inclusion of technical, environmental, and social indicators in a multi-criteria ranking. Within the TEA, data could be prepared accordingly by selecting metrics that reflect the KPIs. However, the TEA ranked renewable heating options according to NPV. Performance indicators from the technical, social, and environmental domains were part of the assessment but not incorporated into a ranking based on non-monetary criteria. MCDA allowed for a more comprehensive ranking that could be compared to the NPV score. Most importantly for this application, MCDA was a means to directly integrate stakeholder values into decision-making. A fundamental part of MCDA is to assign weights to the defined criteria which reflect the importance of that specific criteria relative to the others. This part of MCDA was essential for synthesizing results in this study which can be achieved by various MCDA methods.

The best-worst method (BWM) developed by Rezaei [67] was applied to obtain weights in Chapter 8. BWM is a pairwise comparison-based method that reduces complexity while maintaining more accurate outcomes and ensuring consistency in the answers provided. This was vital in this research where the goal was to integrate traditional values into engineering principles. The project developer assigned weights to the previously defined criteria following the BWM process in a guided online meeting. BWM generates better results than simple weighting methods and other comparison-based methods while simultaneously checking for consistency, and the weighting could be isolated from the rest of the process. Against the condition of criteria independence, the Weighted Sum Model was applied to combine normalized scores with weights to the performance scores of the heating alternatives to compare NPV scores to the multi-criteria ranking. The use of the method is further reflected upon in Section (reflection bwm).

3.3. Data collection

Conducting research with an Indigenous community is often motivated by the goal of contributing to the community's well-being or advancing social justice. However, conflicts may arise regarding the knowledge that is revealed or shared [16]. The knowledge and data must be protected and handled in agreement with community participants while different community values must be accommodated and acknowledged as much as possible [16]. In this research study, data was collected under the umbrella of the LANDMARC project under HORIZON 2020 and dealt with according to the General Data Protection Regulation. Community contact was established through an ongoing partnership between LANDMARC and Fort McKay in a supervised manner. Data inputs from LADNMARC were given only by permission and handled strictly confidential. No personal data is displayed without having consent for it and sources are not fully presented in case of regulatory conflicts. The research was conducted in cooperation with the project developer of the greenhouse project to whom research findings were regularly presented and discussed in ongoing LANDMARC meetings of the FMFN sustainabilty working group. The use of data from the meetings was agreed upon by the participants. The POPD in Appendix A.3 addresses the ethical implications and data protection measures related to managing personal data for research carried out within LANDMARC.

Through a value source analysis in Section 4, community values were acknowledged and made transparent in an attempt to integrate TEK in this study. Another issue in participatory research deals with the question of who receives credit for the gained knowledge. Cochran et al. [16] explains that "[...] it is important to understand that knowledge gained from Indigenous communities is both local and specific to a given research effort, but it is also global in terms of history and potential impact". In this research, it is ensured that intellectual property (IP) rights from research outcomes remain for and with the community. Key design elements of the Aquaponic Greenhouse are currently part of a patenting process in collaboration with the project developer. For that reason, critical elements were removed and will not be shown. The research also ensures that relevant findings, suggestions, and recommendations are fed back to the community in a culturally appropriate manner.

3.4. Limitations of the study

The holistic and integrative nature of this study introduces several limitations. While the research aims to address the technical, economic, social, and environmental dimensions of the project, time constraints required compromises in the depth of analysis. Key areas such as the techno-economic analysis and value-sensitive design were prioritized, but a comprehensive exploration of the policy landscape including financial subsidies or regulatory frameworks for clean energy projects was beyond the scope of this thesis. The early stage of the project was another limiting factor. The analysis is an initial approximation of understanding broad connections where many aspects were uncertain and could change quickly. At the same time, new ideas were tested in a developed research framework.

Incorporating Traditional Ecological Knowledge into engineering principles was challenging due to high uncertainties. The exploratory nature of the study in a context that dealt with differing cultural beliefs was not always easy to align with the academic requirements of my studies at TU Delft. The program has guidelines and evaluation criteria for my thesis in place that ask for clear design and/or engineering approaches that were taught. This is an understandable standard procedure in any University but limited to how TEK could be integrated and its role in this research. Generally, following a human-centered approach including values in an engineering setting was challenging and contradictory since the aim was to break down something highly subjective and intangible into a measurable process. The categorization and interpretation of values within the value-sensitive design approach were subject to bias as it was carried out by myself. A mitigation strategy applied was the use of AI to develop narratives out of the analysis.

Stakeholder engagement was an essential part of the research established through the project developer and indirect sources such as interviews and literature. However, direct engagement with other community members was not achieved. A community survey was planned and organized for the multi-criteria integration to reflect stakeholder values in addition to project values. Due to difficulties in simply translating the weighting process to a survey, the expiring LANDMARC project, and general time constraints, the survey was excluded from this thesis. Important perspectives articulated directly by FMFN members are thereby not included in the multi-criteria ranking. However, follow-up research strategies to conduct the survey outside of this study were discussed in a LANDMARC meeting together with the project developer.

More specific limitations within the modeling part were challenges in obtaining cost data from Canadian suppliers that further limited accuracy and required reliance on European data which may not fully reflect regional differences in market dynamics. Incorporating well-established validation processes was difficult in this unexplored field. Parameters in the model were largely validated based on experimental studies or studies that did not fully reflect a similar environment. Sustainability metrics such as carbon emissions and energy efficiency were included but a full life cycle assessment of the greenhouse and heating systems was not conducted. This limits the ability to fully evaluate long-term environmental trade-offs. Additionally, the research findings and models were tailored to the specific socio-technical and environmental context of Fort McKay and may not be transferable to other regions without adjustments for local conditions.

These constraints along with general uncertainties surrounding the feasibility of renewable heating technologies in northern Alberta, underscore the need for further research and empirical testing.

4

Community-Centric Evaluation

"A business that makes nothing but money is a poor business."
(Henry Ford)

4.1. Stakeholder analysis

The identification of stakeholders is an important first step to get an overview of the environment. FMFN collaborates with various government entities, industry partners, academia, and other communities in different areas and on different levels. Diverse interests and interdependencies can strongly influence sustainability projects, such as the AG project. Having a sense of the distinct power relations among stakeholder groups helps to identify and to understand different needs and perspectives. Figure 4.1 shows a broad classification of context-relevant stakeholders for this research. Stakeholders shown in light blue represent indirect stakeholders who do not necessarily interact with the system at hand but can be affected by it [25]. Those are external stakeholders from government bodies, the private sector, and academia. Stakeholders in dark blue are direct stakeholders from the FMFN community or ones that directly interact with the system [25].

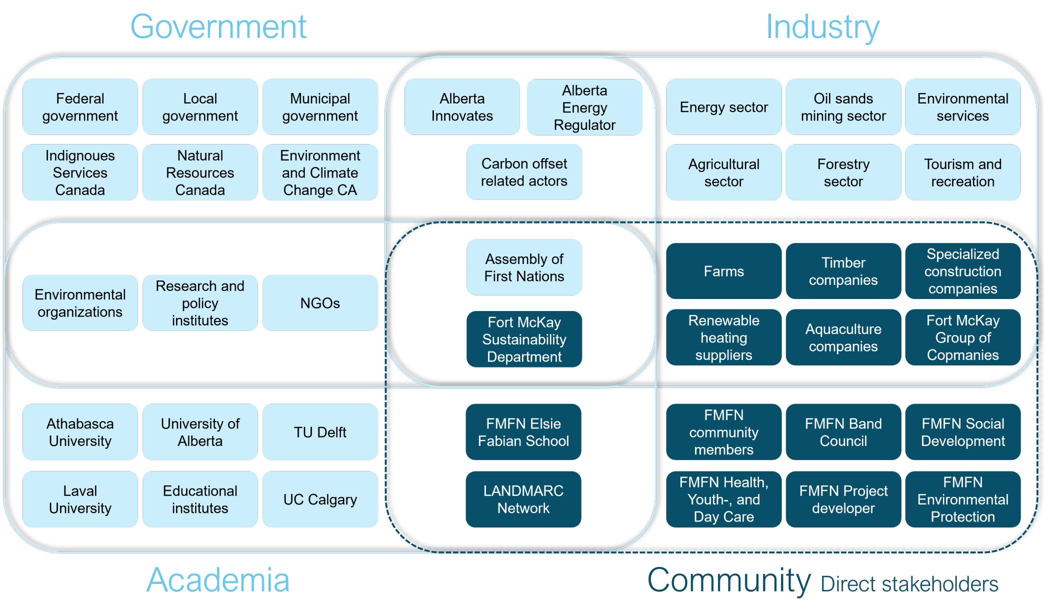

Figure 4.1: Quadruple Helix Stakeholder Map

Governments range from federal to municipal level and can also include agencies that focus on a specific field or topic such as Indigenous Services Canada (ISC), Natural Resources Canada (NRCan), and Environment and Climate Change Canada (ECCC). ISC supports First Nations, Inuit, and Métis communities in socio-economic development; NRCan promotes sustainable forestry and clean energy projects; and ECCC is responsible for environmental policies, climate action as well as funding for carbon offsets [33, 34, 31]. Intersecting governmental and academic stakeholders typically bridge research and policy implementation such as environmental organizations, NGOs, or other institutes. Universities in Alberta showcase community-focused research and Indigenous collaboration while placing a strong focus on sustainability studies [84, 5]. Government bodies linked to the private sector can be innovation drivers, energy regulators, or carbon offset actors. Relevant industry sectors cover energy, oil sands mining, environmental services, agriculture, forestry, and tourism. One stakeholder that interacts with all 4 fields is the Assembly of First Nations (AFN), which represents Canadian First Nation communities by creating dialogues about rights, concerns, and priorities between First Nations, governments, businesses, and the general public [4].

Direct stakeholders can be categorized into companies or organizations relevant to certain areas of the greenhouse project such as LANDMARC partners, farms, timber-, construction-, heating-, and aquaculture suppliers; and FMFN community stakeholders like the project developer, members, the band council, and various community departments and facilities. The direct stakeholders are mapped on a Power-Interest (PI) Grid in Figure 4.2, displaying high or low power in affecting the project as well as high or low interest regarding the implementation. Greenhouse suppliers are merged into a single stakeholder reflecting all companies involved in providing greenhouse-related services. The Fort McKay Sustainability Department and FMFN Environmental Protection are also combined into one stakeholder ”FMFN Sustainability Environment” for the PI analysis.

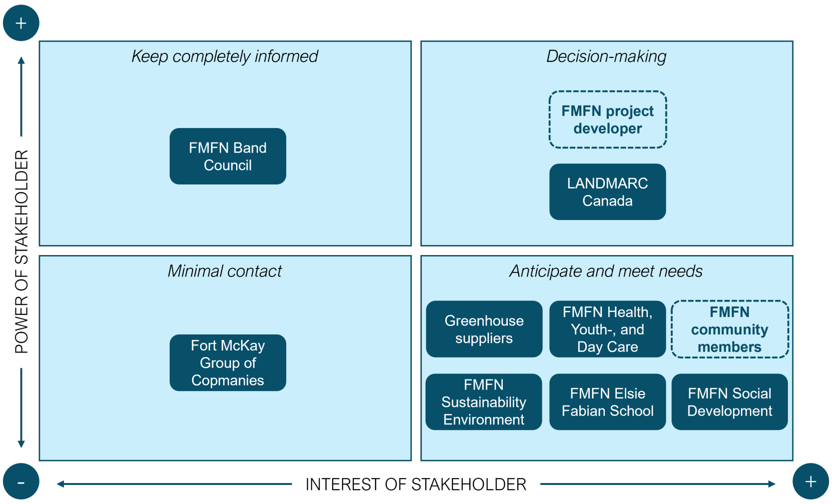

Figure 4.2: Power-Interest Grid: Direct Stakeholders

The PI Grid can be seen as a matrix that is made up of four fields to which stakeholders are assigned: (1) Stakeholders with low power and low interest who require minimal contact, (2) Stakeholders with low power but high interest whose needs should be met, (3) Stakeholders with high power but low interest who should be kept informed, and (4) Stakeholders with high power and high interest who represent decision-makers in this case.

The Fort McKay Group of Companies (FMGOC) is an oilfield construction and services company owned by FMFN including business units of strategic services, logistics, mechanical and heat treatment services, and joint ventures [24]. FMGOC is assigned to category 1 as their field of work mostly addresses sectors that are not relevant to the greenhouse project, although they also address sustainability topics and heat treatment services that could be of interest. Category 2 includes greenhouse suppliers, FMFN divisions (Health, Sustainability & Environment, Education, and Social Development), and most importantly all FMFN community members. Greenhouse suppliers have an economic interest in being chosen to provide services for greenhouse implementation but exhibit limited power. FMFN Health-, Youth-, and Day Care have a high interest because the greenhouse project also aims to improve the health of community members by providing fresh produce which could be part of the facility's nutritional plan. The same holds for the Elsie Fabian School that additionally, could incorporate practical educational programs with the greenhouse. The FMFN Sustainability and Environmental Protection departments can have a high interest in promoting and supporting all aspects of sustainable development, specifically the application of renewable energy and potential carbon offsetting. The FMFN Social Development areas might see opportunities such as employment and other benefits that the project brings along. The high interest of community members stems from the idea of providing community-based growing plots for those interested in gardening or other community-based activities that could be carried out in the greenhouse. The Band Council is appointed to category 3 as their interest in the project itself might be limited but they have a regulatory function and are responsible for approval which makes them also an indirect decision-making. They can heavily influence project developments. Finally, the project developer and LANDMARC Canada are designated to category 4 with high interest and high power. The project developer is the project owner who intends to implement the greenhouse vision as a social enterprise in Fort McKay. LANDMARC is not a decision-maker but influences decisions as researchers collaborate and work closely together with the project developer. The main stakeholder focus for further analysis is on the project developer and community members, which are marked with dotted lines in Figure 4.2.

4.2. Values

The search for academic literature in an attempt to define ”values”, quickly resulted in a realization that value theory seems to remain unresolved and unavoidably leads to the exploration of deeply philosophical questions such as: Is value determined by personal preferences or independent of human perception? Many scholars define human values in the domain of personal and cultural belief systems, moral guiding principles of a social group, or worldviews [3, 35]. This makes things problematic if the aim is to identify Indigenous values with a Western scientific approach. According to Groenfeldt [35], the dominant Western concept of rational science has developed into a global standard for the judgment of any society and belief. However, Western and Indigenous beliefs and worldviews are inherently different. The understanding and meaning of values might already be distinct and individual. My own understanding of it probably differs as a so-called Third Culture Individual (TCI) who grew up bilingual in five different countries up to the age of 13. Chun [15] states that the Hawaiian language does not have any word for values, morals, and ethics which apparently is not unusual for traditional cultures since morals are a fundamental part of their daily life. This indicates how differently it might be perceived by various cultural societies. Keeping all that in mind, for this research values are defined as *”what is important to people in their lives, with a focus on ethics and morality”* adopted from the VSD approach by Friedman and Hendry [25].

In academic literature, values are increasingly categorized into *intrinsic*, *instrumental*, and *relational values* which started to be more adopted within studies from 2016 in addition to the classification of instrumental and intrinsic (non-instrumental) values [39]. Table 4.1 defines the three types of values and summarizes relevant associations for better understanding.

Table 4.1: Types of values [39]

Value type	Definition	Relevant associations
Instrumental	Means to achieve human ends or satisfy human preferences and intended as usefulness for humans, utility, or benefits	Strongly associated with anthropocentrism, utilitarianism, and technocratic approaches
Intrinsic	Values expressed independently of any reference to people as valuers regardless of importance or usefulness to humans	Strongly associated with ecocentric worldviews and moral obligations towards other species; Weakly associated with altruistic values and spirituality
Relational	Values of meaningful and reciprocal human relationships beyond means to an end (with nature and among people through nature)	Strongly associated with broad values such as stewardship, responsibility, care, affection, reciprocity, harmony, justice, and spirituality

Himes et al. [39] conducted an extensive literature analysis to classify each of those value types according to its core meaning while considering different worldviews to support codification in empirical studies. The meaning of instrumental, intrinsic, and relational values can overlap, as they are context-specific and depend on perspectives of different knowledge systems [39]. Oversimplified, one could say that Western worldviews are more represented by instrumental values, while Indigenous worldviews are more associated with relational values.

Within VSD, stakeholders are understood by roles rather than actors to account for duties, contextual identities, and circumstances [25]. An important distinction that follows from this rationale is the one between *project values*, *designer values*, and *stakeholder values*, which are defined as value domains in this research. Project values relate to the project goals and are articulated by the project developer; designer values are personal and professional ethical values that are reflected upon by the designer, individually; and stakeholder values relate to all other direct stakeholders [25].

4.3. Aquaponic Greenhouse

4.3.1. Value source analysis

Table 4.2 shows expressed project values related to the Aquaponic Greenhouse including a categorization of the articulated value and its associated value type.

Table 4.2: Project values: Aquaponic Greenhouse

Articulated value	Category	Value type
Stakeholder: Project developer		
Connecting community members for shared learning and preservation of traditional knowledge	Education; TEK; Reciprocity	(Instrumental); Relational
Improving well-being and health of community members by supplying fresh produce	Health; Care	(Instrumental); Relational
Attract tourism to show people that FMFN is a progressive community that can lead in sustainability	Economic development; Sustainability; Pride	Instrumental; Relational
Pave the way for future generations to ensure prosperity for the community	Social development; Economic development	(Instrumental); Relational
Concern for members who struggle e.g. with supplying their kids by themselves while working hard everyday	Health, Care, Responsibility	Relational
The weather conditions are increasingly fluctuating, impacting the community and calling for both climate change mitigation and adaptation strategies	Climate impacts; Food security; Safety	Instrumental; Relational
Vision of an indoor ecosystem with community space, clean air, and fully automated which can be a stopping point for tourists	Food security; Health; Innovation; Economic development	Instrumental; Relational
Regain control of our own development and shape it in a way that resonates with our culture and traditions while adapting to the external circumstances	Autonomy; Self-determination; TEK; Innovation; Responsibility	Instrumental; Relational
Cultivating catfish with spiritual meaning in aquaponics, and growing medicinal plants due to decreasing soil quality and land conversion on outside	Self-determination; TEK; Innovation	Instrumental; Relational
Revitalize our food system and maintain traditional culture of harvesting	Self-determination; TEK; Innovation	Instrumental; Relational
Supply the school and other facilities with healthy food and use the greenhouse for sharing and learning	Health; Reciprocity; Care	(Instrumental); Relational
We are done with other people telling us what to do and how to do things, money is not the issue	Autonomy; Self-determination; Justice	Instrumental
Testing growth of potatoes (among others) with self-built aeroponics system for starch-rich diet of community	Plant species; Innovation; Care	Instrumental; Relational

Table 4.3 highlights the count of assigned topic categories for the articulated project values.

Table 4.3: Inductive coding: Project values

Nr.	Category	Count	Nr.	Category	Count
1	Innovation	5	10	Autonomy	2
2	Health	4	11	Education	1
3	TEK	4	12	Sustainability	1
4	Self-determination	4	13	Pride	1
5	Care	4	14	Social development	1
6	Economic development	3	15	Climate impacts	1
7	Reciprocity	2	16	Safety	1
8	Responsibility	2	17	Justice	1
9	Food security	2	18	Plant species	1

Table 4.4 shows designer values associated with the Aquaponic Greenhouse. In VSD, it is essential to be transparent about the researcher's values regarding the project to identify bias and subjectivity since every researcher brings his own mindset to work that comes with underlying objectives, influencing the research and design [25]. Of course, it is already biased to identify one's own values but having that awareness can lead to a more neutral assessment.

Table 4.4: Designer values: Aquaponic Greenhouse

Articulated value	Category	Value type
Stakeholder: Designer and researcher (myself)		
Concern for climate change and its impacts on vulnerable actors	Climate impacts; Care; Justice; Sustainability	Relational
Analytical systems design thinking with data-driven solutions but also care for aesthetics	Systems engineering; Aesthetics	Instrumental
Curiosity and interest for natural processes and non-human species, also to address sustainability	Curiosity; Nature; Sustainability	Intrinsic; Instrumental
Prioritization of stakeholder needs and contextually appropriate recommendations as an external observer	Respect; Responsibility; TEK	Instrumental; Relational
Awareness of cultural differences and need for understanding diverse knowledge systems for suitable cultural integration in design	Care; Responsibility; TEK	Instrumental; Relational
Collaborating with the community and feeding back research results that might be supportive	Collaboration; Reciprocity	Instrumental; Relational
Critical of economic model but awareness of lacking alternatives and necessity of project success	Justice; Economy	Instrumental
Interest in innovative design regarding environmental and social sustainability	Innovation; Sustainability; Social development	Instrumental
Responsible for technical prioritization of efficiency and reliability to propose functioning solutions	Responsibility; Efficiency; Reliability	Instrumental

Values are derived from a positionality statement that examines personal background, role within the project, relationship to stakeholders, and impact on outcomes. Table 4.5 highlights the count of assigned topic categories for the articulated designer values.

Table 4.5: Inductive coding: Designer values

Nr.	Category	Count	Nr.	Category	Count
1	Sustainability	3	10	Nature	1
2	Responsibility	3	11	Respect	1
3	Justice	2	12	Reliability	1
4	Care	2	13	Efficiency	1
5	TEK	2	14	Reciprocity	1
6	Climate impacts	1	15	Economy	1
7	Systems engineering	1	16	Innovation	1
8	Aesthetics	1	17	Collaboration	1
9	Curiosity	1	18	Social development	1

Stakeholder values identified from the literature are displayed in Table 4.6. The table encompasses broader values associated with FMFN community members and the band council.

Table 4.6: General stakeholder values: Aquaponic Greenhouse

Articulated value	Category	Value type
Stakeholder: FMFN community members [26]		
Muskeg as reliable sources for water, travel corridors, medicine, material and food for both people and animals	Nature; Health; Animals	Instrumental; Intrinsic; Relational
Health concerns (asthma) and ensuring healthy sustainable populations of culturally important species to maintain cultural heritage	Health; Care; Sustainability; TEK; Self-determination; Responsibility	Instrumental; Relational
Earth and air are not healthy so we are not healthy	Health; Reciprocity; Spirituality	Relational
Stakeholder: FMFN community members [78]		
Limited access to cultural sites (I can no longer go where I want when I want)	TEK; Autonomy	Instrumental; Relational
A changing environment means a loss of our identity because our interaction with the land is being removed	Environmental protection; Identity; Spirituality; Justice	Relational
Stakeholder: FMFN community members [7]		
Networks for harvesting as well as spiritual and social exchange extend beyond confined reserves which is not acknowledged	TEK; Social development; Spirituality; Autonomy	Relational
Stakeholder: FMFN Band Council [20]		
Prosperity by participation in economic oil sands development, as involvement in local resource activities remains the best hope for social well-being of First Nations	Economic development; Dependency; Social development; Responsibility	Instrumental; Relational

Table 4.7 summarizes values from gardening interviews with elders. In the interviews, three elders who are involved in different gardening practices are asked about those activities. They could reflect potential greenhouse users and provide valuable insights linked to challenges and needs.

Table 4.7: Stakeholder values from gardening interviews: Aquaponic Greenhouse

Articulated value	Category	Value type
Stakeholder: FMFN Elder - Interview 1		
Experiences with local wildlife, including wolverines and massive bears, visiting his garden, but he has a good understanding of the local fauna	Animals; Nature; Respect	Relational
Adaption of gardening system, making it bear-proof (because of risk for bear) and adding low-cost digester as compost from local shops is too expensive	Adaption; Care; Innovation; Waste recycling; Affordability	Instrumental; Relational
Limited soil-depth (1 foot) with permafrost underneath peatland avoiding plant growth in most areas	Climate impacts; Land conversion; Failed crops	Instrumental
Plants grown: bushes, fruits, potatoes, cabbages, some massive zucchinis, cucumbers, various types of tomatoes. peppers, corn, sprouts, railroad grapes, Haskap, Honey, and Saskatoon berries	Plant species; Successful crops	Relational
Giving away spare vegetables to other members when harvest is plentiful	Reciprocity; Care; Respect	Relational
Some unsuccessful planting due to water evaporation in May (remaining frost) resulting in shorter planting season	Climate impacts; Failed crops	Instrumental
Privileged to have time for gardening in a working town like Fort McKay, as it requires constant monitoring of soil and patience, mostly affordable for retired people	Appreciation; Economy; Patience; Retirement	Instrumental
"Use what you have in your garden as much as possible. There is no need to spend a lot of money when you have the resources available"	Re-use; Waste recycling; Affordability; Self-sufficiency	Relational
Self-sufficient garden management with occasional help from his children and grandchildren to whom he actively passes on knowledge of his experience	Self-sufficiency; Reciprocity; Education; TEK	Relational
Stakeholder: FMFN Elder - Interview 2		
Siblings in Ontario on farming land stated that the perception of greenhouses is not entirely positive	Greenhouse; Farming; Perception	Relational
Third year gardening with learning by doing and learns from her mistakes	Practical; Education	Instrumental
Started growing plants in her basement after retirement but it did not succeed due to cold temperatures.	Climate impacts; Failed crops	Instrumental
Hose drip system for automated watering which she would replace with a connected rainwater irrigation system	Adaption; Innovation; Efficiency	Instrumental
Has a greenhouse in usage from early spring, growing cucumbers (failed to grow) and tomatoes.	Greenhouse; Climate impacts; Failed crops	Instrumental
Composting during winter to allow for land to regenerate, and mentions challenging bad soil quality requiring large amounts of dirt	Waste-recycling; Reciprocity; Land conversion; Manual work	Instrumental; Relational
Problems with invasive plants that are difficult and time-consuming to remove manually	Pests; Manual work	Instrumental
Variety of crops including different types of tomatoes, carrots, green onions, beetroots, raspberry-, cranberry-, and strawberry bushes	Plant species; Successful crops	Relational
Failed crops due to green worms include potatoes, cucumbers, cabbages	Pests; Failed crops	Relational
Tree leaves are unhealthy, probably caused by a lack of nutrients according to agricultural expert	Health; Failed crops	Relational

Articulated value	Category	Value type
Hesitant about continuing gardening due to challenging terrain, unhealthy labor with lack of soil beds, financial reasons, and lack of support	Health; Land conversion; Affordability; Manual work	Intrsumental
Sharing harvest with neighbors and family members while consuming grown tomatoes every week	Reciprocity; Care; Respect; Self-sufficiency	Relational; Instrumental
Stakeholder: FMFN Elder - Interview 3		
Leading Environmental Guardian, responsible for stewardship of traditional land	Stewardship; Responsibility; Care; Sustainability	Relational
Has a beautiful greenhouse, initially roofed with plastic glazing which was removed for rain and sun exposure	Pride; Aesthetics; Material; Adaption	Instrumental
Bad soil quality resulted in building an innovative dual system of raised beds and fence, requiring less effort to harvest variety of crops	Efficiency; Adaptation; Innovation; Manual work	Instrumental
Adaption of plastic canvas routing as rainwater irrigation system	Efficiency; Adaptation; Innovation; Self-sufficiency	Instrumental
Not composting due to increased labor and lack of storage options, but willingness to share his composting materials with other members	Manual work; Affordability; Reciprocity; Care	Relational; Instrumental

Table 4.8 on the following page, highlights the count of assigned topic categories for the articulated stakeholder values.

Table 4.8: Inductive coding: Stakeholder values

Nr.	Category	Count	Nr.	Category	Count
1	Reciprocity	5	23	Animals	2
2	Adaptation	5	24	Sustainability	2
3	Care	5	25	Autonomy	2
4	Health	5	26	Dependency	1
5	Failed crops	5	27	Perception	1
6	Innovation	4	28	Aesthetics	1
7	Climate impacts	4	29	Pride	1
8	Affordability	4	30	Stewardship	1
9	TEK	4	31	Self-determination	1
10	Responsibility	3	32	Practice	1
11	Spirituality	3	33	Farming	1
12	Efficiency	3	34	Economic development	1
13	Manual work	3	35	Environmental protection	1
14	Waste recycling	3	36	Identity	1
15	Land conversion	3	37	Re-use	1
16	Greenhouse	2	38	Retirement	1
17	Education	2	39	Patience	1
18	Successful crops	2	40	Economy	1
19	Plant species	2	41	Appreciation	1
20	Pests	2	42	Justice	1
21	Nature	2	40	Material	1
22	Social development	2			

4.3.2. Results and value alignment

Table 4.9 lists the 10 most counted categories that were identified from the articulated values of each domain. The blue-colored ones represent value categories that are shared across all three value domains, and the green-colored ones appear in two of the three categories. This indicates a high level of alignment of values between the project developer, designer, and other stakeholders. Note, that those are categorizations of expressed values. For instance, the presence of "Traditional Ecological Knowledge" within designer values does not mean that I hold TEK, but that my articulated value was categorized into that, which relates to the importance of integrating TEK into the design.

Table 4.9: Top counted categories of value domains

Nr.	Project values	Designer values	Stakeholder values
1	Innovation	Sustainability	Reciprocity
2	Health	Responsibility	Adaptation
3	TEK	Justice	Care
4	Self-determination	Care	Health
5	Care	TEK	Failed crops
6	Economic development	Reliability	Innovation
7	Reciprocity	Innovation	Climate impacts
8	Responsibility	Climate impacts	Affordability
9	Food security	Reciprocity	TEK
10	Autonomy	Aesthetics	Responsibility

Looking at all identified categories, 9 out of 50 categories are shared among all three domains, while 11 are shared across two domains. This confirms the high level of alignment when considering that a majority of categories come from stakeholder values from the gardening interviews. Those articulated values can be about very specific topics. The unshared categories do not imply value tensions but can be explained by different contexts of value sources which becomes visible when observing the assigned value types shown in Table 4.10.

Table 4.10: Percentage of assigned value type across value domains

Value type and combinations	Project values	Designer values	Stakeholder values
Relational	38.46%	10%	40.63%
Instrumental & Relational	53.85%	30%	21.87%
Instrumental	7.69%	40%	37.5%
Instrumental & Intrinsic	0%	10%	0%
Instrumental & Intrinsic & Relational	0%	10%	0%

The largest part of project values (54%) were assigned to a combination of instrumental and relational types, as the values expressed a means to an end. It is important to understand that the context of the conversations in the project meetings mostly revolved around means to an end, namely to make the greenhouse vision come true. However, the utility derived from the expressed project values was always directed toward the collective well-being of the community and not toward a different goal. Despite that, 38% of values are purely relational which corresponds well with a similar number of around 40% of stakeholder values. In a different context, value types would shift more from instrumental to relational ones. A similar rationale can be applied to designer values and also stakeholder values. As a designer, your whole job is about finding appropriate means to achieve human ends for some stakeholder group. In the case of stakeholder values, the higher proportion of instrumental values is due to the context of the gardening interviews in which community members were asked about the practical implementation of growing practices, in which some kind of usefulness for someone is commonly present.

Overall, the highest alignment can be seen between project values and stakeholder values, which is logical since the project developer is a community member, who is working on a greenhouse vision for the community. Designer values are slightly distanced from the two as I am an external researcher aiming to collaborate with the project developer in service to the community. Against this background, i do not identify any sort of value tensions that demand ways of mitigation.

4.3.3. Value-based narrative

A value-based narrative was developed by AI based on the value source analysis regarding the Aquaponic Greenhouse and its design:

A Day at the Fort McKay Aquaponic Greenhouse

Morning: **A Community-Driven Start**

At dawn, the doors of the Fort McKay Aquaponic Greenhouse open to a mix of Elders, youth, and local families. Daylight streams through the greenhouse's glass panes, illuminating rows of vegetables growing via an aquaponic system that circulates nutrient-rich water from a small fish basin—carefully chosen catfish, which carry cultural and spiritual meaning for some members of the community.

Midday: **Knowledge Exchange and Traditional Ecological Knowledge**

As the day progresses, the greenhouse transitions into an educational hub. Children from the Elsie Fabian School arrive for a hands-on science lesson, while a group of older youth from the community's Environmental Protection Department sets up experiments comparing modern aquaponics with traditional growing practices.

Afternoon: **Balancing Costs and Benefits**

After lunch, a band council member visits to discuss the greenhouse's monthly operating costs with the project developer. Although the community has well-established economic ventures in oilfield services, this greenhouse represents a more localized, circular form of enterprise—where the success is measured by community welfare, not just revenue.

Evening: **Reflection, Reciprocity, and Looking Ahead**

As the sun starts to set, the greenhouse transitions into a community gathering space. Visitors walk among the plants, breathe the fresh air, and sample produce. Elders share stories of the land as it was decades ago—when foraging, hunting, and harvesting on the land were primary ways of life. Younger members propose ways to further integrate the greenhouse into local festivities and cultural events.

Conclusion

In this narrative, the Aquaponic Greenhouse emerges as an evolving communal resource—where **project values** (community well-being, autonomy, TEK integration) intersect with the **designer's values** (technological reliability, sustainability, and cultural respect) and the broader **stakeholder values** (reciprocity, stewardship, affordability, and cultural identity). The shared emphasis on *relational* and *instrumental* values shows a strong alignment across all parties: rather than any deep conflicts, most differences center on specific techniques (e.g., pest management, composting systems) or on how to balance cost versus complexity.

As the greenhouse continues to grow—both literally and metaphorically—it serves as a testament to Fort McKay First Nation's self-determination and resilience. By honoring the land and culture while embracing purposeful innovation, the community stands as a model of how localized food and knowledge systems can flourish, even amid challenging environmental and socio-economic conditions.

4.4. Renewable heating system

4.4.1. Value source analysis

Table 4.11 shows expressed project values related to the renewable heating system, including deductive categories of renewable heating technology selection and concerning KPIs.

Table 4.11: Project values: Renweable heating system

Articulated value	RHT selection	KPIs
Stakeholder: Project developer		
Attract tourism to show people that FMFN is a progressive community that can lead in sustainability	Visibility; Renewable	Sustainability
Fully automated system	Visibility; Automation	Automation
Use organic waste from 260 homes and request animal manure from buffalo farm to produce biogas	Anaerobic digestion with biogas	Waste recycling; Re-use
Available grid access for natural gas and electricity	Hybrid; GSHP	Ease of operation
We are not renewable anywhere despite huge potential for using available resources, solar, water and more	Solar energy; Biogas; Biomass	Self-sufficiency
People will adopt renewables if we can provide a low maintenance system that reduces water, electricity, and other consumption	GSHP, Solar thermal collectors	Low maintenance; Affordability
Self-sustaining technologies and awareness of reducing carbon emissions is growing	Low emission technologies	Off-grid; Carbon emissions
Harnessing the suns energy with solar panels or many other ways	Solar PV; Passive solar;	Solar potential

Table 4.12 shows expressed designer values related to the renewable heating system, including deductive categories of renewable heating technology selection and concerning KPIs.

Table 4.12: Designer values: Renweable heating system

Articulated value	RHT selection	KPIs
Stakeholder: Designer		
Need for technical reliablility	Well-established technologies	Reliability
Thermal efficiency to reduce demand and costs	Passive solar design	Efficiency
Providing lowest cost possible but ensuring technical performance	Biodigester	Low-cost; Reliability
Hybrid systems can be balance out strength and weaknesses of concerning renewable options	Hybrid systems	Share of renewables
Systems need to be placed inside for better performance and increased lifespan	Boiler technologies	Lifespan
Exploration of passive solar systems due to Alberta's high solar potential	Solar thermal collectors; Passive solar design; Thermal storage	Thermal capacity; solar potential
Preference of circular system with efficient re-use of waste inputs from AG	Biodigester; Biomass	Waste recycling; Re-use
Importance of evaluating resource availability within community	Biodigester; Biomass; GSHP; STC	Resource availability
Interest in Earthships: Off-grid sustainable green buildings	Passive and active solar; Biodigester; GSHP	Off-grid; Self-sustaining

Table 4.13 shows expressed stakeholder values related to the renewable heating system, including deductive categories of renewable heating technology selection and concerning KPIs.

Table 4.13: Stakeholder values: Renweable heating system

Articulated value	RHT selection	KPIs
Stakeholder: FMFN Elder - Interview 1		
Adaption of gardening system with low-cost digester as compost from local shops is too expensive	Anaerobic digestion	Waste recycling; Re-use; Affordability
Use of leaves, rotten trees, coffee grains, peelings, eggshells, and grass clippings as compost that generates its own heat during Fall	Anaerobic digestion; Indirect heating	Waste recycling; Re-use; Affordability
"Use what you have in your garden as much as possible. There is no need to spend a lot of money when you have the resources available"	Anaerobic digestion; Indirect heating	Resource availability; Waste recycling; Re-use; Affordability
Stakeholder: FMFN Elder - Interview 2		
She mentions that if she could collect, store, and build a connected system, she would use rainwater	Circular systems	Resource availability; Re-use
Stakeholder: FMFN Elder - Interview 3		
Not composting due to increased labor and lack of storage options, but willingness to share his composting materials with other members	Anaerobic digestion	Collective resources; Labor-intensity

Table 4.14 highlights the count of identified categories for all value domains.

Table 4.14: Deductive coding: RHT selection and KPIs

Nr.	RHT selection	Count	Nr.	KPIs	Count
1	Biodigester	4	1	Re-use	6
2	Anaerobic digestion	4	2	Waste recycling	5
3	Passive solar design	2	3	Affordability	4
4	GSHP	2	4	Resource availability	3
5	Solar thermal collectors	2	5	Reliability	2
6	Hybrid systems	2	6	Low-cost	2
7	Biomass	2	7	Efficiency	1
8	Solar PV	1	8	Off-grid	1
9	Circular systems	1	9	Carbon emissions	1
10	Boiler technologies	1	10	Self-sufficiency	1
11	Solar energy	1	11	Lifespan	1
12	Visibility	1	12	Automation	1
13	Renewable	1	13	Thermal capacity	1
14	Well-established systems	1	14	Share of renewables	1
15	Low emission technologies	1	15	Collective resources	1
16	Circular systems	1	16	Labor-intensity	1

4.4.2. Value-based narrative

A value-based narrative was developed by AI based on the value source analysis regarding renewable heating systems with a focus on technology and KPI selection:

Selecting and Implementing a Renewable Heating System

Morning: **The Vision and the Urgency**

In a meeting room at the FMFN band office, the **project developer** lays out a vision:

"We want a system that showcases our potential for sustainability—something that makes visitors say, 'This community is leading the way.' We have organic waste from hundreds of homes, manure from a local buffalo farm, and abundant sunlight. How can we harvest these resources for heat?"

The developer's enthusiasm is fueled by the desire to *attract tourism*, reduce *carbon emissions*, and create a *fully automated* model that highlights community self-sufficiency. At the same time, a sense of urgency underpins the discussion. The greenhouse cannot risk crop failure in harsh winter conditions. The **designer** voices the need for technical reliability:

"It's crucial that we have consistent heat even on the coldest nights. A purely off-grid system might struggle without backup. Hybrid solutions could balance strengths and weaknesses."

They agree to gather more input from the broader **FMFN community**, ensuring the final renewable heating technology aligns with local needs and capacities.

Midday: **Community Voices on Resource Use and Labor**

A community workshop at the greenhouse site brings together Elders, gardeners, and the Environmental Protection team. Posters and sketches illustrate *anaerobic digestion (biodigester)*, *solar thermal collectors*, and *ground-source heat pumps (GSHP)*. People circulate between stations, sharing their experiences. One Elder, who has been composting for years, lights up at the mention of an on-site biodigester:

"We throw out so much—kitchen scraps, coffee grounds, even fallen leaves. All of it could become heat. I love the idea, but is it *affordable*? Many can't spend lots of money or time on fancy systems."

Another Elder expresses mixed feelings:

"I don't have time or space to compost, so I skip it. But if neighbors want my scraps, I'm happy to share. If you build a big system, who will run it?"

A younger gardener looks at the solar station sketches:

"I've seen solar panels and tubes. They work well, but we need to make sure we capture enough sunlight in winter. We can't rely on just that if the sun is low or it's snowing."

By mid-afternoon, the designer and project developer have a clearer sense of how any chosen RHT must balance: community resource availability, affordability, low labor intensity, and consistent performance in a subarctic climate.

Afternoon: **Designing KPIs Around Values**

Back at the office, the core team refines their Key Performance Indicators (KPIs). Each KPI is linked to values expressed by both the project developer and stakeholders, with the designer adding technical depth:

Waste Recycling & Re-Use - **Why it Matters:** Elders and the developer share a vision of turning household and buffalo waste into valuable energy.

Affordability & Low Maintenance - **Why it Matters:** High-cost or high-labor systems deter community uptake and long-term success.

Reliability & Technical Performance - **Why it Matters:** Harsh winters threaten greenhouse production. A system that fails in extreme cold undercuts the entire Aquaponic Greenhouse project.

Resource Availability & Adaptability - **Why it Matters:** FMFN's local feedstocks (manure, organics), land conditions, and climate patterns shape realistic RHT options.

Share of Renewables & Carbon Reduction - **Why it Matters:** The project developer wants to showcase real climate action.

Collective Resources & Labor-Intensity - **Why it Matters:** Some Elders want to share compost; others don't have storage space or time. Efficiency is key.

Evening: Converging on a Hybrid System

By late evening, the project developer, the designer, and a few community representatives sit around a table covered in sticky notes and feasibility graphs. They tentatively decide on a **hybrid solution**:

Biodigester for Baseline Heat The community's organic waste and buffalo manure become the primary energy source. This aligns with shared values of *re-use* and *circularity*, directly addressing the Elder's statement: "Use what you have." The design includes an *automated* feedstock hopper to reduce labor-intensity. Maintenance is still necessary (checking pH, temperature) but minimized via sensors.

Passive Solar Enhancements The greenhouse itself is reoriented and equipped with improved *insulation* and possibly a *solar thermal collector*. This lowers overall heat demand, matching the designer's push for thermal efficiency and harnessing Alberta's abundant sun where possible.

Natural Gas Backup or Grid-Tied Electricity A fallback system ensures *reliability* when temperatures plunge below –30°C or if feedstock supply runs low. Although the community wants to reduce reliance on fossil fuels, a partial backup is seen as prudent until the biodigester and passive solar elements prove themselves.

As the discussion winds down, a sense of collective ownership takes root. People imagine walking visitors through the greenhouse and pointing out the boilers powered by upcycled community waste, the solar tubes shining in the winter light, and the backup system quietly on standby—an embodiment of FMFN's commitment to self-sufficiency, innovation, and cultural values.

Conclusion

By weaving together **project goals** (showcasing sustainability, self-sufficiency), **designer concerns** (technical reliability, efficiency, cost), and **stakeholder preferences** (waste recycling, low labor, affordability), the **renewable heating system** becomes more than a technical fix. It is a **communal endeavor**, rooted in shared values of resourcefulness, respect for the land, and collective well-being.

4.4.3. Technology and KPI selection

The literature review identified various renewable energy technologies as promising for a community-based AG such as in the context of Fort McKay. Geothermal energy including seasonal geothermal storage for use in colder months, large-scale geothermal power plants utilizing geothermal acquifiers through existing wells, and geothermal heat pumps show great potential. Possible cost reductions of around 35% are estimated for geothermal energy and even 30 - 60% when using existing wells [60, 65]. However, there is a lack of papers examining geothermal energy despite its large potentialaquifers and geological conditions of the region can be a limiting factor [92]. Project and designer values from the values source analysis could not be directly linked to geothermal energy but indirectly support GSHP.

Solar technologies, in particular the integration of solar thermal energy storage such as solar thermal collectors are identified as beneficial. Gorjian et al. [29] conclude in their assessment of solar technologies that a large, amount of a greenhouse's energy demand can be covered by solar energy. Solar PV is recommended to drive electrical components but not for covering thermal demand, since it requires extravagant financial and technical resources [29, 60]. Furthermore, solar PV will produce most of the energy in summer where it is not needed for heating and cannot be stored in large amounts. Wind energy is also more compatible with electrical demand as additional conversion processes are linked to energy losses and storage remains challenging. Solar technologies also resonate well with identified project and designer values.

Biomass energy is recognized as highly efficient regarding energy conversion and reduction of costs [28]. Blair and Mabee [10] identified biomass boilers as one of the lowest-cost ways to substantially reduce GHG in short term. Biomass boilers and CHP technologies seem to be competitive with traditional natural gas heating systems [10]. Biomass aligns well with all values in the sense that waste recycling and re-use of resources arethe highlighted. Most stakeholder values refer to composting, but any biomass with a minimum calorific value can be used for a biomass boiler even eliminating one step of producing a gas first.

Anaerobic digestion coupled with biogas is especially suitable for a socio-economic that is characterized by livestock farming [60]. Achieving a constant yield of biogas remains challenging though and other biofuels apart from biogas are suggested as well [92]. In Alberta, renewable biogas projects are commonly backed by financial support in the range of 25-33% [37]. Project values include the idea of using organic waste from the community directly and also from a buffalo farm which reflects designer considerations of resource availability. Additionally, stakeholders are familiar with the composting (anaerobic digestion process) to produce fertilizer which is an additional benefit for the greenhouse context.

The narrative suggests a hybrid solution, in the end, consisting of a biodigester solution for baseline heat enhanced by passive solar elements, which is backed up by the grid. This heating system setup is very much supported by the recommendations of the literature. A final selection of technologies to review is listed in Table 4.15.

Table 4.15: Technology selection

Nr.	Type of energy	Technology selection
1	Bioenergy	Biomass boiler
2	Bioenergy	Bio digester with biogas boiler
3	Geothermal energy	Ground source heat pumps
4	Bioenergy & fossil fuel	Hybrid 1: Bio digester with biogas (natural gas) boiler
5	Geothermal & bioenergy	Hybrid 2: Ground source heat pump and biomass boiler

Table 4.16 shows the jointly chosen KPIs based on suitable TEA integration and defines each indicator.

Table 4.16: KPIs and their definition

Nr	KPI	Definition
Technical		
1	**Reliable**	The heating system is reliable if it can be trusted to heat the greenhouse consistently without failures
2	**Easy to operate**	The heating system is easy to operate if it can function by its own without needing much additional manual work
Environmental		
3	**Climate-friendly**	The heating system is climate-friendly if its net greenhouse gas emissions impact is close to zero
4	**Waste recycling**	The heating system is recycling waste if biological waste from the greenhouse produce can be re-used to heat the greenhous
Social		
5	**Off-grid**	The heating system is off-grid if it's powered by renewables that are self-sustaining
Economic		
6	**Affordable**	The heating system is affordable if the financial costs of equipment and operation are low

The KPIs were selected based on the results in Table 4.14, where similar indicators were merged. Rezaei [71] used similar indicators in an MCDM approach for sustainable energy prioritization. Resource availability was excluded due to uncertainties in this project context despite its importance.

5

Aquaponic Greenhouse Design

"Ultimately, the only wealth that can sustain any community, economy or nation is derived from the photosynthetic process - green plants growing on regenerating soil."

(Allan Savory)

5.1. Constraints, objectives, and attribute selection

Constraints and objectives were summarized and listed based on the narratives from the previous section in Table 5.1 and Table 5.2.

Table 5.1: Building constraints and objectives

Greenhouse building	Attributes
Constraints	
Dimensions	Max length of 100m due to property restriction
Snow shedding	Steep angle of roof
Clean air	Air filters, closed greenhouse, CEA
Water irrigation	Design directing water flow
Storm resistance	Materials, structure, multi-layer glazing
Functional objectives	
Good heat retention	Night curtains, closed greenhouse, insulation, hydronic radiant heating, thermal energy storage
Water collection	Design allowing to capture water flow
Wildlife interference	Closed greenhouse for protection of both human and animals
Good heat distribution	Hydronic radiant heating: infloor or direct piping under growing area
Solar energy utilization	Passive solar design, solar gains, thermal energy storage, arrangement of growing system, south orientation
Spatial optimization	Arrangement of growing systems and aquaponic system
Non-functional objectives	
Community activities	Allocation of culturally welcoming space for community and non-growing related activities such as education, recreational space
Storage space	Storage along backside, 2nd layer before entrance for heat retention
Space for solar panels	Roof or front
Traditional elements	Incorporation of familiar and traditional design aspects in architecture
Attract tourism	Aesthetic design

Table 5.2: Growing system constraints and objectives

Growing system	Attributes
Constraints	
Aquaponics	Hydroponics combined with nutrient solution from aquaculture
Constant inside climate	Closed greenhouse, Hydronic radiant heating
System reliability	Decoupled aquaponics, sump tank, variety of crops, combination of growing systems
Functional objectives	
Lighting	Supplement lighting for winter using growing lights
Profitability	Use of NFT, DWC, and gravity-fed airlift pumps
Waste recycling	Collection of waste from produce and fish for inputs as heating
Composting	Collective composting and shared use for fertilizer
Good space utilization	Vertical farming, arrangement of systems for fast harvesting, cylindrical centered fish tank
Non-functional objectives	
Traditional practices	Incorporate soil-based system for medicinal plants and community gardening
Fish type selection	Catfish because of suitability and spiritual meaning
Education	Allow for visual presentation of processes

Table 5.1 shows constraints, functional and non-functional objectives as well as attributes that relate to the design choice, and Table 5.2 lists the same for the growing system inside the building.

Parajuli et al. [60] evaluated the viability of renewable energy sources to meet the energy demand of an Aquaponic Greenhouse in the Himalayan Region of Nepal, by analyzing the potential of lowering the cost of energy (COE), reducing fossil-fuel consumption, and increasing profitability while addressing food-related challenges. They also showcased a design from which implications could be derived and used, visualized in Figure 5.1.

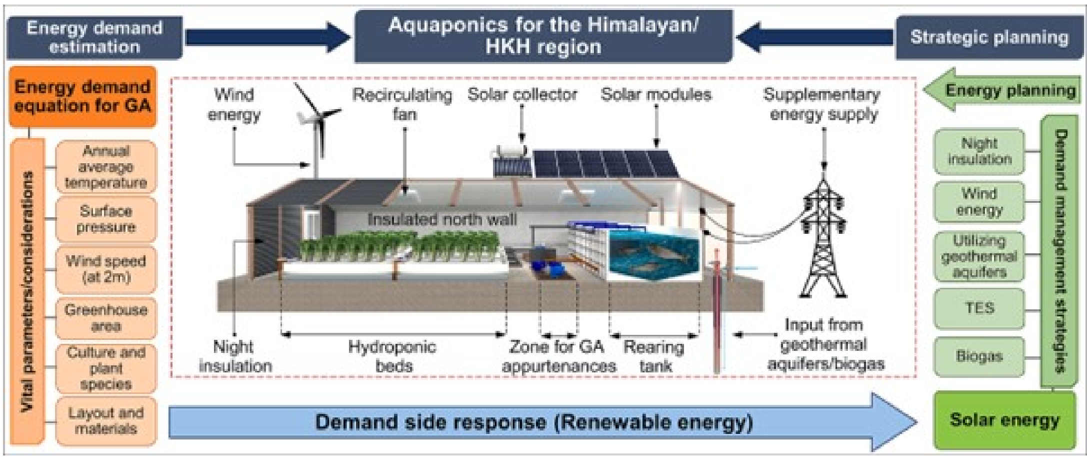

Figure 5.1: System design of an AG in Nepal's Himalayan region [60]

Passive solar heating with night insulation is strongly recommended as well as integrating locally available energy. The building design uses passive solar elements with an insulated north wall as thermal storage but the shallow angle would not prevent snow shedding. The aquaculture tank and growing beds are separately arranged on each side with space for system components in between. Structural components are not well-defined and could be underdeveloped for stormy weather. Section 5.2 connects design choices to the model.

5.2. Model design concept

5.2.1. Overview

The most relevant attributes incorporated in the model are the selection of Brown Bullhead Catfish for aquaculture as they can survive in lower water temperatures but are also resistant to fluctuations. A combined use of NFT and soil-based growing systems was selected to allow for the traditional way of growing medicinal plants or deep root vegetables. NFT was prioritized over DWC as it is more efficient in water usage, achieves higher yields, and is well-established in vertical farming. A passive solar design is applied, trying to keep the size as small as possible to reduce the thermal demand while maintaining steep angles for snow shedding. The basic model principle with a given example of calculated parameters is visualized in Figure 5.2.

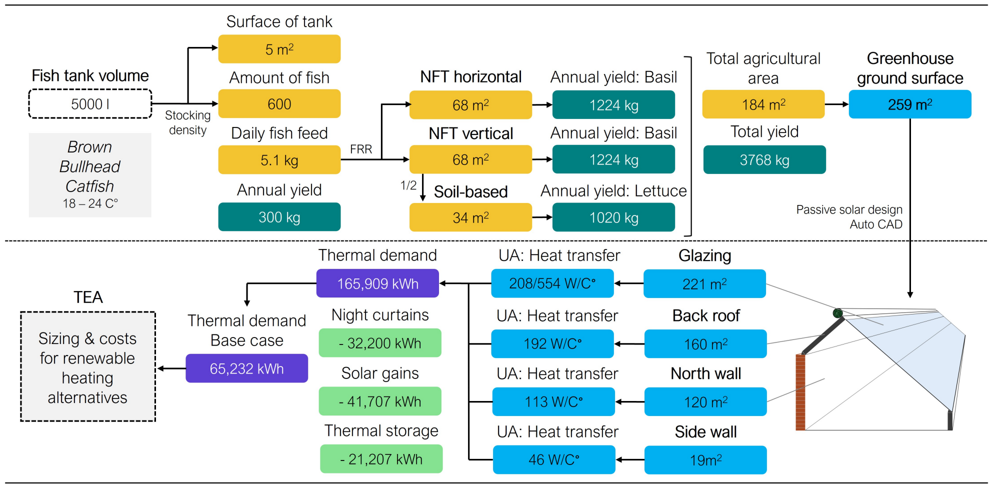

Figure 5.2: General concept

The model uses the water volume of the fish tank as the singular input variable, determining greenhouse size, and all cost considerations later on in the TEA. A range between 5000 liters and 11000 liters was set to be reviewed which is based on technical requirements and constraints related to the greenhouse size. A greenhouse with a tank volume of less than 5000l would restrict the passive design and not serve the purpose of a community-scale project. On the other hand, a greenhouse bigger than 11000l would exceed the dimension constraint of staying within 100 meters in length. This again, relates to the passive solar design which in this model only increases in length (towards East and West) to preserve the proportions in which the passive solar effect is utilized. Within aquaponics, stocking density and Fish Feed Ratio (FRR) are the most important parameters that allow for calculating the growing size in relation to how much nutrients the aquaculture system can provide. The soil-based system was fixed in relative size to the NFT system (1/2 of horizontal or vertical). With the growing space size, yields can be estimated, and total greenhouse ground surface size can be defined based on additional space allocation.

In the next step, a visual model was created to show the design and also validate the spacing arrangements of the major components. In addition, to the ground surface, all dimensions of the external building surfaces are specified now which is required to calculate and estimate the thermal demand. U-values and surface areas allow for calculating heat transfer (or heat loss in this case). Savings from using night curtains, solar gains, and thermal storage capacities of the passive solar design were considered to reduce the thermal demand. The general thermal demand estimation could be used as the starting point for the TEA.

5.2.2. System sizing

The system sizing parameters are responsible for balancing the interactions between aquaculture and hydroponics and determining the space allocation within the greenhouse. The tables in this section summarize the fixed and derived parameters for aquaculture, NFT, and soil-based systems. For the model, Brown Bullhead Catfish is selected as the fish type, basil production is assumed for NFT, and lettuce for soil-based. The fish tank volume (V) is the key input variable that impacts all other parameters such as overall greenhouse productivity. Table 5.3 shows the assumed values for the fixed parameters and also defines derived ones.

Table 5.3: Aquaculture: Brown Bullhead Catfish

Symbol	Parameter	Value	Unit
V	Fish tank volume (input)	5000 - 11000	[l]
Fixed parameters			
SD	Stocking density	0.05	[kg/l]
FFR	Fish Feed Ratio	1.65	[% of body weight]
WG	Weight gain per fish	0.5; 0.8	[kg]
Derived parameters			
AY	Annual yield (cycle)		[kg]
N	Number of fish		[amount]
FF	Daily fish feed requirement		[kg]

Fixed parameters like stocking density and fish feed ratio are standard practices for maximizing fish growth while maintaining water quality. Derived parameters are key factors for the cost analysis of greenhouse operations. The formulas below show their relationship.

$$AY_{\text{fish}} = V \cdot SD, \quad N_{\text{fish}} = \frac{AY_{\text{fish}}}{WG}, \quad FF = N_{\text{fish}} \cdot WG \cdot \frac{FFR}{100}$$

The NFT system is sized based on the nutrient output of the fish tank. Fixed parameters such as FFR, plant density, and harvesting cycles determine yields as shown in Table 5.4.

Table 5.4: NFT: Basil

Symbol	Parameter	Value	Unit
Fixed parameters			
FRR	Feed Rate Ratio	40	[g/m^2]
PD	Plant density	20	[plants/m^2]
HC	Harvesting cycle	50	[days]
Y	Yield	2	[kg/m^2]
Derived parameters			
A	Planting area		[m^2]
N	Number of plants		[amount]
AY	Annual yield		[kg]

The planting area is essential for space arrangements of the greenhouse design. Number of plants is used for assigning normalized aquaponics-related costs per plant. The annual NFT yield is a key influencing factor for income and profitability. Values are calculated as follows:

$$A_{\text{NFT}} = \frac{FF \cdot 1000}{FRR}, \quad N_{\text{basil}} = PD \cdot A_{\text{NFT}}, \quad AY_{\text{basil}} = \frac{360}{HC_{\text{basil}}} \cdot Y_{\text{basil}} \cdot A_{\text{NFT}}$$

The simpler soil-based system including four parameters is displayed in Table 5.5.

Table 5.5: Soil-based: Lettuce

Symbol	Parameter	Value	Unit
Fixed parameters			
HC	Harvesting cycle	50	[days]
Y	Yield	4	[kg/m^2]
Derived parameters			
A	Planting area		[m^2]
AY	Annual yield		[kg]

The planting area of the soil-based system is defined in the ratio of one-quarter of the total NFT system, $A_{\text{soil-based}} = A_{\text{NFT}} \cdot \frac{1}{4}$. Annual yield is calculated in the same way, AY_{lettuce}.

About 25% of the total greenhouse size is considered for general space allocation, community space, and additional equipment. 75% relates to the sum of fish tank surface area and planting areas. The ground surface provides the base for a 3D model and allows for component arrangement considerations.

5.2.3. CAD model

Note: Major design elements of the model cannot be shown due to an ongoing patenting process and IP rights.

The CAD model represents the smallest evaluated size of 259 m^2 ground surface using a 5000l fish tank for the aquaculture system. The whole design was focused on utilizing passive solar energy as much as possible while balancing structural simplicity and making it visibly appealing as shown in Figure 5.3. Keeping it compact optimizes energy efficiency which had to be slightly compromised by the steep angles to ensure proper snow shedding. Another advantage of the steep angles is for cooling effects in summer, as they allow for placing ventilation outlets along the top where most heat is trapped. Opening them will create a perfect airflow if the air is sucked in from the bottom front which can probably cool the building without any additional energy requirements.

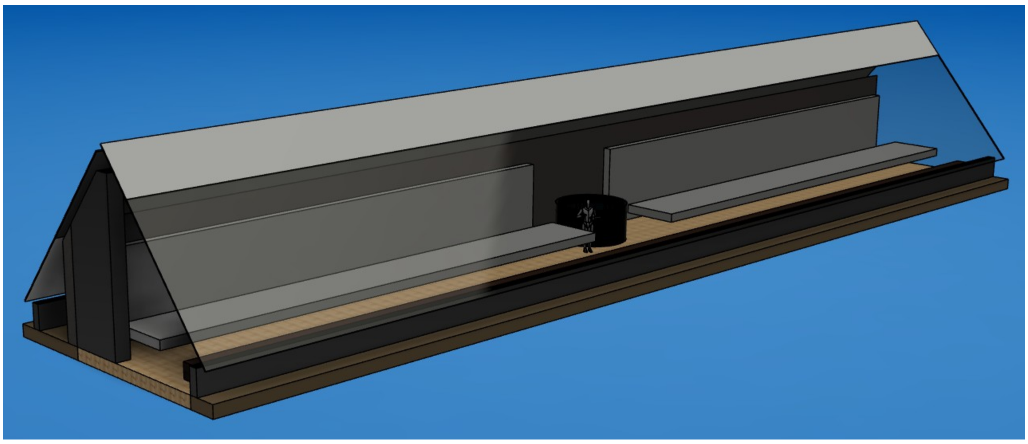

Figure 5.3: CAD model: Main view

The space-saving cylindrical fish tank is placed in the center where it can directly access all growing systems within a short distance, thereby requiring less piping and other connecting elements. The inside is visualized in Figure 5.4. The north wall is modeled as a 60cm brick wall to retain a high amount of heat which can be released during night, and receives most solar radiation during winter months when the sun angle is low. Because of the passive solar effect, growing arrangements are limited because the sun can only be obtained from one side which also poses issues with shadowing.

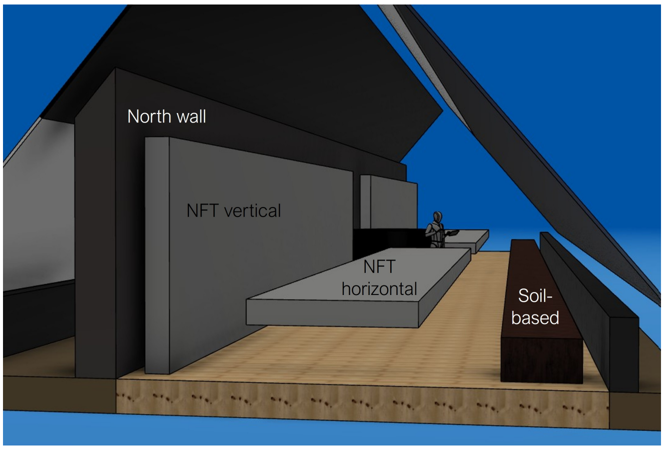

Figure 5.4: CAD model: Inside arrangement

For that reason, it's clearly visible that the soil-based system as the smallest and lowest one is placed towards the front, after which the horizontal NFT is elevated just so much that enough radiation reaches the vertical NFT system. Note that in reality, it transmits much more radiation to the north wall.

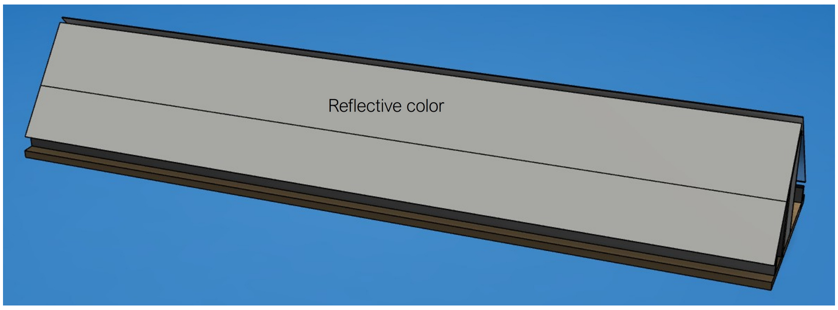

Figure 5.5: CAD model: Reflective backside

The backside uses reflective colors with low solar absorptance to prevent heat in summer (Figure 5.5). From the side (with removed lower back) the storage space becomes visible which extends along the entire length illustrated in Figure 5.6. It could be used for machinery, fuels like biomass, any gardening equipment, and possibly even for integrating a biodigester. The north wall also releases heat towards the back, keeping it warm and improving anaerobic digestion for higher biogas yields. The closed back will also increase the temperature in winter as it acts like an entrance room.

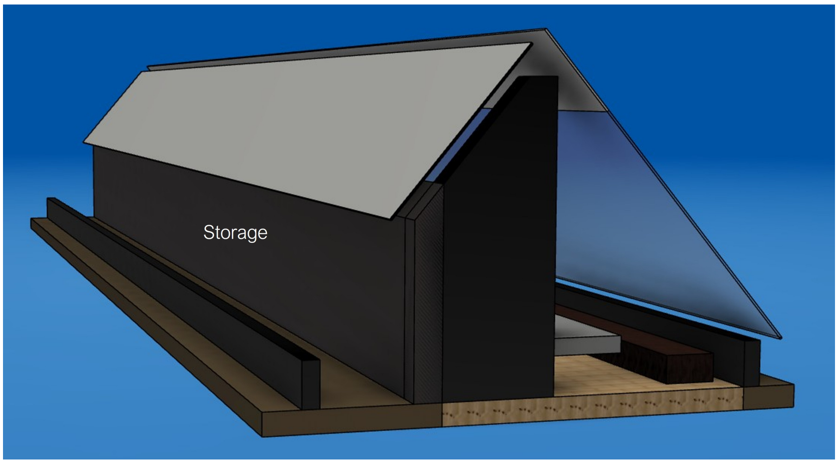

Figure 5.6: CAD model: Storage space

The front is fitted with a small roofing area to cover the north wall from solar radiation during summer, and to provide a structure to attach the rolling curtains. It's also meant for mounting solar thermal collectors or solar panels for electrical energy demand. The building design also facilitates the integration of an irrigation system for water collection and sustainable use. It could be fully connected and automated with a drip system for the soil-based system.

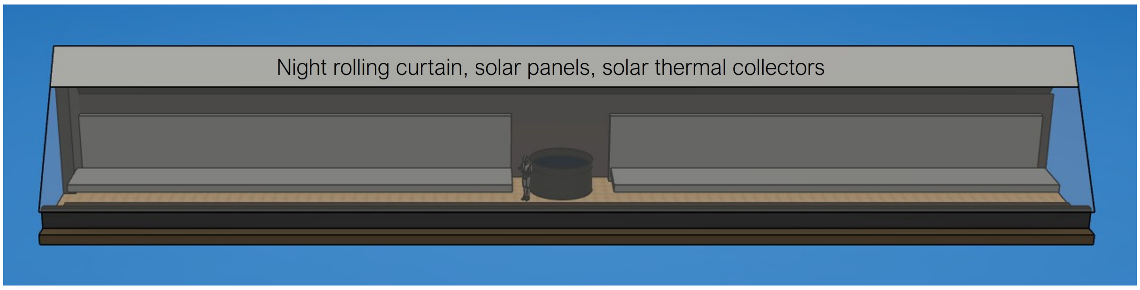

Figure 5.7: CAD model: Front view

The CAD model validates the spacing and arrangement of the components inside and translates the ground surface into a 3-dimensional model which is required to calculate the thermal demand.

5.2.4. Thermal demand

The thermal demand is calculated with the Heating Degree Method which requires U-values which measure how much a structure allows for heat transfer. Multiplying the U-value with the surface of a structure provides UA which reflects the overall heat transfer. The thickness of a material is already included in the U-value. Table 5.6 lists all considered external surfaces with the assumed U-value.

Table 5.6: External components for heat transfer calculation

Components / Symbol	Parameter	Value	Unit
Fixed parameters			
North wall	U-value	0.8	[W/(m^2*C°)]
East and west wall	U-value	1.2	[W/(m^2*C°)]
Roof back	U-value	1.2	[W/(m^2*C°)]
Roof front	U-value	1.2	[W/(m^2*C°)]
South glazing	U-value	2.5	[W/(m^2*C°)]
South wall	U-value	1	[W/(m^2*C°)]
Insulated ground	U-value	0.3	[W/(m^2*C°)]
Night curtain	U-value	1.5	[W/(m^2*C°)]
Derived parameters			
A	Surface area		[m^2]

The total UA is the sum of all components which represent the building. The formula had to be slightly adjusted due to the use of night curtains. Glazing has the highest U-value showing the highest heat losses. When using a night curtain, a combined U-value of curtain and glazing is applied which decreases heat losses. For daytime, U-values are summed up as listed in Table 5.6 excluding the night curtain. During night the combined U-value of south glazing and night curtain is used.

$$UA_{\text{total\_day}} = \sum_{\text{components}} UA_{\text{component}}$$

$$UA_{\text{total\_night}} = \sum_{\text{components}} UA_{\text{component}} + UA_{\text{combined\_glazing, curtain}}$$

The combined U-value is 0.94 which is a significant reduction that comes close to the heat transfer coefficient of the north wall which has the key function of storing and releasing heat. Sunset and sunrise data were obtained to specify day hours and night hours within a day. UA_{day} and UA_{night} are multiplied by the ratio of day hours and night hours respectively.

Table 5.7 shows the monthly heating degree days (HDD) for Mildred Lake and Fort McMurray Airport which were the closest accessible weather stations by RETScreen based on NASA data. The full climate data set from RETScreen is shown in Appendix B.2. HDD is a measure that estimates heating requirements by examining the difference between a baseline indoor and average outside temperature. When the outside temperature exceeds the indoor temperature, the HDD value becomes zero. Table5.7 presents HDD for each month which is the sum of all daily values. July is the only month in Mildred Lake where its above 18C° and no heating is required.

Table 5.7: Monthly heating degree days (HDD): 18C°

Month / Symbol	Parameter	Value	Value	Unit
Fixed parameters		*Mildred Lake*	*Fort McMurray Airport*	
January	HDD	1107	1172	[°C·day]
February	HDD	848	921	[°C·day]
March	HDD	750	803	[°C·day]
April	HDD	426	456	[°C·day]
May	HDD	242	245	[°C·day]
June	HDD	63	102	[°C·day]
July	HDD	0	43	[°C·day]
August	HDD	50	87	[°C·day]
September	HDD	216	267	[°C·day]
October	HDD	465	456	[°C·day]
November	HDD	747	810	[°C·day]
December	HDD	977	1094	[°C·day]
Derived parameters				
Dh	Daytime hours ratio			
Q	Thermal demand			[kWh/month]

The thermal demand of the greenhouse is a critical factor in determining the heating requirements to maintain a stable internal climate throughout the year. The formula calculates the total thermal energy required to offset heat loss, accounting for heat transfer through all external surfaces during both day and night.

$$Q_{\text{heating}} = \left(\frac{UA_{\text{day}} \cdot \text{HDD} \cdot 24 \cdot D_h}{1000}\right) + \left(\frac{UA_{\text{night}} \cdot \text{HDD} \cdot 24 \cdot (1 - D_h)}{1000}\right)$$

Solar gains are an essential consideration in reducing the overall heating demand. The south-facing glazing allows sunlight to penetrate the greenhouse during the day, immediately heating the interior. The formula incorporates factors such as the daily solar radiation, glazing area, transmittance of glazing, absorptance, and shading factor. These gains are subtracted from the thermal demand as they reduce heating requirements. Additionally, calculations of thermal storage capacity are applied using the same formula but specifying the area to the north wall and the fish tank with more accurate absorptance factors. The formula estimates storage capacity and can therefore be used for heat release capacity under the condition that about the same amount of heat stored is released again. This condition is given for the north wall and water within the fish tank. Table 5.8 depicts average daily solar radiation levels for each month and parameter values.

Table 5.8: Daily solar radiation (I) and thermal energy release

Month / Symbol	**Parameter**	**Value**	**Value**	**Unit**
Fixed parameters		*Mildred Lake*	*Fort McMurray Airport*	
January	I_{solar}	0.58	0.77	[kWh/m²/day]
February	I_{solar}	1.44	1.81	[kWh/m²/day]
March	I_{solar}	2.92	3.45	[kWh/m²/day]
April	I_{solar}	4.59	4.82	[kWh/m²/day]
May	I_{solar}	5.48	5.53	[kWh/m²/day]
June	I_{solar}	5.68	5.84	[kWh/m²/day]
July	I_{solar}	5.55	5.63	[kWh/m²/day]
August	I_{solar}	4.59	4.66	[kWh/m²/day]
September	I_{solar}	3.06	3.02	[kWh/m²/day]
October	I_{solar}	1.67	1.79	[kWh/m²/day]
November	I_{solar}	0.80	0.87	[kWh/m²/day]
December	I_{solar}	0.36	0.55	[kWh/m²/day]
τ	Solar transmittance		70	[%]
α	Solar absorptance		0.4; 0.9	-
SF	Shading factor		60	[%]
Derived parameters				
Q_{solar}	Immediate solar gains			[kWh/month]
$Q_{\text{release\_n-wall}}$	Thermal energy release: North wall			[kWh/month]
$Q_{\text{release\_fish-tank}}$	Thermal energy release: Fish tank			[kWh/month]

Solar gains and thermal energy storage as part of the passive solar design in addition to night curtains, are calculated by the provided formula below:

$$Q_{\text{solar-gains}} = A_{\text{glazing}} \times I_{\text{solar}} \times \left(\frac{\tau}{100}\right) \times \alpha_{\text{glazing}} \times \left(\frac{SF}{100}\right) \times \text{days of month}$$

$$Q_{\text{release\_n-wall}} = A_{\text{n-wall\_visible}} \times I_{\text{solar}} \times \left(\frac{\tau}{100}\right) \times \alpha_{\text{n-wall}} \times \left(\frac{SF}{100}\right) \times \text{days of month}$$

$$Q_{\text{release\_fish-tank}} = A_{\text{fish-tank}} \times I_{\text{solar}} \times \left(\frac{\tau}{100}\right) \times \alpha_{\text{fish-tank}} \times \left(\frac{SF}{100}\right) \times \text{days of month}$$

The total thermal demand for each month is calculated by accounting for all factors of heat transfer through external surfaces, solar gains, and thermal energy storage as provided in the formula. This ensures that the model accurately reflects the performance of the greenhouse under varying seasonal conditions.

$$Q_{\text{heating-new}} = Q_{\text{heating}} - (Q_{\text{solar-gains}} + Q_{\text{release\_n-wall}} + Q_{\text{release\_fish-tank}})$$

Passive solar applications reduce the initial thermal demand and result in improved energy efficiency of the greenhouse which aligns with the project's sustainability goals. This detailed approach provides a reliable estimate of heating requirements but also provides the foundation for calculations regarding the renewable heating supply in Chapter 6. The integration of a passive solar design and advanced insulation measures underscore the importance of combining architectural and technical solutions to meet the thermal demand effectively.

6

Techno-Economic Analysis

"The use of solar energy has not been opened up because the oil industry does not own the sun."
(Ralph Nader)

6.1. Model design concept

6.1.1. Overview of renewable heating technologies

Figure 6.1 provides a comprehensive overview of selected renewable heating technologies to meet the thermal demand of the AG. Five systems are highlighted including passive solar design, solar water collectors (STCs), a geothermal heat pump, a biodigester to produce biogas, and a biomass boiler. These systems have been selected for their compatibility with the greenhouse, local climate conditions, and the goal of achieving sustainable, efficient, and reliable heating performance throughout the year.

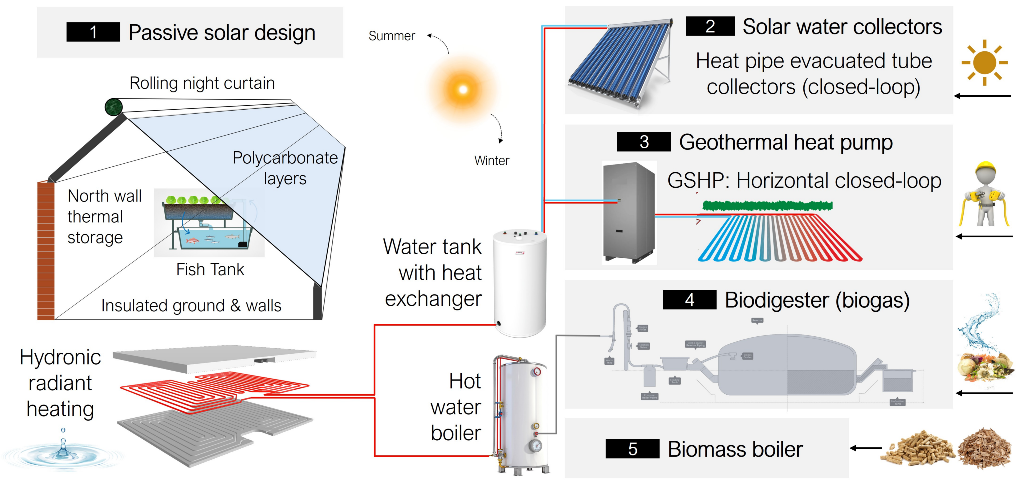

Figure 6.1: Renewable heating systems

The passive solar design serves as the foundation, minimizing thermal demand through natural heat capture and retention, while other technologies act as supplementary heating sources. These systems were chosen for their ability to integrate seamlessly with hydronic radiant heating, a method preferred for its uniform heat distribution, which is essential for maintaining optimal growing conditions in the greenhouse. Hydronic radiant heating doesn't require very high temperatures and the piping can be laid directly under the growing areas or underfloor. The advantages of a water-based system are its efficiency, steady release of heat, and that it doesn't interfere with the air, humidity levels, and co_2

amount which are all factors that can negatively impact plant growth if those are suddenly altered. The heating technologies can all connect either via a hot water boiler or a water tank with a heat exchanger.

Solar water collectors use heat pipe evacuated tube technology in a closed-loop configuration to capture solar energy and transfer it to a water-based heat exchanger. This heated water is then stored and can be used as an additional heat source for hydronic radiant heating. These collectors are especially effective in sunny conditions and provide renewable energy to the system. **Solar thermal collectors** were **excluded from the analysis** because of unjustifiable system sizing dimensions that require extravagant financial resources. The problem in this context remains that STCs can never meet the peak demand and strongly overproduce in summer. An attempt to use it for partial coverage with GSHP also did not yield any positive results.

The geothermal heat pump operates using a horizontal closed-loop system buried underground. The loop absorbs heat from the ground which maintains a relatively stable temperature year-round. This heat is then transferred via the GSHP to the heating system. GSHPs are highly efficient and ensure a consistent heating supply, especially during colder months when solar gains are limited.

A biodigester processes organic waste to produce biogas that can be burned to generate heat. The resulting heat is transferred to the hydronic heating system through a hot water boiler. In addition to providing a renewable energy source, a biodigester supports waste recycling and provides fertilizer through an anaerobic digestion process.

A biomass boiler uses solid organic material derived from plants or animals with an acceptable calorific value as fuel to generate heat. The system burns the biomass in a controlled manner and transfers heat to a water-based heat exchanger. Biomass is a reliable renewable energy source, particularly in regions with access to agricultural byproducts or forestry residues.

6.1.2. Base case: Natural gas boiler

The selection of renewable heating technologies and their integration with the greenhouse model is implemented in the Excel-based TEA. The Excel model serves as the computational backbone for evaluating the performance, costs, and preliminary feasibility of each renewable heating alternative under varying operational conditions. The base case for heating the AG utilizes a natural gas boiler as a well-established and cost-effective heating method suitable in the Alberta context. It serves as a benchmark for performance comparison. Table 6.1 outlines the fixed and derived parameters for this system, which draws data from the heating demand model.

Table 6.1: Heating supply

Symbol	Parameter	Value	Unit
Fixed parameters			
t_{lifespan}	Project lifespan	20	[years]
η	Thermal efficiency	0.95	[%]
CV	Calorific value	11	[kWh/m^3]
C_{m}	Maintenance cost	0.0018	[$CAD/kWh]
Sz	Sizing factor	10	[l/kW]
EF_{CO2}	Emissions factor	1.962	[kg CO_2/m^3]
Derived parameters			
$Q_{\text{heating\_supply}}$	Heating requirement		[kWh/month]
P_{min}	Min. power requirement		[kW]
Q_{gas}	Required natural gas		[m^3/month]
$V_{\text{min, buffer}}$	Min. buffer tank size		[l]
CO_2	CO_2 emissions		[t CO_2]

The thermal demand of the greenhouse serves as the basis for determining the heating supply requirements by simply dividing the boiler's thermal efficiency to account for system losses. The resulting value is the demand that it has to supply with its efficiency.

$$Q_{\text{heating, supply}} = \frac{Q_{\text{heating}}}{\eta}, \quad Q_{\text{gas}} = \frac{Q_{\text{heating, supply}}}{\text{CV}}$$

The formula is provided above alongside the calculation to obtain the required gas to meet that demand. The boiler's minimum power requirement is determined by the peak demand of the coldest month which is mostly January. Monthly kWh are scaled down to kW which provides the peak power output the boiler has to be capable of providing.

$$P_{\text{min}} = \text{peak demand of} \left(\frac{Q_{\text{heating, supply}}}{\text{days of month} \times 24} \right)$$

The peak demand is the key factor for the system sizing of the boiler and buffer tank. The combination ensures adequate hot water storage for maintaining stable heat distribution throughout the greenhouse. The minimum buffer tank size is determined by the sizing factor.

$$V_{\text{min, buffer}} = P_{\text{min}} \times S_z$$

CO_2 emissions across the lifecycle are calculated by summing up monthly gas requirements and multiplying it by the emissions factor and the project years. The outcome should be provided in t instead of kg.

$$CO_2 = \sum Q_{\text{gas}} \times \frac{EF_{\text{CO2}}}{1000} \times t_{\text{lifespan}}$$

Table 6.2 lists the different applied boiler and buffer tank sizes sizes for the evaluated range of greenhouse sizes and their respective costs.

Table 6.2: Hot water boiler system sizing

Symbol	Parameter	1	2	3	4	Unit
Viessmann Vitodens 100-W | B1HE Central Boiler						
P	Power output	120000	150000	199000	225000	[BTU/h]
C_{boiler}	Cost	6713	7333	8033	9083	[$CAD]
Buffer tank / Accumulator Tank (Cordivari)						
V_{buffer}	Buffer tank	500	800			[l]
C_{buffer}	Cost	1420	1775			[$CAD]

The boiler sizes are calculated by the condition of meeting the peak demand. As soon as the peak demand exceeds the boiler power output, the next largest size is utilized within the model.

$$C_{\text{boiler}} = \begin{cases} C_{\text{1-boiler}} & \text{if } P_{\text{min}} < P_1 \\ C_{\text{2-boiler}} & \text{if } P_1 \leq P_{\text{min}} < P_2 \\ C_{\text{3-boiler}} & \text{if } P_2 \leq P_{\text{min}} < P_3 \\ C_{\text{4-boiler}} & \text{if } P_3 \leq P_{\text{min}} < P_4 \end{cases}$$

The same rationale is applied to the buffer tank size with regard to the minimum volume.

$$C_{\text{buffer}} = \begin{cases} C_{\text{1-buffer}} & \text{if } V_{\text{min, buffer}} < V1_{\text{buffer}} \\ C_{\text{2-buffer}} & \text{if } V_{\text{min, buffer}} \geq V1_{\text{buffer}} \end{cases}$$

The most essential fixed parameters for the financial analysis based on a cashflow statement over the whole lifecycle period, are provided in Table 6.3.

Table 6.3: Cash flow statement

Symbol	Parameter	Value	Unit
Fixed parameters			
r	Discount rate	12	[%]
P_{gas}	Natural gas price	0.0134	[$CAD/kWh]
$P_{\text{electricity}}$	Electricity rate	0.16	[$CAD/kWh]
$C_{\text{fish-feed}}$	Fish feed cost	2	[$CAD/kg]
P_{fish}	Sales price of fish	8.8	[$CAD/kg]
P_{basil}	Sales price of basil	7.5	[$CAD/kg]
P_{lettuce}	Sales price of lettuce	5	[$CAD/kg]
Derived parameters			
$OPEX$	Operating expenses		[$CAD]
$CAPEX$	Capital expenditures		[$CAD]
NPC	Net present cost		[$CAD]
NPV	Net present value		[$CAD]

Derived parameters are summed into OPEX and CAPEX to calculate NPC and NPV with a discount rate of 12%. Detailed OPEX and CAPEX related parameters are not displayed. Revenues are calculated as the produce of fish, basil, and lettuce times the outlined sales prices in Table 6.3.

$$NPC_{\text{heating}} = \sum_{t=0}^{t_{\text{lifespan}}} \frac{\text{CAPEX}_t + \text{OPEX}_t}{(1+r)^t}, \quad NPV = \sum_{t=0}^{t_{\text{lifespan}}} \frac{\text{revenues}_t - \text{costs}_t}{(1+r)^t}$$

6.1.3. Biomass: Agro-pellet boiler

Biomass heating is a renewable alternative to conventional fossil fuel systems that uses organic material as a primary fuel source. Table 6.4 presents the key parameters of the biomass system used to calculate the biomass fuel requirement. The calculation follows the same approach as for gas requirements but converts the fuel into tonnes instead of cubic meters, as the input is solid material rather than gas.

Table 6.4: Heating supply

Symbol	Parameter	Value	Unit
Fixed parameters			
η	Thermal efficiency	0.9	[%]
CV	Calorific value	4.5	[kWh/kg]
C_{m}	Maintenance cost	0.006	[$CAD/kWh]
Sz	Sizing factor	50	[l/kW]
F	Diesel fuel consumption	0.25	[l/km]
EF_{CO2}	Well-to-wheel diesel	2.9	[kg CO_2/l]
Derived parameters			
Q_{biomass}	Required biomass		[t/month]

The formula for determining the required biomass is given as:

$$Q_{\text{biomass}} = \frac{Q_{\text{heating, supply}}}{\text{CV}} \times 1000$$

A Biomass heating system requires solid biomass that cannot be supplied by the grid and needs to be purchased or obtained somewhere and supplied in large amounts. A box truck transport with 6t of load capacity is assumed to handle those operations. The transport is the only emission accounted for in the model as the combustion itself is considered carbon neutral because the organic material already absorbed carbon during its growth which is released again. The condition for carbon neutrality is a cycle of sustainable sourcing in which new organisms are planted. The formula for calculating transport emissions is shown below:

$$CO_2 = \text{yearly pickups} \times \text{distance} \times 2 \times F \times EF_{\text{CO2}} \times t_{\text{lifespan}}$$

Table 6.5: Hot water boiler system sizing

Symbol	Parameter	1	2	3	4	Unit
KEPO ENERGREEN AC						
P	Power output	35	60	70		[kW]
C_{boiler}	Cost	10300	18900	20600		[$CAD]
Buffer tank / Accumulator Tank (Cordivari)						
V_{buffer}	Buffer tank	1500	2000	3000	4000	[l]
C_{buffer}	Cost	3200	3900	5685	7460	[$CAD]

Table 6.5 outlines the various system sizes and related costs that are selected under the previously explained conditions regarding minimum peak demand. The mathematical notation reads as follows:

$$C_{\text{boiler}} = \begin{cases} C_{\text{1-boiler}} & \text{if } P_{\text{min}} < P_1 \\ C_{\text{2-boiler}} & \text{if } P_1 \leq P_{\text{min}} < P_2 \\ C_{\text{3-boiler}} & \text{if } P_2 \leq P_{\text{min}} < P_3 \end{cases}$$

$$C_{\text{buffer}} = \begin{cases} C_{\text{1-buffer}} & \text{if } V_{\text{min, buffer}} < V_{\text{1-buffer}} \\ C_{\text{2-buffer}} & \text{if } V_{\text{1-buffer}} \leq V_{\text{min, buffer}} < V_{\text{2-buffer}} \\ C_{\text{3-buffer}} & \text{if } V_{\text{2-buffer}} \leq V_{\text{min, buffer}} < V_{\text{3-buffer}} \\ C_{\text{4-buffer}} & \text{if } V_{\text{3-buffer}} \leq V_{\text{min, buffer}} < V_{\text{4-buffer}} \end{cases}$$

Table 6.6: Cash flow statement

Symbol	Parameter	Value	Unit
Fixed parameters			
r	Discount rate	12	[%]
$P_{\text{wood-chip}}$	Wood chip price	95	[$CAD/t]
P_{offset}	Carbon offset price	110 (t_1)	[$CAD/t]
$P_{\text{waste-manage}}$	Waste management price	85	[$CAD/t]
Derived parameters			
CO_2offsets	Carbon offsets		[$CAD]
S_{waste}	Waste management savings		[$CAD]

Values of the fixed parameters are displayed in Table 6.6. One major assumption within the model is that the greenhouse project generates carbon offsets as a renewable energy source that can be monetized. Income from offsets is calculated by taking natural gas emissions as the baseline and subtracting emissions linked to biomass (transport) from it. This value can be sold by the offset price which increases every year and is formulated below.

$$\text{CO}_2\text{offsets} = (CO2_{\text{natural gas}} - CO2_{\text{biomass}}) \times P_{\text{offset}}$$

Since any solid material with an acceptable calorific value can be burned, organic waste from the AG such as roots and trees from plants are defined as a resource. Assuming that 18% of the sellable part can be re-used for heat generation resulting in savings:

$$S_{\text{waste}} = AY_{\text{plants}} \times 18\% \times P_{\text{waste-manage}} \times t_{\text{lifespan}}$$

Waste management costs of agricultural waste are around 85$ CAD/t. Waste that cannot be reused must be handled and paid for. Against this logic, re-use potential is calculated as additional income since it is not subtracted from technologies without waste recycling capabilities.

6.1.4. Balloon digester: Biogas boiler

The biogas boiler system uses a biodigester to convert organic waste and water into biogas which is subsequently burned by the same principle as a natural gas boiler to generate thermal energy. A balloon digester is a cost-effective and simple elastic structure that extends as it is filled with biogas. Table 6.4 outlines the key parameters used to evaluate the biodigester and biogas boiler setup.

Table 6.7: Heating supply

Symbol	Parameter	Value	Unit
Fixed parameters			
η	Thermal efficiency	0.728	[%]
CV	Calorific value	5.5	[kWh/kg]
C_{m}	Maintenance cost	0.008	[$CAD/kWh]
Sz	Sizing factor	10	[l/kW]
$\dot{V}_{\text{gas, burner}}$	Consumption rate burner	5.0	[m^3/h]
Derived parameters			
$\dot{V}_{\text{organic-waste}}$	Required organic waste		[l/month]
$\dot{V}_{\text{water}}$	Required water		[l/month]

In contrast to direct utilization of fuel, the required inputs assessed are organic waste and water to produce biogas. Biogas primarily composed of methane CH_4 and carbon dioxide CO_2 need a burner in addition to the boiler for which a combined thermal efficiency is applied. Table 6.8 shows the sizing options for the burner, boiler, and biodigester. The burner ranges from 60kW to 150kW which covers all greenhouse sizes and is separately depicted in the table even though it's one single burner.

Table 6.8: Hot water boiler system sizing

Symbol	Parameter	1	2	3	4	Unit
Biogas burner BG300-2						
P	Power output	60	150			[kW]
C_{burner}	Cost	9690	9690			[$CAD]
Osby Parca Trio Boiler 65						
P	Power output	65	130			[kW]
C_{boiler}	Cost	10000	15000			[$CAD]
Sistema 40						
$\dot{V}_{\text{waste, in}}$	Waste input	250	500	750	1000	[l/day]
$\dot{V}_{\text{water, in}}$	Water input	500	1000	1500	2000	[l/day]
$C_{\text{biodigester}}$	Cost	7000	14000	21000	28000	[$CAD]

The boiler size selection is again based on peak demand but the digester size depends on water requirement in this case.

$$C_{\text{boiler}} = \begin{cases} C_{\text{1-boiler}} & \text{if } P_{\text{min}} < P_1 \\ C_{\text{2-boiler}} & \text{if } P_1 \leq P_{\text{min}} < P_2 \end{cases}$$

$$C_{\text{biodigester}} = \begin{cases} C_{\text{1-biodigester}} & \text{if } \dot{V}_{\text{water}} < \dot{V}_{\text{1-water, in}} \\ C_{\text{2-biodigester}} & \text{if } \dot{V}_{\text{1-water, in}} \leq \dot{V}_{\text{water}} < \dot{V}_{\text{2-water, in}} \\ C_{\text{3-biodigester}} & \text{if } \dot{V}_{\text{2-water, in}} \leq \dot{V}_{\text{water}} < \dot{V}_{\text{3-water, in}} \\ C_{\text{4-biodigester}} & \text{if } \dot{V}_{\text{3-water, in}} \leq \dot{V}_{\text{water}} < \dot{V}_{\text{4-water, in}} \end{cases}$$

Required organic waste is derived from the daily input specifications of the supplier but needs to be adjusted based on the thermal demand because the production will also decrease in warmer months. For that, the ratio between required biogas and produced biogas is used for correction.

$$\dot{V}_{\text{organic-waste}} = \dot{V}_{\text{waste, in}} \times \text{days of month} \times \left(\frac{\text{required biogas}}{\text{produced biogas}}\right)$$

According to specifications, water input equals two times animal manure input which is stated as:

$$\dot{V}_{\text{water}} = 2 \times \dot{V}_{\text{organic-waste}}$$

The biodigester also applies for waste management savings in two different ways: The fish manure produced from the aquaculture can be collected and fed into the digester, and for this project, it is assumed that animal manure can be collected from a buffalo farm.

Table 6.9: Cash flow statement

Symbol	Parameter	Value	Unit
Fixed parameters			
P_{water}	Water rate	10.93	[$CAD/$m^3$]
$P_{\text{waste-manage}}$	Waste management price	50	[$CAD/t]
cr	Conversion rate of fish	0.3	
Derived parameters			
S_{waste}	Waste management savings		[$CAD]

To derive the amount of fish excrement, a conversion rate of 30% from fish feed to fish waste is assumed which means that the fish takes in 70% of the feed into its body.

$$S_{\text{waste, aquaponics}} = FF \times cr \times \frac{\text{days of months} \times 12}{1000} \times P_{\text{waste-manage}} \times t_{\text{lifespan}}$$

Savings calculations for the farm are straightforward. It should be mentioned that the labor and transport costs are not displayed but are considered and balanced out the additional income through the waste management service.

$$S_{\text{waste, farm}} = \sum \dot{V}_{\text{organic-waste}} \times P_{\text{waste-manage}}$$

6.1.5. GSHP: Closed-loop horizontal system

GSHP operates by extracting heat from the ground via an underground looped piping network that is filled with a water-antifreeze solution. This fluid absorbs heat from the earth and transfers it to the heat pump, where it is compressed and upgraded to a higher temperature. The heat is then distributed through the hydronic radiant heating system. GSHP's high system efficiency of 410% makes it economically attractive during operation despite much higher investment costs. Table 6.10 shows specification parameters.

Table 6.10: Heating supply

Symbol	Parameter	Value	Unit
Fixed parameters			
η	System efficiency	4.1	[%]
lp_{h}	Horizontal loop	150	[m/t]
lp_{m^2}	Piping per m/m^2	5	[m/m^2]
C_{pipe}	Cost of pipe	7	[$CAD/m]
C_{labour}	Labor installation cost	22.5	[CAD/m^2$]
C_{m}	Maintenance cost	0.003	[$CAD/kWh]
$EF_{\text{CO2, Alberta}}$	Emissions factor Alberta	490	[g CO_2e/kWh]
$EF_{\text{CO2, Quebec}}$	Emissions factor Alberta	1.7	[g CO_2e/kWh]
Derived parameters			
$P_{\text{min, ref}}$	Min refrigeration power		[t]
l_{pipe}	Pipe length		[m]
$C_{\text{installation}}$	Total installation cost		[$CAD]
E	Electrical energy requirement		[$CAD]

Min power is converted to t as it relates to refrigeration from which the pipe length can be determined.

$$P_{\text{min, ref}} = P_{\text{min}} \times 3.51685, \quad l_{\text{pipe}} = lp_{\text{h}} \times P_{\text{min, ref}}$$

The piping values are required to estimate ground loop installation costs that are quite significant because of excavating activities and laying a large piping network including labor and backfill.

$$C_{\text{installation}} = C_{\text{pipe}} \times l_{\text{pipe}} + C_{\text{labour}} \times \frac{l_{\text{pipe}}}{lp_{\text{m}^2}}, \quad E = \frac{Q_{\text{heating}}}{\eta_{\text{system}}}$$

Systems sizing is shown in Table 6.11 demonstrating high investments of the heat pump.

Table 6.11: Heat exchanger system sizing

Symbol	Parameter	1	2	3	Unit
Nordic W Series Liquid to Water Heat Pumps					
P	Power output	10	15	20	[t]
C_{heatpump}	Cost	39972	49310	55505	[$CAD]

The same conditioned rationale applies again but with power displayed in refrigeration t instead of kW.

$$C_{\text{heatpump}} = \begin{cases} C_{\text{1-heatpump}} & \text{if } P_{\text{min, ref}} < P_1 \\ C_{\text{2-heatpump}} & \text{if } P_1 \leq P_{\text{min, ref}} < P_2 \\ C_{\text{3-heatpump}} & \text{if } P_2 \leq P_{\text{min, ref}} < P_3 \end{cases}$$

6.1.6. Hybrid integration and optimization

Hybrid options were chosen based on initial NPV results and technical suitability. Biodigester and natural gas showed synergies because the burner and boiler selected for biogas also support natural gas provision. This reduces investment costs and a grid-backed solution eliminates the low system reliability of the biodigester system. In cases of disruptions of supply, the system would not fail. It also reduces the high labor and maintenance requirements of a biodigester system but maintains the advantages of recycling potential from composting and fertilizer production as well as waste management treatment from produce. It represents a highly circular option that is still reliable and allows for testing optimized biogas yields from anaerobic digestion. It also facilitates scaling up the biogas provision because the natural gas supply is so flexible and cheap. A drawback is the not fully renewable energy option and CO_2 emissions are higher which also depends on the assigned share.

The system was optimized based on NPV results for the range of reviewed greenhouse sizes illustrated in Figure 6.2.

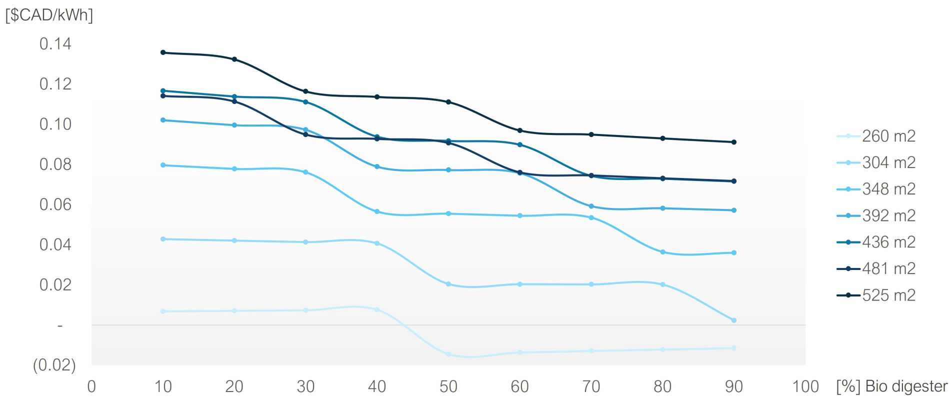

Figure 6.2: Hybrid optimization: Biodigester (Biogas) & Natural gas boiler

Each line in the graph represents a greenhouse size. The Y-axis indicates the NPV per kWh while the X-axis shows the share of the biodigester in the hybrid construct. Conversely, is the natural gas proportion the opposing value, for instance, if you look at 20% on the X-axis, this relates to a hybrid solution of 20% biogas and 80% natural gas. A share was determined for each greenhouse size by optimizing for a positive value with a biogas share larger than 50% and opting for high points for increased biogas utilization. This means that for example if the second line from the bottom is examined: looking at 50%, the line continues to the right and starts dropping after 80%. In this case, 80% share of biogas would be selected as there is not a large difference in the NPV value but the goal is to increase renewable energy share. Table 6.12 shows the selection of proportions used in the TEA for Hybrid-1BN.

Table 6.12: Biogas and natural gas shares with corresponding NPV

Share/AG size	**260m^2**	**304m^2**	**348m^2**	**392m^2**	**436m^2**	**481m^2**	**525m^2**
Biogas share in (%)	40	80	70	60	60	50	50
N_gas share in (%)	60	20	30	40	40	50	50
NPV in (CAD/kWh)	0.01	0.02	0.05	0.08	0.09	0.09	0.11

The second option only allowed for the combination of GSHP and biomass boiler because it was supposed to be a fully renewable option and biodigester as well as GSHP are both the least economically feasible options, leaving only the mentioned choice. Technically they go well together because GSHP can provide a steady thermal input while biomass boilers can react quickly to sudden needs but are more prone to disruptions within the supply chain. The second optimization based on NPV outcome is visualized in Figure 6.3.

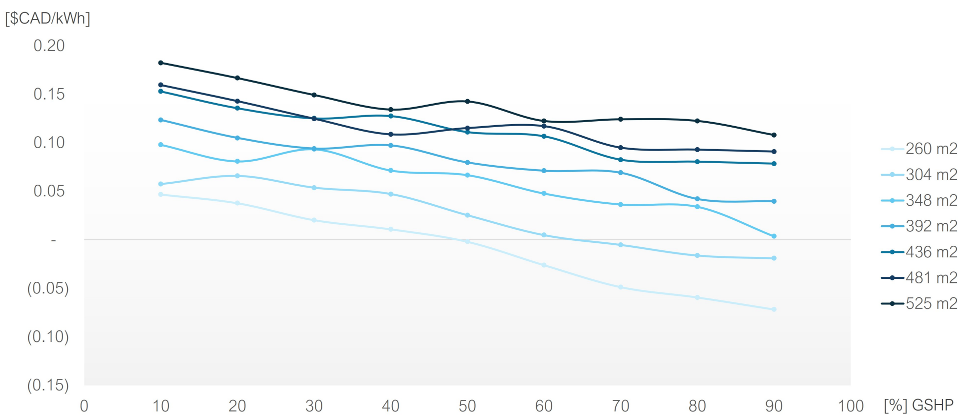

Figure 6.3: Hybrid optimization: GSHP & Biomass boiler

The share was determined in the same rationale by optimizing for a positive value with a GSHP share larger than 30% though to maintain the cooling capabilities for summer and opting for high points to increase NPV value since both technologies are renewable. Table 6.13 displays the selection of proportions used in the TEA for Hybrid-2GB.

Table 6.13: GSHP and biomass boiler shares with corresponding NPV

Share/AG size	**260m^2**	**304m^2**	**348m^2**	**392m^2**	**436m^2**	**481m^2**	**525m^2**
GSHP share in (%)	30	40	30	40	40	60	50
Biomass share in (%)	70	60	70	60	60	40	50
NPV in (CAD/kWh)	0.02	0.05	0.09	0.10	0.13	0.12	0.14

7

Model Results

"All models are wrong, but some are useful."
(George E.P. Box)

7.1. Aquaponic Greenhouse

7.1.1. Produce

Table 7.1 introduces the most relevant parameters that will reappear and act as a reference for the following presentation of results. Fish tank volume is the only input variable in the model, while all other parameters such as greenhouse size, thermal demand, and financial analysis are calculated based on it. The greenhouse sizes are closely linked to the fish tank volume because the AG design was built around it. Greenhouse sizes are used as reference points for varying production and thermal energy demand. The size of 392 m^2 with an 8000 liter fish tank volume is used as a reference for comparing results in the following sections since it reflects the center size. To demonstrate the range and to get a feeling of what the sizes mean, the total annual produce of fish, basil from the NFT system, and lettuce from the soil-based system are displayed in Table 7.1. Furthermore, the monthly supply shows how many adults can be supplied by the greenhouse for an entire month assuming a caloric intake of 2000 kcal, and the thermal demand is stated in MWh.

Table 7.1: Guiding production variables and parameters

$V_{\text{fish-tank}}$	Unit	AG_{m^2}	Annual produce	Unit	Monthly supply	Annual demand	Unit
5000	[l]	260	3.2	[t]	42 Adults	96	[MWh]
6000	[l]	304	3.9	[t]	50 Adults	110	[MWh]
7000	[l]	348	4.5	[t]	58 Adults	123	[MWh]
8000	[l]	392	5.2	[t]	67 Adults	137	[MWh]
9000	[l]	436	5.8	[t]	75 Adults	150	[MWh]
10000	[l]	481	6.4	[t]	83 Adults	164	[MWh]
11000	[l]	525	7.1	[t]	92 Adults	178	[MWh]

The center-range size marked in blue, provides a total annual produce of 5.2 tons which can nourish 67 adults for a month. The thermal demand of the passive solar design AG is 137-megawatt hours for the Albertan context. Table 7.2 compares the annual production of the three systems relative to the m^2 of growing space.

Table 7.2: Annual production per growing space and corresponding nutritional values

Systems	**Aquaculture** Catfish	**NFT** Basil	**Soil-based** Lettuce	**Unit**
Annual produce	50	14	29	[kg/m²]
	59500	3888	4896	[kcal/m²]

The aquaculture system has the highest density as the fish tank yields heavier fish on a much smaller surface. When comparing NFT to a soil-based system it must be considered that lettuce weighs more than basil, increasing the value. But looking at calories per m^2 still provides the soil-based system with a higher value even though lettuce provides slightly fewer calories per 100 grams. Of course, the fish tank produce needs to be included in that comparison as it is a connected system, but it could be worthwhile to compare a fully soil-based greenhouse to the AG since the costs associated with a soil-based system are significantly lower. A soil-based greenhouse would also have less limiting requirements towards the heating system and is more flexible in terms of temperature fluctuations, which could result in further cost reduction.

7.1.2. Costs and revenues

This section analyzes non-heating related CAPEX, OPEX, and revenues that almost have to solely hold up against all other costs to show profitability in the model rationale.

The upper part of Table 7.1 displays a broad cost breakdown of the total CAPEX (in 1000 $CAD) related to the building and growing systems, decreasing from bottom to top. Building material and construction labor have the highest upfront costs which was also identified by Lobillo-Eguíbar et al. [50] in their economic sustainability assessment of small-scale aquaponic systems for food self-production. Next on the line is the vertical NFT system with 36,000 $CAD which is double the amount of the horizontal NFT. But the vertical system also utilizes space much better which is essential to maintain smaller sizes in order to reduce the thermal demand. Growing lights also comprise a significant portion of investment (almost the same as the vertical NFT), particularly when considering that they only represent the surface area of the horizontal NFT system in the model. The soil-based system is placed on the front with glazing above it which doesn't allow for mounting anything and the vertical NFT probably receives enough light from the growing lights as it is close by. The aquaculture system is relatively affordable and soil-based as mentioned earlier by far leading in terms of cost efficiency. The CAPEX structure highlights the dependency on advanced systems like the NFT setup, which supports higher yields and resource efficiency. However, the notable cost of labor and materials underscores the necessity for strategic sourcing and potential local resource utilization to minimize financial burdens.

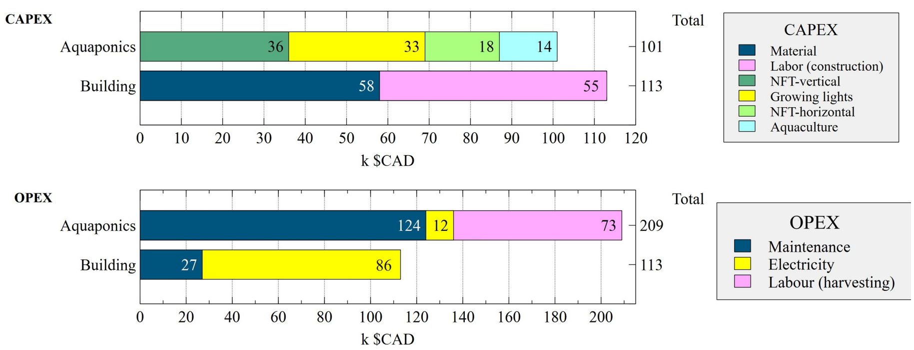

Figure 7.1: CAPEX and OPEX: Non-heating 392m²

The lower part of Table 7.1 outlines the operational expenditures of the reference greenhouse size of $392m^2$, showcasing recurring costs that are essential for sustaining operations. Within operations, the aquaponic system is the more cost-intensive part. The largest component is maintenance costs of which a major portion comes from fish feed costs. Electricity requirements result from supplying the growing lights, which are assigned to the building in the graph, and calculated under the condition of having 16 hours of light per day which is supplemented by LED lighting as soon as daylight hours become shorter after the summer months. A smaller fraction of electricity input is needed to drive the pumps of the aquaponic system. Labor costs are less than electrical supply but remain high at 73,000 $CAD over the whole life-cycle (undiscounted). This emphasizes the energy-intensive nature of aquaponic systems.

The proportion of discounted CAPEX and OPEX are shown as negative costs in Figure 7.2. Additionally, the relationship between costs and revenues across increasing greenhouse sizes is examined, and normalized per unit of produce for comparability. CAPEX and OPEX are plotted against the revenue streams generated from fish, basil, and lettuce produce. The findings reveal that as greenhouse size increases, both CAPEX and OPEX slightly decrease due to economies of scale and enhanced productivity. The produce sales remain proportional per unit but larger greenhouse sizes show a higher total value because of reduced costs. Even small cost reductions can be decisive as the sales are the only income and have to outweigh the total heating costs. This trend suggests that larger AG sizes are more economically viable, reinforcing the importance of scalability in aquaponic greenhouse projects.

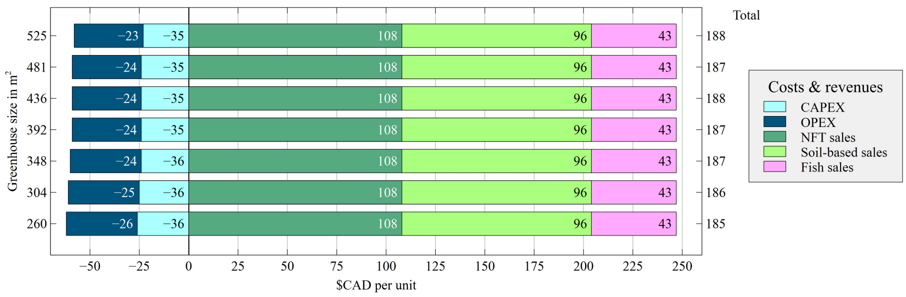

Figure 7.2: Costs and revenues: Non-heating over increasing AG size

The combination of CAPEX, OPEX, and revenue data underscores the importance of balancing initial investments with operational efficiency. The interplay between high CAPEX, particularly in labor and materials, and ongoing OPEX, driven by maintenance and electricity, presents a dual challenge for economic sustainability. Strategies to mitigate these costs, such as energy-efficient systems or locally sourced feed, could greatly enhance profitability. Furthermore, scaling up the greenhouse size emerges as a critical factor for achieving financial viability, as larger systems leverage fixed costs more effectively and provide higher total revenues.

7.1.3. Thermal load curve and passive solar effect

This section evaluates and compares the thermal energy demand between passive solar use and non-passive solar utilization over the year, thereby quantifying the passive solar effect.

The annual thermal load curve illustrated in Figure 7.3, highlights the greenhouse's heating requirements across all months for the size of 392 m^2. The green surface reflects the thermal demand without night curtains and passive solar utilization, while the dark blue load area demonstrates the actual thermal demand of the modeled passive solar AG. The light blue line shows the percentage of heating reduction from the passive solar design relative to the initially calculated heating requirement (without passive solar use). The peak demand is visible around December and January, while the demand significantly drops in the warmer months. The passive solar effect has an immense impact on heat reduction across all months and accelerates in spring when the sun comes closer to Earth. From that point, heating requirements are eliminated from April until September while the green area demonstrates a continuous thermal demand even in peak summer. In summary, passive solar heating provides substantial energy savings during transitional months, offsetting significant heating needs and linked costs. It is undoubtedly the most cost-effective renewable heating alternative out of all.

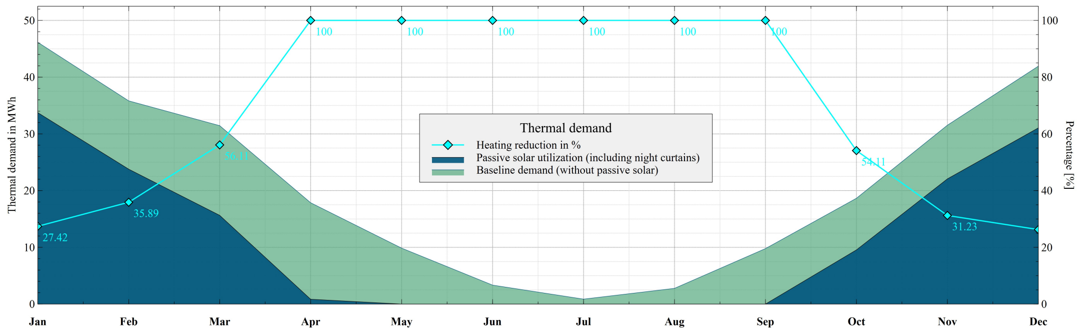

Figure 7.3: Thermal load curve comparison: 392m²

Figure 7.4 illustrates the annual heating demand per unit over the range of evaluated greenhouse sizes. The pink line shows the average annual heating reduction in percentage. The graph demonstrates that the passive solar effect amplifies with increasing greenhouse size which is also reflected in the decreasing thermal demand. This can be explained by how the model sizes larger greenhouses, namely, by expanding the length towards East and West which increases the surface of the glazing while the north wall keeps the same distance from the glazing. This allows more solar radiation to enter the building for immediate solar gains but particularly thermal energy storage of brick wall and fish tank that absorb the heat and release it during night.

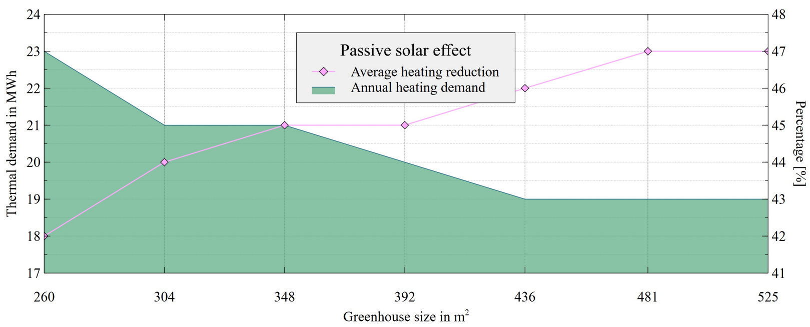

Figure 7.4: Passive solar effect over increasing AG size

In addition to decreasing CAPEX and OPEX with increasing greenhouse size, also the significantly reduced thermal demand further pushes costs down with larger sizing. The following section examines the impact of variation for the most relevant input variables such as CAPEX and OPEX within the model.

7.1.4. Sensitivity analysis

To evaluate the robustness and adaptability of the non-heating related AG parameters, a sensitivity analysis was conducted. This analysis explores the influence of key variables on the overall NPV value of the base case. The base case focuses on operations of the aquaponic system without comparing heating alternatives yet. A natural gas boiler system is modeled which needs to be included to display the NPV. The variables, however, have no direct impact on the heating technologies. The analysis provides insights into how fluctuations in parameters, such as investment costs, operational expenses, and energy prices, can affect system viability in general, visualized in Figure 7.5.

The graph shows all input variables on the left with corresponding unit measurements. On the most right the respective input values of the variables are displayed. A high and medium impact was chosen for negative scenarios in which the input variable was increased or decreased by 20% for high impact, and by 10% for medium impact. Increased costs for instance result in a lower NPV value while increased sales prices result in higher sales and therefore also higher NPV. The low impact was selected only for positive impact on the NPV such as the mentioned increased sales price or reduced costs. The orange dotted line demonstrates the threshold of a positive NPV value. Any impact exceeding the line towards the left represents a negative NPV for that impact. The numbers next to the impact bars reflect the change in NPV by percent, meaning that an impact with -100% would match with the orange dotted line because the impact of the changing variable would decrease the NPV by 100% resulting in zero.

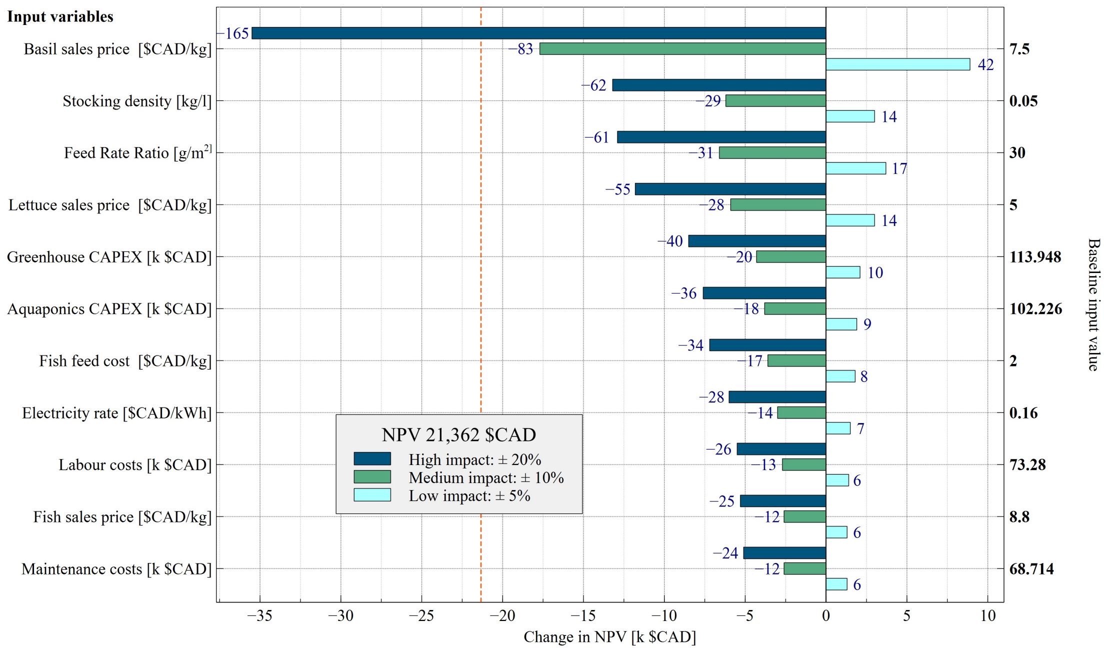

Figure 7.5: Sensitivity analysis: Base case 392m²

The only variable that can push the NPV of 21,362 $CAD towards the negative area with a 20% alteration, is the basil sales price of the NFT system, making it the most sensitive variable. This again was a finding of Lobillo-Eguíbar et al. [50] in their study, where vegetable market prices were the most sensitive parameters influencing profitability, validating the model. The high sensitivity of this variable is because the NFT system is 4 times the size of the soil-based lettuce production, and as mentioned earlier almost the only generation of income. Reducing the price will strongly impact the NPV but the same holds for increasing it on the positive side.

The following most sensitive parameters are stocking density and feed rate ratio. Both variables are linked to the sizing of planting area based on the aquaculture system. The stocking density dictates the amount of fish held in the tank, thereby also defining the amount of nutrients available for the plants. The FRR is a key metric in aquaponics which relates the amount of fish feed to the growing area as this is what is converted by the fish and released to the plants to balance the cycle. Increasing the stocking density by 20%, or decreasing the FRR by the same value, results in a 60% decrease of the NPV. The FRR shows the only non-linear change in impacts because a change in this variable does not match with the greenhouse design.

The smaller lettuce production still ranks high on sensitivity for the same reason as basil sales, followed by capital investments in the building and aquaponic system. Fish feed costs alone have a surprisingly high impact on NPV, followed by electricity rates for lighting and pumps. Labour costs, fish sales prices, and maintenance costs are on the lower end of evaluated variables but still result in a higher change in NPV than the change in impact.

7.2. Techno-economic heating comparison

7.2.1. Costs and income

This section further analyses costs and additional income with regard to heating. CAPEX, OPEX, and income of the renewable heating systems are compared to natural gas provision.

Figures 7.6 show the composition of CAPEX for each heating technology in a mid-range greenhouse scenario (392 m^2). The CAPEX includes the purchase and installation of the hydronic radiant installation which stays the same across technologies, the main heating system such as the hot water boiler, additional components, and the buffer tank.

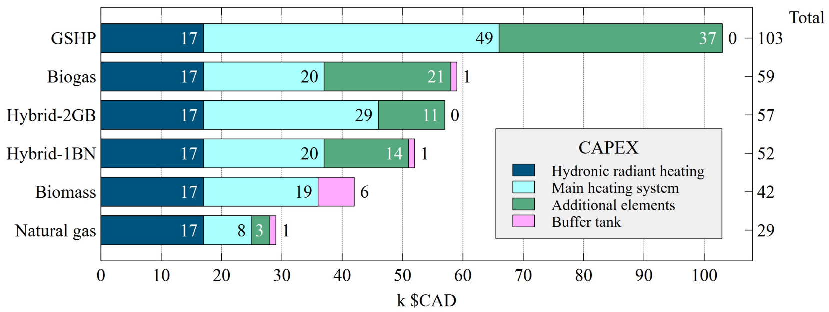

Figure 7.6: CAPEX heating: 392m²

GSHP has the highest CAPEX due to the expensive heat pumps and ground loop installation with total upfront costs of 103,000 $CAD. Natural gas on the other hand requires only 29,000 $CAD as initial investments. A biomass boiler comes closest to a natural gas boiler in terms of costs with a total of 42,000 $CAD. Both hybrid options are centered within the mid-range, which is an unexpected result at first since hybrids require double the investment. However, Hybrid-1BN can share the burner and boiler with natural gas which lowers overall equipment costs relative to a standalone biogas system because the digester decreases in size while the other machinery stays the same which is clearly visible in the graph when comparing Biogas and Hybrid-1BN. Hybrid-2GB still requires slightly less upfront cost than the biodigester which requires balloon digesters on top of the already expensive biogas boiler system.

The OPEX accounts for recurring costs such as fuel (gas, electricity, water), maintenance of the heating system, transport and labor requirements, and cooling. The comparison is depicted in Figure 7.7.

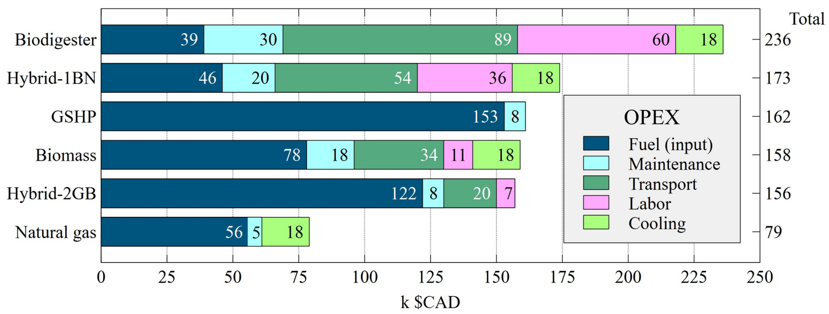

Figure 7.7: OPEX heating: 392m²

Natural gas remains dominant with regard to low operational costs, followed by the Hybrid-2GB option. The hybrid options take place between the technologies they combine which is logical and also applies to CAPEX. The Biodigester system also experiences high operational costs due to greater labor intensity and transport requirements, assuming that resources have to be obtained from the buffalo farm or similar way in a 100km radius. Biomass and GSHP are in the same range around 160,000 $CAD for the whole life-cycle (undiscounted). GSHP has a more stable and lower operating expense of electricity as the only major input, increasing reliability as long as the electricity source is also reliable. GSHP is also the only technology that is capable of cooling in summer, thus eliminating cooling costs. Hybrid-1BN demonstrates moderately higher costs than GSHP at 173,000 $CAD as the second highest.

Within the model, each system's combined costs can be compensated by the mentioned sales of aquaponics and soil-based production, or through secondary offsets such as carbon credits and savings by offering a waste management service to external actors like the buffalo farm, or by avoiding waste management fees due recycling capabilities. Figure7.8 illustrates CAEPX and OPEX (discounted per kWh) as negative costs, and carbon offsets as well as waste management savings as additional positive income. The difference is displayed on the left. In this graph the proportional intensity of CAPEX and OPEX for each technology becomes more visible.

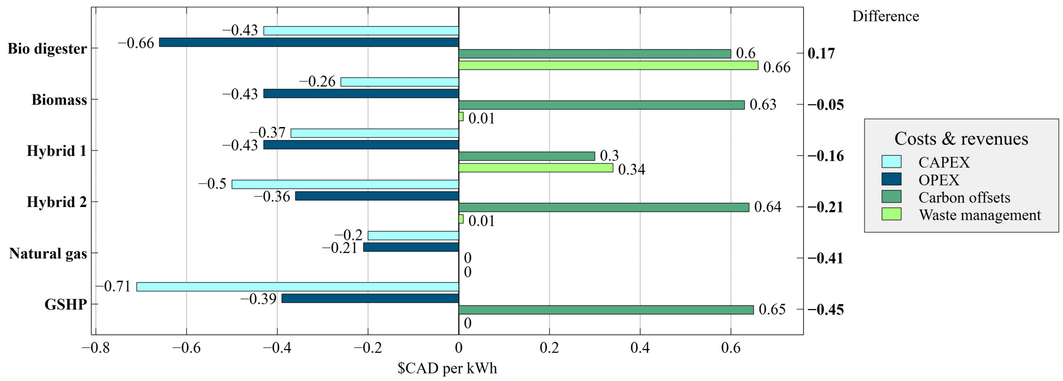

Figure 7.8: Costs and additional income: 392m²

Overall, the biogas system scores the best in the sense that it holds the potential to fully compensate for its high costs by carbon offsets and waste management. The biodigester can recycle AG waste and serve as a waste disposal site for external enterprises which could be capitalized if an offer is less than waste disposal fees. Biomass follows due to similar offsets and a tiny amount of recycled biomass from the AG produce, but mostly due to the lower CAPEX and OPEX. the hybrid options are again clearly a product of the single technologies and are found in the mid-range again. Natural gas has low-cost requirements but does not apply for carbon credits and shows no recycling capabilities.

The natural gas option remains the cheapest in any financial metric, but some renewable alternatives, especially biomass and biodigester (and their hybrid companions) show potential for additional cost offsets and long-term stability if resources can be secured locally. As a standalone technology, the biodigester system seems too expensive and unreliable. The main cost-driving factor is the frequent pickup of large amounts of animal manure. A better solution could quickly make it economically competitive.

7.2.2. Net Present Value

The net present value incorporates both up-front and ongoing costs, and the AG produce plus any secondary income discounted over 20 years with 12%. It is used as a metric to compare the feasibility of project alternatives. Figure 6.12 compares NPV values for the selected heating technologies across all greenhouse sizes. the heating technologies are listed on the left from highest to lowest NPV while the respective value for 392 392m² is indicated on the right side. The different sizes are displayed in colors from small (red) to large (green). NPV values are shown in $CAD per kWh of the general thermal demand for each size.

It's visible that natural gas and biomass as heating technologies are stronger with smaller sizes but flat out a bit at larger sizes. The hybrid options have too high upfront costs to cover smaller sizes but show an increased NPV for the mid to large range. Hybrid-1BN always outperforms the full biodigester solution due to decreased natural gas integration costs. The biogas system also doesn't cope well with small sizes but shows great stability and increases at a larger scale. GSHPs are not suited for small sizes in a standalone setting because of the extravagant capital investments. When scaled up though, the spread of investment over higher production volumes can yield a respectable stable NPV. The development from highly negative to positive comes fast at the end range. It would be interesting to assess the behavior of further size increase. Hybrid-2GB remains behind a standalone biomass boiler but demonstrates high synergies considering GSHP's much worse performance alone in terms of costs. If the biomass boiler covers peak loads in the hybrid setting, the required pump capacity can be lowered which also lowers the capital cost of GSHP significantly.

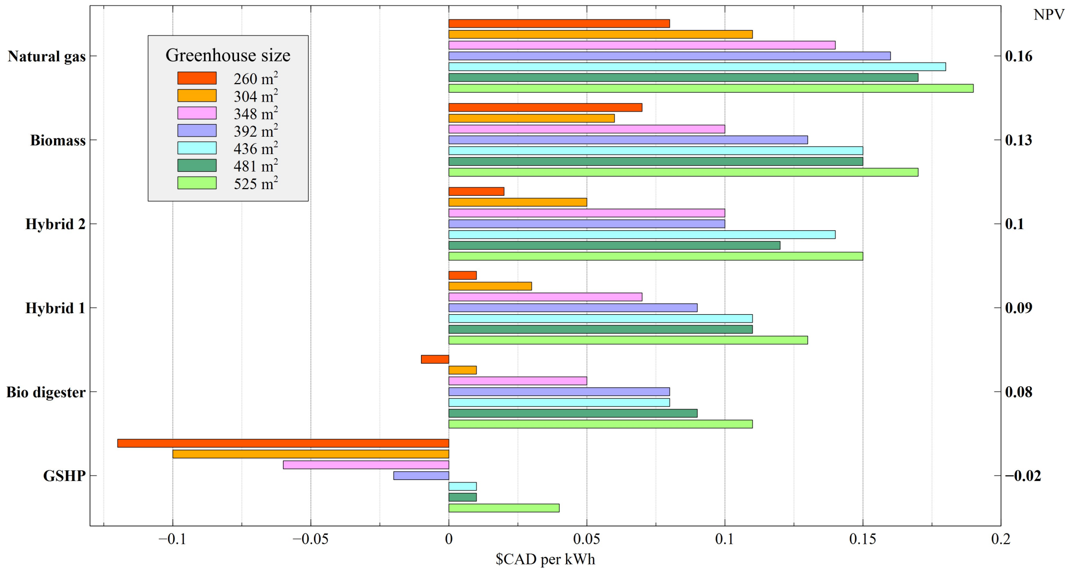

Figure 7.9: NPV over increasing AG size

The graph clearly confirms that larger greenhouse sizes are more economically viable by showcasing higher NPV value for any technology. Besides economic metrics, carbon emissions were evaluated as part of the TEA.

7.2.3. Carbon emissions

To assess environmental sustainability, Figure 7.10 displays total carbon net emissions over the 20-years period for each system as a major indicator.

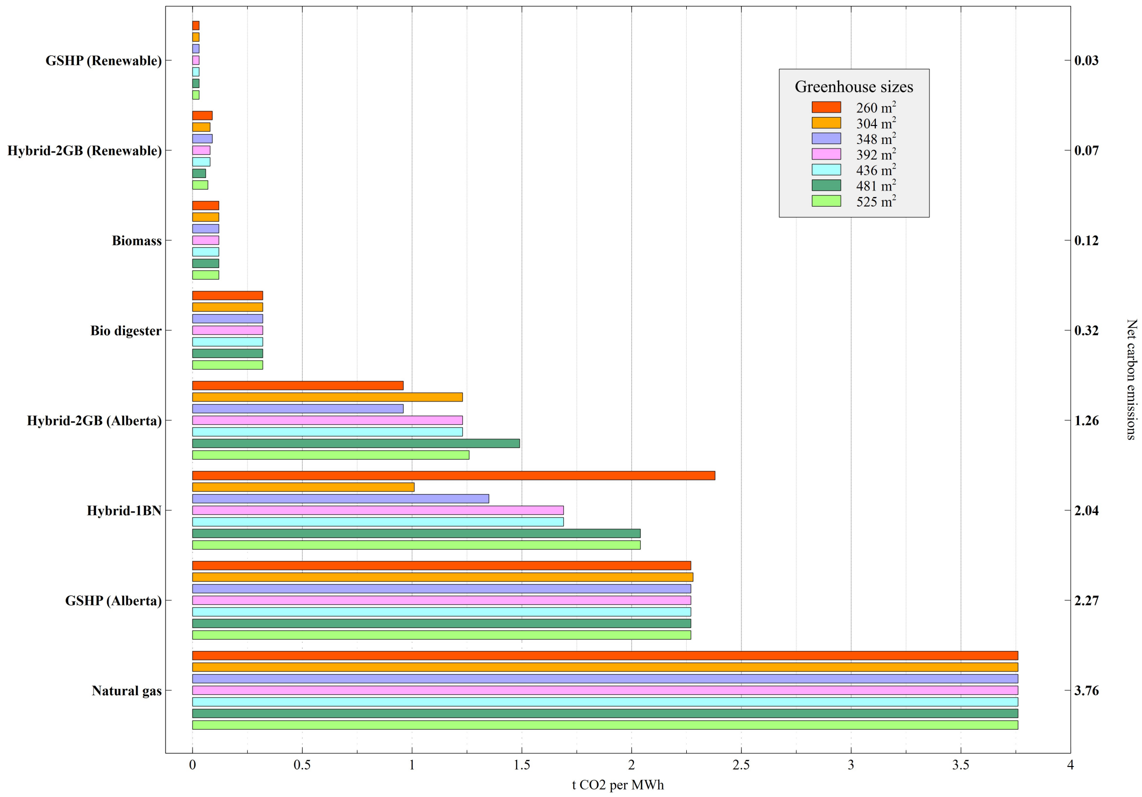

Figure 7.10: Carbon emissions over increasing AG size

Emission calculations follow the methodology from Section 6.1.3, which considers both direct combustion and upstream/transport factors. The graph can be read similar to Figure 6.12 as it displays calculated emissions across greenhouse sizes in t of CO_2 per MWh. The model calculations are linear, resulting in equal emissions per MWh in varying sizes except for the hybrid options. Due to the varying share of technologies in different sizes, the net emissions impact can change.

Natural Gas is by far the highest emitting technology, reflecting its fossil-fuel origin. GSHP can showcase the lowest emissions but also the second highest, depending on the origin of the electricity used to power the heat pump. With the Alberta electricity mix, it cannot be defined as a renewable energy. This drastically changes if the electricity supplied comes from renewable sources. The same logic applies to Hybrid-2GB which partly consists of GSHP in addition to a biomass boiler. Hybrid-1BN is also quite carbon intense with a 40% natural gas boiler proportion. Bio digester and biomass would come close to carbon neutrality without transport requirements which are the main part of their calculated emissions.

From a climate perspective, biomass, biodigester, GSHP, and Hybrid-2GB offer the largest emissions cuts, especially if resources are locally obtained and the electricity grid's emissions factor improves over time.

7.2.4. Sensitivity analysis

A sensitivity analysis was conducted for each renewable heating technology for the reference size of 392m^2 to illustrate how changes in critical parameters affect the system's NPV. For the evaluation of the sensitivity of the heating technologies, a benchmark impact was incorporated to assess what kind of value is required for certain variables to arrive at the same NPV output as the natural gas boiler. It was applied only to input requirements, such as fuel and other materials, as well as the transport distance for collecting inputs since these parameters can be more flexibly adjusted, reduced, or eliminated through various means

Figure 7.11 illustrates the sensitivity of critical variables for GSHP with an NPV value of -3,114 $CAD. The graph follows the same rationale as Figure 7.5 from the previous Section 7.1.4. The benchmark line for the base case NPV is displayed as a green dotted line whereas the orange dotted line again shows the transition to a negative (in this case positive) NPV. The mentioned benchmark impact is combined with the low impact but visible through the bar reaching the NG (natural gas) line with the displayed altered input value that is required to compete with a natural gas boiler. The remaining values that do not show a value and do not reach the line show results of a 5% change towards a positive impact in the input variable.

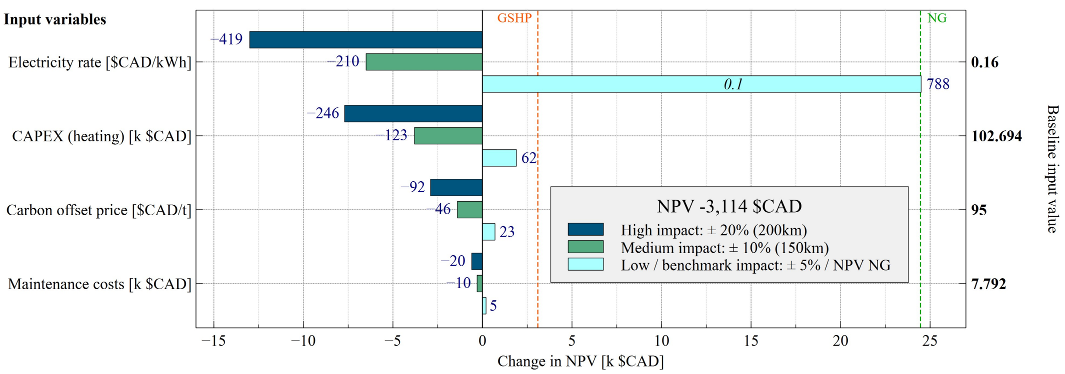

Figure 7.11: Sensitivity analysis: GSHP 392m²

GSHPs are strongly dependent and highly sensitive to electricity rates. A 20% alteration in electricity rate can decrease the already negative NPV by another 420%. On the contrary, a reduction from 0.16 $CAD per kWh to 0.1 $CAD in electricity pricing would increase the NPV of GSHP by 788% to the same scale as a natural gas boiler. The CAPEX also demonstrates high sensitivity but cannot be significantly reduced in a standalone system

Figure 7.12 depicts the biodigester system's sensitivity with an NPV value of 11,277. The high impact for transport distance was adjusted since a 20% alteration of the baseline input of 100 km does not reflect realistic changes for the context. The high impact therefore relates to 200 km while the medium impact calculates with 150 km.

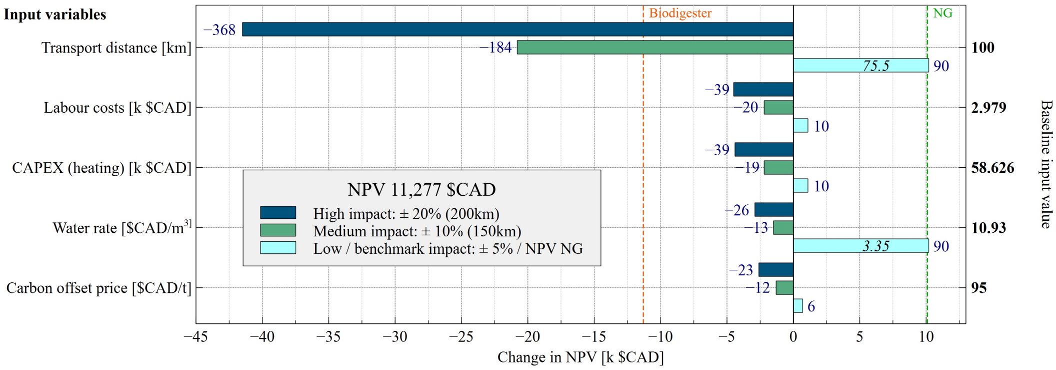

Figure 7.12: Sensitivity analysis: Biodigester 392m²

The graph clearly illustrates that the primary challenge for the biodigester system is resource availability, which is closely linked to the transportation of organic waste inputs. Even small increases in transport distance can quickly result in a negative NPV. Conversely, reducing the distance from 100 km to 75.5 km aligns the NPV with that of a natural gas boiler. This presents both an opportunity and a risk for biogas systems, emphasizing the importance of securing local resources before implementation. Reducing the water rate from 10.93 CAD/m² to 3.35 CAD/m² would raise the NPV to match that of a natural gas system. This analysis highlights the significant potential of a biodigester system, despite economic challenges. Securing local resources and lowering water costs could position a biogas system among the most financially viable renewable technologies evaluated.

Figure 7.13 shows the sensitivity analysis of a biomass boiler system which demonstrates the highest NPV of renewable heating technologies at 17,178 $CAD.

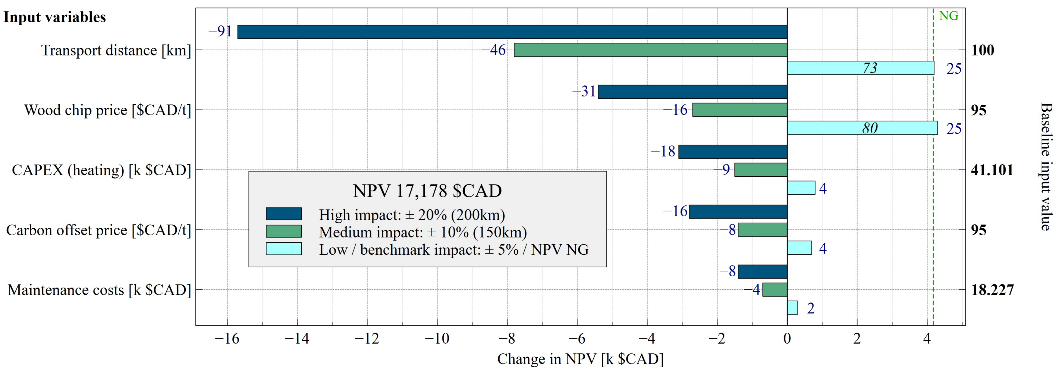

Figure 7.13: Sensitivity analysis: Biomass 392m²

Unlike other renewable options, biomass has relatively stable fuel prices and is also less sensitive to price fluctuations. However, transport distance can still significantly impact NPV, though not as severely as in the biodigester case. The baseline wood chip price was set at 95 CAD/t, and reducing it to 80 CAD/t would align the NPV with that of natural gas. During the research, the most accurate estimate of usable solid biomass for an agro pellet boiler was obtained at 63 CAD from a local recycling company. This highlights the significant potential of this technology, particularly when local resources are secured. Additionally, a 25% reduction in transport distance would bring the NPV in line with that of natural gas.

The sensitivity of the hybrid options effectively demonstrates the combined sensitivity of the evaluated technologies, with NPVs falling within similar ranges. Hybrid-1BN has an NPV of 12,884 CAD, while Hybrid-2GB shows a slight increase to 14,168 CAD for a system size of 392 m^2. The graphs are shown in Appendix B.3. Transport distance remains the most sensitive variable in the biogas (60%) and natural gas (40%) combination, where minor changes can turn the NPV negative. Reducing the sourcing radius to 65.7 km or lowering the water rate to nearly zero would raise the NPV to match that of a standalone natural gas boiler. Similarly, the second hybrid solution is highly sensitive to transport distance due to its 60% biomass share and to electricity rates because of its 40% GSHP supply. Making it competitive with a natural gas boiler would require reducing the transport distance to 23 km, lowering the electricity rate to 0.134 CAD/kWh, or decreasing the biomass price by 53.5 CAD/t. Hybrid-2GB demonstrates strong potential and flexibility in achieving better economic performance through various adjustments. Additionally, if properly managed, it is the cleanest option in terms of environmental impact.

8

Multi-Criteria Integration

"Sometimes you make the right decision, sometimes you make the decision right."
(Phil McGraw)

8.1. Multi-criteria decision-making: Best-Worst Method

8.1.1. Introducing BWM

The value identification facilitated a better understanding of community values and what FMFN stakeholders perceive as important. Guided by VSD principles, a value-sensitive AG design could be established that reflects those values. The techno-economic analysis was conducted based on those design specifications which were incorporated into a technical and financial feasibility analysis, that provided valuable insights about the characteristics of the renewable heating technologies as well as performance indications for a set of potential alternatives that showcase different strength and weaknesses. The results can certainly support in a decision-making process but I'm not the one to decide on behalf of the community. One major goal of the study is to integrate traditional values into engineering principles for which BWM developed by Rezaei [67] was applied. It illustrates how community members can express their priorities, which can then be incorporated into a decision-making process to generate a ranking based on their given preferences.

BWM is an established tool that helps decision-makers to systematically assign weights to criteria based on stakeholder input to then rank a set of alternatives accordingly [67]. Compared to other multi-criteria approaches, such as the Analytical Hierarchy Process, BWM typically requires fewer pairwise comparisons, and reduces complexity without compromising on robust outcomes. Furthermore, BWM incorporates an inherent mechanism to mitigate cognitive biases of decision-makers throughout the process including both anchoring bias and equalizing bias [70, 69]. For this research, BWM was applied to obtain weights of KPIs defined in Table 4.16 in Section 4.4.3.

Step 1 of conducting BWM is to determine a set of decision criteria $(c_1, c_2, ..., c_n)$ and present it to the decision-maker. In this application, the decision-maker is the FMFN greenhouse project developer, and the decision criteria are the co-developed KPIs for which weights are obtained that relate to importance.

In **Step 2**, the decision-maker chooses the most important and the least important indicators. The BWM process was conducted through the linear BWM solver provided under *https://bestworstmethod.com/*. The method was introduced first before guiding the project developer through the process in an online meeting. The excel sheet which also served as the questionnaire was filled out jointly.

In **Step 3**, the decision-maker determines his preference of the most important indicator over all other indicators on a scale between 1 and 9. The resulting *Best-to-Others vector* relates to:

$A_B = (a_{B1}, a_{B2}, ..., a_{Bn}),$

in which a_{Bj} indicates the preference of the most important indicator B over indicator j. $a_{\mathrm{BB}} = 1$ must be given [67].

In **Step 4**, the decision-maker provides his preference of all indicators over the least important indicator using the same scale. The resulting vector relates to:

$A_{\mathrm{W}} = (a_{1\mathrm{W}}, a_{2\mathrm{W}}, ..., a_{\mathrm{nW}}),$

in which a_{jW} indicates the preference of the indicator j over the least important indicator W. $a_{\mathrm{WW}} = 1$ must be given [67].

In the final **Step 5**, the optimal weights $(w_1^*, w_2^*, \dots, w_n^*)$ are obtained mathematically by minimizing the maximum differences of $|w_B - a_{Bj}w_j|$ and $|w_j - a_{jW}w_W|$ following the model:

$$\min \max_j \{|w_B - a_{Bj}w_j|, |w_j - a_{jW}w_W|\}$$

subject to:

$$\sum_j w_j = 1, \quad w_j \geq 0, \text{ for all } j.$$

This relates to the following linear model that outputs the optimal weights $(w_1^*, w_2^*, \dots, w_n^*)$ and the objective function value ξ [68]:

$$\text{min } \xi$$

subject to:

$$|w_B - a_{Bj}w_j| \leq \xi, \text{ for all } j,$$
$$|w_j - a_{jW}w_W| \leq \xi, \text{ for all } j,$$
$$\sum_j w_j = 1,$$
$$w_j \geq 0, \text{ for all } j.$$

The consistency ratio returns a number between 0 and 1, representing higher consistency if the value is closer to 0. Liang, Brunelli, and Rezaei [49] proposed the following approach to compute the consistency ratio CR:

$$CR = \max_j CR_j$$

in which:

$$CR_j = \begin{cases} \frac{a_{Bj} \times a_{jW} - a_{BW}}{a_{BW} \times a_{BW} - a_{BW}}, & a_{BW} > 1, \\ 0, & a_{BW} = 1. \end{cases}$$

The calculated ratio is then matched with an associated threshold value which is provided by Liang, Brunelli, and Rezaei [49] based on the number of criteria and applied scale. The linear BWM solver was used to obtain weights and calculate the input-based CR. The associated threshold value is 0.3337 for six criteria and the maximum value of 9 applied by the decision-maker on the scale [49].

8.1.2. Application and project integration

In the case of the greenhouse project, KPIs have been defined and a set of alternatives to be evaluated corresponds to potential heating alternatives to meet the thermal demand of the AG. The KPIs have to be linked to metrics that reflect the performance. The metrics do not necessarily have to be a number value but they need to be transferable to a numbered scale. The KPIs were jointly defined and categorized into technical, environmental, economic, and social indicators. Assigned metrics were selected based on the data availability of the TEA. Table 8.1 lists and defines all KPIs for this project and shows assigned metrics that represent the KPIs for the multi-criteria assessment.

The indicator *Reliable* combines two metrics: (1) the number of technologies implying if it's a hybrid system that is backed by a second technology and thus more reliable; and (2) maintenance costs for the heating system which is a common metric used for reliability, which avoids that the hybrid use of two unreliable technologies receives a high score due to the first metric. An average of the two metrics is applied, expressing equal importance for the indicator *Reliable*. The reason for using a combined scale was the importance of accounting for the increased reliability of using a hybrid option. The performance values illustrated in Table 8.3 demonstrate that the application of equal weights resulted in a more accurate representation of reliability since the hybrid options score the highest followed by a natural gas boiler. This validates the use of equal weights for simplicity and does not require further adjustment.

The rationale for applying BWM in this study was to provide a simple way of expressing values for community members which can be quantified and transformed into a ranking that is easy to follow. The calculations in between that process were not meant to be dealt with by participants which is also the reason why performance metrics of the KPIs were not part of any external weighting process. This part was purposefully held in isolation to account for cultural differences and to not complicate things for participants. Initially, ways were explored for community members to take part in the BWM process through a survey without any deeper knowledge and understanding of the whole project, which could not be finalized due to time constraints and other complications. This approach was also conflicting with BWM as a method designed for decision-makers and experts which will be further discussed in Section 9.2.1. The aggregation of dependent criteria is commonly also not accepted due to potentially misleading results by criteria interaction. However as mentioned earlier, this was necessary to compare NPV scores to multi-criteria scores and provide a more conclusive outcome. The early project stage doesn't allow for an actual decision on a technology yet but the ranking illustrates how technology preference can change based on the weighting of different indicators or values.

Table 8.1: KPIs and metrics

KPI	Definition	Metric	Unit
Technical			
Reliable	The heating system is reliable if it can be trusted to heat the greenhouse consistently without failures	$n_{technologies}$ & $C_{maintenance}$	[amount] & [$CAD]
Easy to operate	The heating system is easy to operate if it can function by its own without needing much additional manual work	$C_{labour} + C_{transport}$	[$CAD]
Environmental			
Climate-friendly	The heating system is climate-friendly if its net green-house gas emissions impact is close to zero	CO_2	[t CO_2]
Waste recycling	The heating system is recycling waste if biological waste from the greenhouse produce can be re-used to heat the greenhouse	$\dot{V}_{waste}$	[kg]
Social			
Off-grid	The heating system is off-grid if it's powered by renewables that are self-sustaining	Share $_{\text{renewables}}$	[%]
Economic			
Affordable	The heating system is affordable if the financial costs of equipment and operation are low	$C_{levelized-heat}$	[$CAD/kWh]

Ease of operation is indicated by combined labor and transport costs. In the model, some technologies require transportation to obtain the fuel which is reflected by the transport costs. *Climate-friendly* relates to net emissions impact of CO_2. *Waste recycling* indicates how much of the amount of waste that is produced in the AG, the heating system can use at heating input. *Off-grid* is considered a social indicator related to self-sufficiency and independence, represented as the share of renewable energy within the heating system. For the final indicator *Affordable*, the levelized cost of heat was selected as a metric which is a ratio of NPC per kWh.

The metrics allow for evaluating the performance of the KPIs for each renewable heating alternative. GSHP was split into two distinct categories because their emissions are dependent on the type of electricity that is supplied (Section 7.2.3). GSHP_A assumes electricity input from the Alberta mix, and GSHP_R assumes electricity provision according to the Quebec mix which is mainly supplied by hydropower, representing renewable energy in this case. The hybrid-2GB alternative also includes GSHP as a technology and was also split into hybrid-2GB_A and hybrid-2GB_R for the assessment. The performance values are illustrated in Table 8.2.

Table 8.2: Performance values of KPI metrics

Metric	Ng	Bm	Bg	GpA	GpR	H1	H2A	H2R	Unit
n_{tech}	1	1	1	1	1	1	2	2	[amount]
C_{maint}	259	911	1502	410	410	940	700	700	[$CAD]
C_{l+t}	0	2239	7448	0	0	4469	1343	1343	[$CAD]
CO_2	26	1	2	16	0	12	8	1	[t CO_2]
$\dot{V}_{waste}$	0	792	1517	0	0	1517	792	792	[kg]
Share	0	100	100	0	100	60	60	100	[%]
C_{heat}	0.27	0.53	0.8	068	0.68	0.61	0.61	0.55	[$CAD/kWh]

Ng: Natural gas; *Bm:* Biomass; *Bg:* Biogas; *GpA:* GSHP_A; *GpR:* GSHP_R; *H1:* Hybrid-1BN; *H2A:* Hybrid-2GB_A; *H2R:* Hybrid-2GB_R.

To make the KPIs comparable based on the metrics, the values are normalized using Min-Max normalization. The normalization translates performance values onto a scale from 0 to 1, where 0 represents the minimum value and 1 the maximum value. Depending on if a higher value expresses a better performance or a worse, the formula for Normalized(X_{ij}) or Inverted (X_{ij}) was applied which is shown below:

$$\text{Normalized}(x_{ij}) = \frac{x_{ij} - \min_j(x_{ij})}{\max_j(x_{ij}) - \min_j(x_{ij})}, \quad \text{Inverted}(x_{ij}) = \frac{\max_j(x_{ij}) - x_{ij}}{\max_j(x_{ij}) - \min_j(x_{ij})}$$

The BWM steps to obtain optimal weights for the KPIs was carried out by the FMFN project developer with a consistency ratio of 0.083 which is well below the associated threshold of 0.3337 and thereby fully acceptable. The obtained weights of the KPIs and the corresponding normalized performance scores of the heating technologies are displayed in Table 8.3.

Table 8.3: Performance matrix

KPI	Weight	Ng	Bm	Bg	GpA	GpR	H1	H2A	H2R
Affordable	0.317	1	0.52	0	0.24	0.24	0.36	0.47	0.47
Off-grid	0.178	0	1	1	0	1	0.6	0.40	1
Reliable	0.178	0.61	0.29	0	0.53	0.53	0.88	1	1
Waste recycling	0.178	0	0.52	1	0	0	1	0.52	0.52
Climate-friendly	0.119	0	0.98	0.92	0.37	1	0.55	0.68	0.99
Easy to operate	0.031	1	0.7	0	1	1	0.4	0.82	0.82

The KPI *Affordable* was considered the most important one, and *Easy to operate* the least important indicator. *Off-grid*, *Reliable*, and *Waste recycling* were regarded as equally important by the project developer followed by *Climate-friendly*. The normalized performance scores show values between 0 and 1 in which 0 = the worst performance and 1 = the best.

The weighted sum model is used to calculate the total score for each technology in which each performance value is multiplied by the weight of matching KPI and summed up. This provides a final score for each heating alternative based on the obtained weights of the KPIs which presents a ranking.

8.1.3. Results

Table 8.4 presents the ranking of the heating technologies based on the prioritization of KPIs from the BWM process by the project developer.

Table 8.4: Final ranking of heating technologies based on KPI weights

Rank	Total score	Heating system
1	0.741	Hybrid-2: GSHP (Renewable electricity) & Biomass boiler
2	0.633	Hybrid-1: Biogas (with biodigester) & Natural gas boiler
3	0.625	Biomass boiler
4	0.597	Hybrid-2: GSHP (Alberta electricity mix) & Biomass boiler
5	0.497	Ground Source Heat Pump (Renewable electricity)
6	0.465	Biogas with biodigester
7	0.456	Natural gas boiler
8	0.456	Ground Source Heat Pump (Alberta electricity mix)

9

Discussion

"Discussion is an exchange of knowledge; an argument an exchange of ignorance."
(Robert Quillen)

9.1. Indigenous leadership in global sustainability

To return to and develop the discussion initiated in the introduction, this section will further investigate Indigenous-led sustainability. It is important to understand the underlying causes of the problems that are dealt with. Historically, IPLC experienced colonial oppression by settlers who structured their economies around exploiting people such as IPLC and resources to directly benefit them. A growth-driven system that undermined traditional values was forced onto IPLC which caused the majority of problems that remain today. Resource extraction like oil sands mining continues to result in vast disturbance of traditional land, disrupting traditional ways of harvesting. Concurrently, the same economic system caused climate change, with severe global impacts and further challenges for IPLC (Note that the term "economic system" is a great generalization and simplification for many factors). A global strategy to fix climate change that has been identified by Fischer et al. [19] among others, is sustainable land stewardship which has been carried out by IPLC for millennia. This whole context in which this project takes place seems highly paradoxical, as visualized in Figure 9.1.

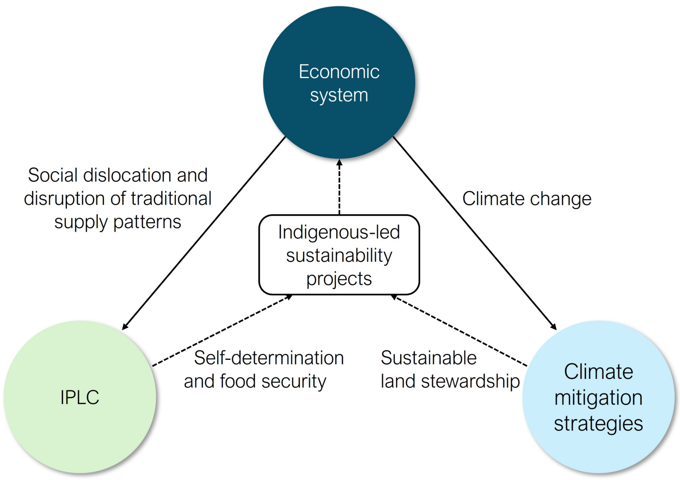

Figure 9.1: Paradox of Indigenous-led sustainability

The value identification in Chapter 4 found that Indigenous values are relational while Western values tend to be instrumental. Traditional values and TEK are about relationships regarding reciprocity, respect, responsibility, and relevance for the sake of giving without asking for something in return [47]. Acknowledging Indigenous values now in global sustainability by advocating for sustainable land stewardship is problematic and again, follows the rationale of Western instrumental ways of thinking despite the good intentions. Now that it can be helpful to fix a problem, it is promoted but those values were undermined all along when climate change was not regarded as a threat. Indigenous-led sustainability projects should be carried out for reasons of reconciliation by providing ways of self-determination without burdening IPLC with responsibilities to fix climate change. Sustainability will be an outcome because Indigenous values are inherently sustainable. The paradox related to such projects is that they have to take place within the economic system, which is the major barrier to success. I'm assessing the economic feasibility of renewable heating alternatives in this study because without proving economic sustainability, projects won't receive funding or cannot be implemented. An underlying problem is that economic valuation commonly doesn't account for environmental and social costs or benefits if they cannot be translated into monetary terms. The example of oil sands mining activities in the Athabasca region demonstrates very well that short-term profits are prioritized without accounting for environmental and social costs. The challenge also relates to this study in which only carbon offsets were included in the TEA as they are monetized. Other values were integrated into the previous and following parts.

However, the synergies between sustainable land stewardship as a mitigation strategy and traditional ecological knowledge can still be beneficial for IPLC. It can act as a means to receive funding for projects like the FMFN greenhouse projects to shape their own future, regain independence, and revitalize traditional ways. There are opportunities to monetize such as carbon offsets, which can improve community well-being. It could follow a similar rationale as the participation in the oil sands mining industry which creates economic security which is used for the community. The difference is that those projects are sustainable and have less value tensions while conserving the land. The identified project values for the AG project confirm the prioritization of collective well-being and sustainable land management. Skinner et al. [77] confirms the finding that greenhouse projects in northern Canada are a possible way to create local food production with social and cultural benefits.

9.2. Reflection on the research framework

9.2.1. Challenges of integrating values

The research study explored ways of integrating TEK and values into engineering principles from different angles. A choice was made to apply a value sensitive design approach for the broadest part of the study. The initial process of identifying community values was guiding for the following analysis but showed difficulties. Values are intangible and subjective and can be interpreted with huge variations depending on the observer. VSD does not provide a clear guideline on how to precisely apply methods but can be seen as an open-minded and flexible paradigm that provides a toolbox to choose appropriate methods for a certain context. The three types of values were useful for the analysis but also seem vague and demonstrate varying definitions across studies. The inductive coding facilitated a more specific categorization of relevant values for the study but exhibited a high potential for bias. Mitigation strategies included the use of AI but also the iteratively applied nature of all analyses which cannot be highlighted well enough by presenting the results. The question remains how it can be assured that my own interpretation and categorization of articulated values was not biased and that potential value tensions did apply? The value tensions in VSD reflect the degree of functioning and collaboration between stakeholders within a project. When diverging interests or moral values are present, it will impact cooperation and project outcomes. Throughout the thesis, trust was built among all project stakeholders, including LANDMARC researchers, the project developer, and myself, and it continued to grow on all sides. Meetings became more frequent in which results were presented, discussed, and progress was aligned. The articulated values from the project developer were not expressed in one meeting but accumulated over time in dynamic conversations which were shaped and also developed in certain directions. Only the end result can be shown in this study but through direct interaction with people, there is some feedback that cannot be read from lines of paper. Another aspect to be mentioned is the long-lasting relationship between the case leaders of LANDMARC and the project developer who guided me through the process and consistently supported the collaboration. The assurance of missing value tensions is validated by those interactions and also reflected in initial results such as the proposed greenhouse design which was received with enthusiasm by the project developer. To me, it is clear that there were no value tensions within the working group of the project and with the project developer.

However, when it comes to stakeholder values, the situation changes. I didn't have any direct contact with other community members and a large part of the analysis had to be based on secondary sources and assumptions. I cannot be sure how well or badly values are aligned also because the stakeholders are a large group of individuals that exhibit different values. This was possibly the greatest limitation and challenge within the study because initially, it was clear that the community members are the most important stakeholders that are affected by the problems and solutions at stake. The study intended to mobilize greater transdisciplinary and participatory approaches. The community survey mentioned in Section 8.1.2 was an idea of a participatory valuation process using BWM that would have demonstrated greater relevance. A dominant challenge was to simplify the BWM process in a survey to be applicable to this context. BWM displays huge advantages in reducing complexity while providing reliable results with inherent mechanisms to reduce human biases, and in confirming consistency in responses [67, 70]. However, BWM is intended for decision-makers and experts within the field of application. Even though the process is relatively simple and easy to conduct when explained, achieving the same result in a self-explanatory survey was difficult. With the project developer, the process was immediately carried out with perfect consistency in about 5 minutes. But it has to be noted that the project developer is an expert in this project with a well-established understanding of not necessarily all detailed technical processes but innovative solutions, TEK, and seeing the bigger picture. At some stage, a decision was made to apply a simpler method such as SMARTER for criteria weighting before the survey was dropped for this study. Even so, using a simpler method comes at the cost of accuracy in the responses. A vision worth exploring might be to apply the rationale of participatory value evaluation (PVE) which is an innovative evaluation framework specifically designed to assess the social welfare effects of public policies by capturing individuals' preferences regarding the most suitable public project alternatives [55]. PVE positions individuals in a decision-maker's seat to evaluate policy options in an online environment where no previous knowledge is required. The survey for the greenhouse project attempted to frame the valuation of KPIs for the renewable heating system in a similar way by asking from a perspective of what would you choose if you were the project leader and had to decide. This procedure can strengthen community efforts since it demands ownership and responsibility in a playful way without fearing any consequences for the decisions. Looking at the identified community values of reciprocity, responsibility, care, and others, this would seem achievable in a positive manner for the community and the context. The survey was only postponed and might reintroduce some of the ideas when implemented.

9.2.2. Synergies between TEK and applied approaches

The greenhouse design was driven by value-sensitive engineering principles that integrated stakeholder views and attempted to incorporate Traditional Ecological Knowledge early on. Throughout the research process, synergies could be recognized between TEK and systems thinking. Systems thinking as part of systems engineering, is a holistic approach to problem-solving that analyzes relationships between people, the environment, and other systems to understand how they influence the functioning of the system as a whole. TEK is also relational and fundamentally about reciprocity which became evident in the AG design process. The exploration of a circular design was about relationships of ecological processes such as the aquaponic system that balances a nutrient cycle in a symbiotic way for fish and plants. The analysis focused on detecting circular resource flows and re-use potential by looking at what other systems require. It could translate in a broader sense to reciprocal relationships between systems. It was strongly present for any natural process and highlighted in the preferred options of the stakeholders such as the biodigester solution that functions on the principle of anaerobic digestion. Various types of community waste can be collected to feed the digester, raising the question of which materials are most suitable for optimal biogas production. A biodigester produces fertilizer that can be used for replenishing the soil (or land) to grow plants again. The resources needed for the biomass boiler are also found in nature, particularly in forests that could be linked to the community. The main difference in the relationships between TEK and systems engineering is that Indigenous reciprocity is about the sake of the relationship itself and giving something back. In systems engineering, it's about understanding the interactions to find a better solution that has a means to an end.

Systems thinking facilitated ways of addressing multiple issues in this project like integrating values within the design and also through the multi-criteria analysis. BWM has proven to be well suited as a tool to integrate non-monetary criteria such as values because the ranking process can be adjusted to its own defined criteria and contexts. MCDM and MCDA demonstrated strong synergies with VSD principles. The initial steps are notably similar or can be similar if MCDM is applied in a context where human values and justice are emphasized. Both frameworks show synergetic potential with TEK as well as Indigenous methods and have proven to be flexible in addressing suitable parts within the research framework. BWM also demonstrated high potential despite the mentioned difficulties in the previous section. The entire potential of integration with participatory processes could not be explored yet but the current application can certainly be seen as a full success. BWM played a crucial role in this study by integrating various essential components and generating more meaningful results. TEK and systems engineering methods could demonstrate stronger synergies and potential for integration if TEK was more acknowledged and accepted in Western science. Relationships within the research process and between participants also contributed to strengthening the technical viability of the greenhouse. Meetings with LANDMARC partners and the project developer demonstrated a clear synergy between the technical and social domains, fostered innovation, and improved the design.

9.3. Viability of renewable thermal energy alternatives

The first renewable heating technology assessed was passive solar energy utilization which is incorporated within the building design. The model accounts for the use of night curtains, immediate solar gains through solar radiation of the South-facing glazing, and thermal energy storage capabilities of the north wall (bricks) and the fish tank (water). Piché et al. [62] concluded that passive solar utilization achieves to maintain minimum inside temperatures of 10°C in northern Canadian greenhouses, without any additional heating. Imafidon, Ting, and Carriveau [40] modeled a Chinese-style greenhouse (a popular type of a passive solar greenhouse) and validates greater economic viability compared to traditional greenhouses with heat savings up to 55 % which is even more than the 42-47 % that the model in this study estimates. The use of a passive solar design is indispensable in this climate context and by far the most cost-effective renewable heating technology as it is incorporated into the building architecture. Passive solar designs are flexible and can be achieved through different architectural ways which makes them adaptable to needs and also costs. The calculations of the model were based on a suggested Aquaponic Greenhouse design which is undergoing a patenting process that verifies also the social acceptance of it. Another cost-effective way to reduce the thermal energy demand is by crop variation. A variety of crops makes the system more reliable in general, and adapting crops to the season and temperature requirements can lower heating requirements as long as it doesn't affect the aquaculture system.

Another initially considered solar technology is solar thermal collectors, which proved less viable for northern Alberta conditions. The fundamental challenge is that solar irradiance is highest in summer, yet the greenhouse requires most heat in winter. Although solar collectors may still be used as a minor contributor such as pre-heating water, they do not constitute a reliable renewable option. On the contrary, solar panels (solar photovoltaic cells) for collecting electrical energy could be highly feasible since electricity is also needed in summer due to Alberta's high solar potential.

GSHP emerged as having high efficiency but is linked to considerable up-front costs in terms of both capital investment and installation complexity. GSHP are more justifiable for larger greenhouse sizes when the system benefits from economies of scale or subsidies. The only input requirement of GSHP is electricity which can alter carbon emissions heavily depending on type of electricity supply. The model compared a fossil-fuel-powered Alberta electricity mix to the one of Quebec which is nearly fully renewable-based (hydropower). Obtaining renewable electrical energy in Alberta most likely increases costs and the electricity mix also determines carbon credit approval. Using renewable energy sources decreases net emissions dramatically. One major advantage of GSHP is its cooling capabilities to avoid critical maximum temperatures in summer. The heating potential through the passive solar design remains uncertain. It is unclear if simple ventilation mechanisms can keep the greenhouse at moderate temperatures but the design provides good prerequisites for increased airflow removal of hot air through the ridge. Installation costs of GSHP can be reduced by synchronizing it with the greenhouse building construction. Excavation costs can be shared and coordinated with the hydronic radiant heating system.

The size of the loop system equates to the power output of the GSHP and therefore needs to be determined before building construction. Scaling the system afterward will add significant costs. GSHP demonstrates high sensitivity to electricity rates which could have the same positive impact. Any kind of incentives regarding Alberta's electricity prices could make it much more viable.

Biodigesters are highly sustainable and allow for circular solutions that recycle waste products to convert them into energy. For the project, aquaponic waste and plant produce residues can be recycled into the digester. However, the amount of produced AG waste accounts for 1.7 % of the average required input. For a mid greenhouse size to meet peak demand in January, 712 l of animal manure and double the amount of water have to be fed into the digester. Obtaining additional community resources or animal manure from a farm is essential. However, the model results suggest that transport and labor costs related to the pick-up and collection of waste can quickly spike in costs if the location is too far away. Locally available resources should be assessed. A rainwater collection system could also be beneficial for digester input requirements but also for irrigation. Another challenge is the impact of temperatures on the performance of the anaerobic digestion. The biogas yields are greater with higher temperatures and will decline if it gets too cold. This requires an inside location of the digester which can generate an unpleasant smell. The back-storage of the proposed AG design could be a feasible option as it is heated by the north wall but separate from the inside of the greenhouse and enables a close connection distance. A biogas system could be viable if the produced gas in summer can be stored for the heating demand in winter, but such storage dimensions would certainly require higher investment costs. Another issue of a digester-biogas solution is the reduced reliability because of secondary conversion, which makes it prone to disruptions. The high costs of a biodigester-biogas solution emerge from additional burner and biogas boiler requirements and the large input volumes in operation. For the greenhouse, a pure biodigester option could still be beneficial for waste recycling, fertilizer production, and for instance using the gas for a simple cooking stove in a kitchen area within the building.

By contrast, a biomass boiler relies on wood residues or similar feedstock, which is often easier to manage than a biodigester. Blair and Mabee [10] evaluated bioenergy systems for a forest-based community in Ontario and concluded that biomass boilers and CHP technologies are competitive with natural gas heating systems. The TEA results also identify biomass boilers as the most economically feasible option out of all renewable heating technologies assessed, presenting an NPV value relatively close to that of a natural gas boiler. Transport distance is also a sensitive parameter but not as sensitive as in the biodigester option. The biomass boiler type applied in the model is an Agropellet boiler which can take in a variety of less processed solid waste with lower calorific value. The model calculates with a value of 4.5 kWh/kg which relates to the value of plant stems as a waste recycling option. Plant residues from the greenhouse produce would cover 2.3 % of the total demand. Biomass boilers can reduce greenhouse gas emissions significantly and are highly suitable for forest-based communities that have locally available resources.

Because each technology alone has notable strengths and drawbacks, hybrid systems can balance complementary benefits, thus ranking the highest according to the KPI weights assigned by the project developer. Table 9.1 presents the final ranking of the multi-criteria scoring to the average NPV ranking of technologies. The multi-criteria scoring accounted for electricity input of Albertan electricity (AE) and renewable electricity (RE) for GSHP and the second hybrid option which explains the two additional systems.

The multi-criteria score shows an inherently different ranking than the NPV scores. The only similarities are low scores of GSHP and standalone biodigester. The difference is surprising since *affordable* was the most important chosen indicator which is reflected in the levelized NPC of heat within the multi-criteria ranking, and yet natural gas only comes into second last place in the total score. It shows nicely how a prioritization of different indicators can drastically change if other values than economics are incorporated. In this application, the importance of being *off-grid*, *reliable*, and to *recycle waste* displaced natural gas as a viable solution despite its economic advantage. Particularly, the hybrid options though perform very well on those criteria.

Table 9.1: Comparison of NPV and multi-criteria scoring

Rank	NPV score	Heating system	Rank	Multi-criteria score	Heating system
1	0.15	Natural gas boiler	1	0.741	Hybrid-2GB (RE)
2	0.12	Biomass boiler	2	0.633	Hybrid-1BN
3	0.10	Hybrid-2GB	3	0.625	Biomass boiler
4	0.08	Hybrid-1BN	4	0.597	Hybrid-2GB (AE)
5	0.06	Biodigester (biogas)	5	0.497	GSHP (RE)
6	-0.03	GSHP	6	0.465	Biodigester
			7	0.456	Natural gas
			8	0.456	GSHP (AE)

Hybrid options are more reliable because they have backup technologies in case one fails. Only natural gas showed higher reliability among single technologies. There is another reason why the hybrids perform so well. Renewable heating technologies can be classified into two types: (1) Technologies to cover baseline demand, and (2) technologies for peak demand. GSHP and biodigester fall under base heating technologies because they can cover a constant and steady demand but are slow at adapting to fluctuations. Natural gas and biomass boilers, on the contrary, can immediately step in and heat up fast. The hybrids exactly merge those opposing characteristics. Combining GSHP with biomass boilers takes away the peak, for which the model was sizing the technologies, illustrated in Figure 9.2. The same holds for the biodigester which only has to cover the demand below the baseline while the agile natural gas boiler can cover the parts above the base. In terms of economics that's very beneficial because the high-investment technologies exhibit large cost reductions and low operational costs are exploited for GSHP and biodigester. The use of renewable electricity for GSHP is preferred in the ranking, but even the fossil-fuel-supplied GSHP ranks in 4th place because it's a smaller system in the hybrid constellation. An advantage of GSHP is the capability to cover the cooling demand in summer that is within the load capacity.

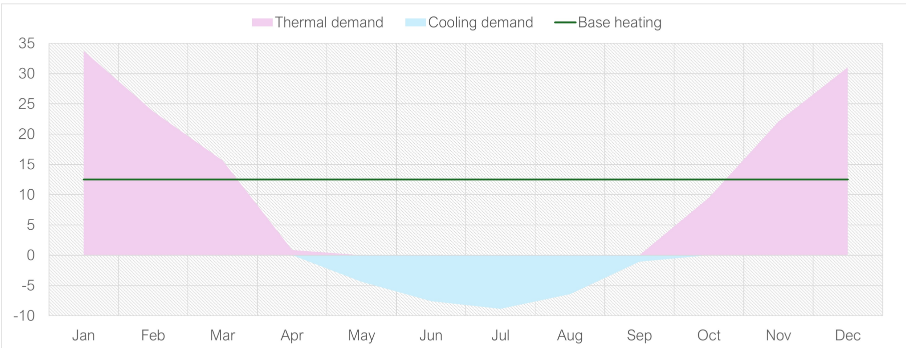

Figure 9.2: Base heating and peak demand

All the highly ranked heating systems on the multi-criteria score, present positive and reasonable NPV values since *affordable* was ranked the most important indicator. The first hybrid option was quite accurately predicted by the AI-generated narrative, but it was based on the value source analysis which gave implications for that. In summary, the hybrid options demonstrate great opportunities to adjust them in the right way to fit the context and benefit FMFN on different levels. They have to be implemented in a strategically thoughtful way to embrace all advantages and reduce risks. Further integration with a rainwater collection system, local sourcing, and alignment with available subsidies or other incentives to reduce electricity rates can have a profound impact on profitability and success.

10
Conclusion

“In some Native languages the term for plants translates to ’those who take care of us’.”
(Robin Wall Kimmerer)

10.1. Key insights from the study

10.1.1. Summary of findings

This research explored the technical, economic, social, and environmental feasibility of meeting the thermal demand of a year-round, community-scale Aquaponic Greenhouse in Fort McKay. Grounded in both systems engineering and value-sensitive design, it also took an exploratory approach to integrating TEK into engineering. The following key findings can be presented:

The narratives accurately captured project-, designer-, and stakeholder values linked to the AG design and renewable heating technologies. Accordingly, the Aquaponic Greenhouse embodies sustainable development that integrates TEK with modern technology to promote food sovereignty, environmental stewardship, and cultural resilience. Designed as a food production system and a community hub, the AG facilitates knowledge exchange, strengthens the local food system, and fosters self-determination. Its implementation underscores the importance of aligning technical feasibility with community values, ensuring that innovations support long-term sustainability while remaining accessible and practical. This balance is particularly evident in the selection of renewable heating systems, where stakeholder engagement plays a crucial role in determining the most suitable technology for the subarctic climate. Community statements reveal a preference for a hybrid heating system that combines a biodigester, passive solar enhancements, and a backup energy source, ensuring reliability, affordability, and minimal labor intensity. The project developer’s vision of showcasing climate leadership aligns with local priorities, including waste recycling, affordability, technical performance, and resource adaptability. The resulting system improves self-sufficiency, cultural preservation, and environmental responsibility. Ultimately, the FMFN Aquaponic Greenhouse stands for Indigenous resilience and innovation, demonstrating how localized food and energy systems can thrive even in the face of challenging environmental and socio-economic conditions. Passive solar utilization substantially reduces the thermal demand and serves as the main guiding principle for the design process. Across all greenhouse sizes, passive solar elements reduce annual heating requirements by up to 47%, confirming that low-cost design solutions can yield significant economic and energy benefits. The proposed greenhouse design showcases an extended symmetrical steep angled opposing roof in which a brick wall runs alongside the center that acts as a huge thermal battery. The growing beds are arranged according to the sun angle with a storage area on the backside for machinery and even an integrated biodigester solution. Boiler systems of the heating technologies can also be placed on the separated backside.

Several renewable energy alternatives show potential for sustainably meeting the thermal demands of an Indigenous-led community-scale Aquaponic Greenhouse in the Alberta boreal forest. Passive solar design emerges as the foundational, most cost-effective technology, integrated into the architecture to capture solar gains and store heat in the thermal mass of the north wall and fish tank. Solar thermal collectors proved less suitable in this subarctic context, while GSHP offers high efficiency but demonstrates significant up-front costs and depends on electricity, thus highlighting the importance of sourcing low-carbon power for carbon credit eligibility. Biodigesters provide a circular option by recycling organic waste into heat and fertilizer, yet sufficient feedstock and labor requirements can limit feasibility. Biomass boilers using locally available wood residues present a competitive, lower-emission alternative to natural gas in terms of cost-effectiveness. Ultimately, hybrid systems that combine baseline technologies like GSHP or biodigester with flexible peak-load options such as biomass or natural gas balance reliability, affordability, and environmental goals. Such hybrids are especially well-suited for community contexts where off-grid resilience, waste recycling, and reduced carbon footprints are prioritized, making them the most viable pathway to sustainably heating an Aquaponic Greenhouse in northern Alberta.

An Indigenous-led sustainability initiative, such as the FMFN greenhouse project, paradoxically attempts to solve the challenges brought upon the community through the economic system which has historically undermined Indigenous Peoples and contributed to climate change but now demands economic feasibility for funding and implementation. Rooted in traditional ecological knowledge and values like reciprocity, respect, and responsibility, Indigenous approaches to land stewardship offer long-lasting sustainable practices, but Western frameworks typically require market-driven justifications. Despite this tension, engaging in projects like the AG can provide pathways to self-determination, economic security, and the revitalization of traditional values. The research highlights the importance of recognizing the inherent sustainability of Indigenous values, even if they are evaluated through predominantly Western economic metrics. Ultimately, the study underscores that integrating relational values into land management can simultaneously address environmental challenges and strengthen community well-being. Indigenous-led efforts are viable and beneficial for both reconciliation and sustainability on all pillars.

The research demonstrates that integrating Traditional Ecological Knowledge and community values into engineering processes can strengthen both the social and technical dimensions of sustainability projects. Specifically, a VSD approach proved flexible for identifying and structuring core community values, though it highlighted the subjective nature of values and the risk of researcher bias. Iterative interactions between researchers, the project developer, and other collaborators helped to mitigate potential bias by providing regular feedback and clarifications. However, the lack of direct community engagement posed a major limitation in ensuring full alignment with stakeholder values. Despite these challenges, the study found a pronounced synergy between TEK and systems thinking which emphasize relational processes and holistic perspectives. TEKs inherent focus on reciprocity resonates with systems thinking analysis of feedback loops and resource flows. A link that is also evident in design elements of biodigesters or biomass boilers that recycle waste into usable energy or fertilizer. However, a key difference remains that systems thinking mostly treats relationships as a means to an end while TEK upholds reciprocity for its own sake.

Moreover, MCDM methods such as BWM proved valuable for incorporating non-monetary criteria into design choices. Although challenges were present in simplifying BWM for broader community participation, the method successfully integrated multiple project criteria and enabled more meaningful and context-specific comparisons of renewable heating technologies. By combining VSD, TEK, and systems engineering methods, the research demonstrated that engineering projects can be enriched when they move beyond purely technical or economic metrics and embrace different knowledge systems. Overall, this study demonstrates that an Indigenous-led AG can be both socio-culturally relevant and technically robust, provided that design and engineering decisions integrate traditional values in a meaningful way and consider resource constraints.

10.1.2. Answer to the research question

In this section, a direct response to the guiding research question ”**What are the potential renewable energy alternatives to sustainably meet the thermal demand of an Indigenous-led community-scale Aquaponic Greenhouse in the Alberta boreal forest?**” is provided.

Sustainability is commonly framed around the three pillars of environmental-, social-, and economic sustainability. The chosen KPIs reflected those domains with an additional technical indicator. To sustainably meet the thermal demand within the RQ can therefore be understood as referring to all four aspects with regard to the renewable heating supply of the Aquaponic Greenhouse. The multi-criteria ranking provided a score based on the KPIs and expressed prioritization by the project developer using BWM for the FMFN context. According to that scoring, the four highest-ranking technologies are: (1) a hybrid option between a fully renewable-powered GSHP and a biomass boiler, (2) another hybrid option between a biodigester solution that uses a combined boiler for natural gas and biogas, (3) a standalone biomass boiler, and finally the same hybrid option ranking 1st but with electricity provision from the grid for the GSHP. The ranking provides a general tendency of favored technologies for the FMFN context but should not be seen as a static result for various reasons. The aggregation with the weighted sum model was carried out against the condition of clearly showing dependencies across indicators. This can result in shifting ranking scores that are not fully accurate and the calculations of the performance scores did not account for a changing environment. There are more factors to be considered from the TEA results. What the multi-criteria scoring accurately determined is the preference for hybrid solutions. The TEA showed that standalone renewable heating technologies are unfeasible due to high risks of reliability issues that can potentially disrupt the entire AG process resulting in major losses on all levels. Another validation of the multi-criteria scoring relates to the strong synergetic interplay of hybrid solutions that are composed of a base load- and a peak load technology which is the case for both hybrids assessed. However, what is not reflected in the scoring is the significant impact on NPV and possibly other indicators as soon as certain parameters change. Considering the early stage of the assessment and high uncertainties, it is very likely that various parameters will be altered throughout further and more detailed analysis when project implementation comes closer. The sensitivity analysis showed how drastically the NPV can be altered when the ”right” or ”wrong” knobs are turned. Another vital factor to include is community acceptance. A technology can showcase the best performance on all indicators but can still be socially and culturally rejected by community members. Finally, scalability and gradual development of technology deployment are additional factors that were not considered in any analysis. The model assumes a fully deployed and integrated system whereas in reality, the option remains to start with a pilot project to test certain conditions and gradually build a system.

The RQ cannot be answered by defining certain technologies as the best solution. Within CoSEM, we were taught to identify trade-offs rather than optimal solutions. Moreover, one could even say context-specific trade-offs. Theoretically, it could be the case that another forest-based community in Alberta solely values economic sustainability for which a natural gas boiler would sustainably meet the thermal demand although it is not a renewable heating technology on which this study sets a focus. Assuming that other Indigenous communities in the Alberta Boreal Forest Region share similar values as FMFN, the following answer can be given:

Generally, biodigester and biomass boilers show high potential as renewable heating technologies in this context as they fulfill important boundary conditions. Both technologies require inputs that are found in nature and demonstrate closer cultural familiarity. The reuse potential is high and byproducts from other processes can be used to fuel the systems. However, both technologies become economically significantly more feasible when resources can be sourced in close proximity which is likely in forest-based communities with surrounding agricultural activities in place. A biodigester consumes large amounts of water which impacts overall profitability profoundly if free water can be obtained. Accounting for reliability and scalability hybrid options out of the two technologies are suggested that start off with a grid-connected backup source. It is not necessarily more sustainable to immediately implement a whole fully renewable system because of uncertainties and also high upfront costs. A grid connection can avoid huge problems in early implementation phases and ensures that disruptions are minimized. Scalability is an important consideration that is not given to all technologies. GSHPs for instance cannot be easily scaled once they are implemented because of elaborate ground loop installations linked to high costs. Scaling this technology would basically mean digging out an entire trench to extend the loops but then a new heat pump is also needed as the loops are adjusted to the power of the GSHP.

From this research, under the assumption that the mentioned conditions are met, potential renewable heating alternatives to sustainably meet the thermal demand of an Indigenous-led community-scale Aquaponic Greenhouse in the Alberta boreal forest are first of all passive solar utilization within the building design with a combined use of night curtains and thermal storage elements. In addition to that, a hybrid solution with biodigester (biogas) for base loads and grid-connected natural gas provision for peak demand is recommended if the biodigester solution can be scaled and improved by different measures to move away from fossil-powered energy over time. The second potential renewable heating alternative is the combination of GSHP as a base and biomass boilers for peaks. This hybrid option demonstrates advantages in cooling capabilities for summer and improved scalability opportunities over natural gas. The heat pump can initially be powered from grid electricity but replaced over time by partial or full renewable electricity from solar PV which is conceivable with Alberta's high solar potential. The first hybrid option is more cost-effective, scalable, and flexible but environmentally more harmful. The second option requires higher upfront costs but can be seen as cleaner and demonstrates greater opportunities of becoming completely off-grid in the future but can only be scaled on the biomass boiler side. Standalone technologies that can be eligible in certain contexts are biomass boiler systems for smaller greenhouse sizes in which a constant resource flow is secured, or GSHP for exceptionally large greenhouses when high capital investments can be provided easily. In principle, however, I would advise against it without any backup for an Aquaponic Greenhouse where the reliability of the heating system is non-negotiable.

10.2. Recommendations for the FMFN AG project

A recommendation is forwarded on the aquaponic greenhouse project in FMFN based on the findings of this study. The two hybrid options include biodigester and biomass boilers which align well with the values and the context of local resources that can be used to supply the systems. As a first step, it is therefore recommended to assess the availability of potential resources, first within the community, and also in close proximity. For biomass boilers, any solid biomass that demonstrates a calorific value of around 4.5 kWh / kg or more should be considered. Any accessibility to forest-based resources can be helpful, such as residues from timber and logging companies that cannot be sold or accumulated during processes. To maximize biogas yields, important factors that determine the performance of the anaerobic digestion process are crude fiber, ash, nitrogen, crude protein, fat, carbohydrates, and dry matter [87]. A comparison of waste products, in terms of methane gas production, conducted in a techno-economic analysis by Al-Wahaibi et al. [87] is shown in Figure 10.1.

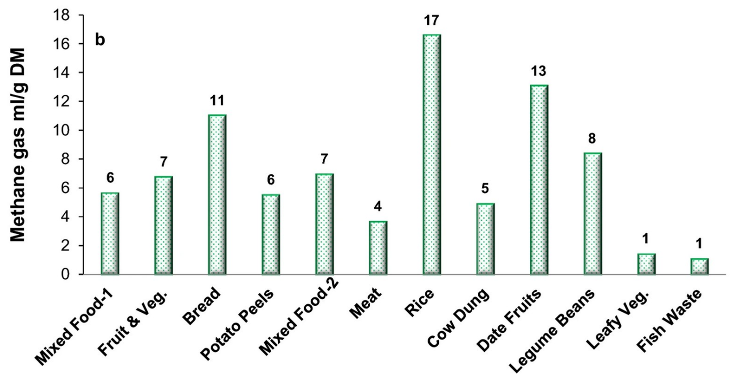

Figure 10.1: Methane gas production over the waste samples for a 24 h incubation period [87]

Rice, date fruits, bread, and legume beans show high biogas production, but the exact mixture should be discussed with the supplier.

The holistic integrative research analysis provided important findings to narrow down the problem but did not account for a detailed evaluation of specific areas of the topic. For the greenhouse project, it is generally recommended to start developing the implementation process step-by-step, because of uncertainties that can be linked to high costs. It is suggested to first evaluate CHP technologies (with biomass boilers) and the integration of renewable energy with the electrical demand. A detailed design of the greenhouse should be finalized first since the entire energy requirement is dependent on it. For that, assumed values in the established model can be replaced with exact identified costs and components through suppliers to increase accuracy. The model can be further extended based on the requirements and needs of the project. The results can provide a good understanding of the economics and through the model, different scenarios can be simulated. It is advised to establish a purely soil-based scenario and compare it to the Aquaponic Greenhouse. The soil-based system proved to achieve high yields with significantly lower costs. The reasoning behind it is to employ a testing strategy for implementation that allows for scaling.

The starting point could be a greenhouse that incorporates soil-based growing beds with hydroponic systems to test growing conditions before connecting the RAS to it. The layout can account for the aquaponics components that are first filled with soil-based growing beds which are easy and inexpensive to remove. Initially, leaving out the aquaponic system makes the heating system more flexible to test with a reduced thermal demand. Heating will consume the most energy in the greenhouse so its possible to test renewable electrical energy integration like solar PV in this setting [40]. The implementation of a scalable pilot project greenhouse is recommended. A greenhouse size needs to be selected so that the model can help as it can simulate various sizes. It is proposed to choose the biggest greenhouse size possible based on available financial resources to achieve the highest passive solar effect that will reduce costs for any following considerations. For the heating system, it is advised to initiate a grid backup to ensure reliability during the testing phase. The grid backup can be chosen based on the two hybrid options from the analysis: (1) a natural gas boiler with a biodigester, and (2) a GSHP system with a grid-connected electrical supply and a biomass boiler. This decision is irreversible because GSHP has to be installed before or alongside the construction of the building. This pilot setup ensures reliability while being flexible to test, the the hydroponic part of the aquaponic system, resource flow and operation of either biodigester or biomass boiler depending on resource availability, and the link to renewable energy for electrical components. With the biomass boiler, CHP technologies can be tested to supply the heat pump with electricity. Solar PV also holds great potential regarding Alberta's high solar radiation potential, which could also be used to drive the heat pump by renewables. For the biodigester solution, storage potential could be tested and developed to store larger amounts during summer that can be used for heating in winter. The biogas production could be optimized and synchronized with resource flows. Once the energy demand side is fully operational, the aquaculture system can be implemented which should also be tested beforehand with a small experimental setup.

Another recommendation for the project is to generate additional income. A consideration could be to sell medicinal plants emphasizing that they are grown in an Indigenous-led sustainability project that contributes to climate change mitigation and carbon emissions reduction. Of course, this must be aligned with participating in the offset market in alignment with the renewable energy project. This could align well with reciprocal values and benefit both the community and customers that prefer natural-sourced medicinal products, crafted from traditional ecological knowledge.

10.3. Contributions and CoSEM relevance

The research study contributed to academia in multiple ways. Various novel topics were explored and discovered. The general attempt to integrate TEK into conventional engineering methods and apply a combination of VSD and systems engineering principles within the study generated results or maybe learnings which are also important contributions. Challenges within the research process were made transparent just as successful outcomes. Synergies between TEK, VSD, and MCDM could be identified which can be further explored in other studies. The integration of values into engineering was successfully carried out and might be applicable to other studies or projects. The study also revealed gaps and issues that need to be addressed and further explored. The idea of a participatory BWM community survey process was initiated but had to be canceled. The exploratory and curious nature of the study opened up multiple areas in need of development. Another important contribution was to showcase Traditional Ecological Knowledge to bring awareness to Indigenous methods and other knowledge systems from which Western science can learn, adopt, and integrate a lot. Making those values transparent is essential as long as it is done in a respectful and supportive way. The contributions were facilitated by a highly uncertain context which is a major aspect that complex systems engineering commonly deals with. Complex socio-technical systems are handled in interdisciplinary settings. Innovations are fostered while accounting for ethical issues. Diverging stakeholder interests need to be managed in international environments. This study clearly brought together a multiplicity of elements according to typical CoSEM character and even more. The interplay of technology, cultural values, social challenges, ecological relationships, integrative methodologies, and engineering approaches surely challenged me as a researcher and demanded to cope with uncertainty in a dynamically changing environment.

10.4. Limitations and future research

The research exhibits limitations that are identified and linked to suggestions of further research to close the gaps. The holistic approach attempted to address multiple areas from different angles to get a complete and broad picture of the problem. The goal was not to conduct a detailed analysis but to show which areas need further development.

A major part was the overarching model that connected the design with the techno-economic analysis. The model is based on a multitude of assumptions that had to be made for the numerous parameters involved. Parameters were validated through studies with experimental setups that demonstrated varied parameters across studies. The multitude of references within the model resulted in high sensitivity. Minor changes in parameters can have a great impact throughout the calculations until the output of the NPV. Therefore, accuracy needs to be increased. Further detailed design considerations that are based on the findings of this research can improve social, environmental, economic, and technical sustainability and bring the project closer to implementation.

A community survey was planned to incorporate stakeholder values which could not be conducted anymore due to time constraints. For the stakeholder values, only indirect sources could be used to interpret and identify such values. Stakeholder engagement is a vital part of the research that particularly emphasizes the inclusion of voices by the ones most affected by the greenhouse project, which are the community members. The greenhouse design and energy supply should be designed in consultation with the wider community to understand the needs and preferences better and facilitate the integration of TEK. A detailed design of the greenhouse should be carried out which includes a structural analysis with material properties and simulation of forces and weather conditions. Rainwater collection and irrigation should be included, as well as air filtration, ventilation, fans, sensors, and insulation with a proper detailed layout and complete components. With that obtained data, the thermal demand can be obtained by dynamic thermal modeling. The model in this research used average monthly climate data inputs which simplified the simulation. For instance, peak demand does not reflect the actual coldest temperature in the month. Software like HOMER, RETScreen, or EnergyPlus can be used for estimating the thermal demand and also simulating and comparing renewable energy supply. A complete analysis including CHP technologies, biogas storage options, renewable electrical energy, and cooling requirements can be carried out. RETscreen is an energy planning software developed by the Government of Canada that supports a whole process of planning, implementation, monitoring, and reporting in early project phases and focuses on renewable energy. Benchmarking, performance evaluation, and financial analysis can be performed. Closing identified knowledge gaps can make it possible to advance the rationale of this conducted research to a more detailed level in which impacts can be more accurately estimated to better integrate fields that could not be evaluated to promote further circularity applications such as in water requirements and most importantly local community resource utilization. Linking those ideas could outperform natural gas even in financial terms and bring major benefits to FMFN.

A policy analysis was not conducted but can yield valuable findings and insights into opportunities for grants, subsidies, carbon offsets, and other unexplored areas. The sensitivity analysis showed clearly how altering the right variables can have profound positive impacts on the outcome. The policy landscape could offer ways to apply such cost reductions through sustainability incentives. Particularly, the domain of Indigenous rights might uncover findings that need to be addressed or new possibilities. As an example, despite all the dysfunctions and challenges related to carbon offsets, is the British Columbia Assembly of First Nations [12] developing community-led land-based carbon credit projects that are in line with respecting and affirming Indigenous rights. It has been confirmed by various international organizations that there is a clear correlation between acknowledging Indigenous rights and decreasing deforestation rates, increasing biodiversity, and strengthening the conservation of carbon sinks [12]. A dialogue with governmental bodies has been established to discuss opportunities and challenges in current carbon policies and related frameworks [12]. Such considerations can be linked to the broader debate of Indigenous land stewardship in global sustainability and might support First

Nations in regaining control over their traditional land.

Another way of acquiring funding could be through the private sector. Not only through direct funding but also by collaborations for instance in which companies within the agricultural and/or renewable energy sector might invest in testing technologies with such a project and can therefore support developments on the financial side. Organizations might also be interested in exploring new pathways for sustainability projects for which TEK can be highly valuable and explored for various applications of integration.

Finally, further means and improved ways of integrating values such as TEK into engineering should be explored since it can yield highly adapted and meaningful results for all stakeholders. This research tested a holistic framework that showed increased benefits on all sides and used multi-criteria analysis with BWM as a means to integrate values without the need to monetize on intangible commodities. The principle of incorporating values into well-established research processes such as VSD could be applied to various fields and organizations. For instance, if employees in a company could participate in decision-making by expressing their values in a similar way, rather than acquiring the knowledge for all technicalities at hand, it could most likely solve various challenges and include the people more in a community-led way. It would probably result in more sustainable decisions on all levels while increasing well-being and other benefits.

This research study discovered a majority of topics to be explored from very specific identified gaps regarding the project to more broad and conceptual ideas that might be applicable to various other fields. The nature of the holistic and integrative framework provided a creative space to investigate multiple challenges from different perspectives and yielded valuable insights that can be further developed and analyzed.

References

[1] Alberta Wilderness Association. *Covering over 58 percent of Alberta's land-base, Boreal Forest Natural Region is an immensely huge and diverse wilderness integral to maintaining Alberta's biodiversity.* 2024. URL: `https://albertawilderness.ca/issues/wildlands/forests/boreal-forest/` (visited on 09/16/2024).

[2] Naveen Arakkal Thaiparambil and Vidya Radhakrishnan. "Challenges in achieving an economically sustainable aquaponic system: A review". In: *Aquaculture International* 30.6 (2022), pp. 3035–3066.

[3] Paola Arias-Arévalo, Berta Martín-López, and Erik Gómez-Baggethun. "Exploring intrinsic, instrumental, and relational values for sustainable management of social-ecological systems". In: *Ecology and Society* 22.4 (2017).

[4] Assembly of First Nations. *Advocating for the rights and quality of life of First Nations people in Canada.* 2025. URL: `https://afn.ca/` (visited on 01/14/2025).

[5] Athabasca University. *Indigenous studies support*. 2024. URL: `https://www.athabascau.ca/au-advantage/indigenous-studies-support.html` (visited on 01/14/2025).

[6] Bateer Baiyin, Kotaro Tagawa, and Joaquin Gutierrez. "Techno-economic feasibility analysis of a stand-alone photovoltaic system for combined aquaponics on drylands". In: *Sustainability* 12.22 (2020), p. 9556.

[7] Janelle Baker. "Research as reciprocity: Northern Cree community-based and community-engaged research on wild food contamination in Alberta's oil sands region". In: *Engaged Scholar Journal: Community-Engaged Research, Teaching, and Learning* 2.1 (2016), pp. 109–124.

[8] Christopher Barrington-Leigh and Mark Ouliaris. "The renewable energy landscape in Canada: a spatial analysis". In: *Renewable and Sustainable Energy Reviews* 75 (2017), pp. 809–819.

[9] Kathleen Berry and Joe Kincheloe. "Rigour and Complexity in Educational Research. Conducting Educational Research." In: *Open University Press* (2004).

[10] M Jean Blair and Warren E Mabee. "Evaluation of technology, economics and emissions impacts of community-scale bioenergy systems for a forest-based community in Ontario". In: *Renewable energy* 151 (2020), pp. 715–730.

[11] Valarie Blue Bird Jernigan et al. "Food sovereignty indicators for Indigenous community capacity building and health". In: *Frontiers in Sustainable Food Systems* 5 (2021), p. 704750.

[12] British Columbia Assembly of First Nations. *First Nations Carbon Offsets*. 2025. URL: `https://www.bcafn.ca/priority-areas/environment/climate-emergency/first-nations-carbon-offsets` (visited on 01/24/2025).

[13] Richard Buchanan. "Systems thinking and design thinking: The search for principles in the world we are making". In: *She Ji: The Journal of Design, Economics, and Innovation* 5.2 (2019), pp. 85–104.

[14] Karla Buffalo et al. "Fort McKay First Nation's involvement in reclamation of Alberta's oil sands development". In: *Mine Closure 2011: Proceedings of the Sixth International Conference on Mine Closure*. Australian Centre for Geomechanics. 2011, pp. 255–261.

[15] Malcolm Naea Chun. *No na mamo: Traditional and contemporary Hawaiian beliefs and practices*. University of Hawaii Press Honolulu, HI, 2011.

[16] Patricia AL Cochran et al. "Indigenous ways of knowing: Implications for participatory research and community". In: *American journal of public health* 98.1 (2008), pp. 22–27.

[17] Louis Cohen, Lawrence Manion, and Keith Morrison. *Research methods in education*. routledge, 2002.

[18] Annik Magerholm Fet and Cecilia Haskins. “Systems engineering”. In: *Business Transitions: A Path to Sustainability: The CapSEM Model*. Springer, 2023, pp. 127–136.

[19] Markus Fischer et al. *Rethinking Land in the Anthropocene: from Separation to Integration Flagship Report*. 2021.

[20] Tom Flanagan. *Community Capitalism of the Fort McKay First Nation*. Fraser Institute, 2018.

[21] Fort McKay First Nation. *Fort McKay First Nation and Suncor Energy to partner on prospective oil sands development opportunity on reserve lands*. 2024. URL: https://www.fortmckay.com/news/fort-mckay-first-nation-and-suncor-energy-to-partner-on-prospective-oil-sands-development-opportunity-on-reserve-lands/ (visited on 09/25/2024).

[22] Fort McKay First Nation. *Inspired by Our Past*. 2025. URL: https://www.fortmckay.com/ (visited on 09/20/2024).

[23] Fort McKay First Nation. *Sustainability Department*. 2024. URL: https://www.fortmckay.com/governance/departments/sustainability/ (visited on 10/03/2024).

[24] Fort McKay Group of Companies LP. *Fort McKay Group of Companies*. 2025. URL: https://fortmckaygroup.com/companies/ (visited on 01/14/2025).

[25] Batya Friedman and David G Hendry. *Value sensitive design: Shaping technology with moral imagination*. Mit Press, 2019.

[26] Ann Garibaldi. “Moving from model to application: cultural keystone species and reclamation in Fort McKay, Alberta”. In: *Journal of Ethnobiology* 29.2 (2009), pp. 323–338.

[27] Sylvie Gauthier et al. “Boreal forest health and global change”. In: *Science* 349.6250 (2015), pp. 819–822.

[28] Sonali Goel and Renu Sharma. “Performance evaluation of stand alone, grid connected and hybrid renewable energy systems for rural application: A comparative review”. In: *Renewable and Sustainable Energy Reviews* 78 (2017), pp. 1378–1389.

[29] Shiva Gorjian et al. “A review on opportunities for implementation of solar energy technologies in agricultural greenhouses”. In: *Journal of Cleaner Production* 285 (2021), p. 124807.

[30] Government of Canada. *Boreal forest*. 2021. URL: https://natural-resources.canada.ca/our-natural-resources/forests/sustainable-forest-management/boreal-forest/13071 (visited on 09/16/2024).

[31] Government of Canada. *Environment and Climate Change Canada*. 2025. URL: https://www.canada.ca/en/environment-climate-change.html (visited on 01/13/2025).

[32] Government of Canada. *Global greenhouse gas emissions*. URL: https://www.canada.ca/en/environment-climate-change/services/environmental-indicators/global-greenhouse-gas-emissions.html (visited on 09/12/2022).

[33] Government of Canada. *Indigenous Services Canada*. 2025. URL: https://www.canada.ca/en/indigenous-services-canada.html (visited on 01/10/2025).

[34] Government of Canada. *Natural Resources Canada*. 2025. URL: https://natural-resources.canada.ca/home (visited on 01/10/2025).

[35] David Groenfeldt. “The future of indigenous values: cultural relativism in the face of economic development”. In: *Futures* 35.9 (2003), pp. 917–929.

[36] Reinhard Haberfellner et al. *Systems engineering*. Springer, 2019.

[37] Alexander C Hayes et al. “Techno-economic evaluation of a tandem dry batch, garage-style digestion-compost process for remote work camp environments”. In: *Waste management* 58 (2016), pp. 70–80.

[38] Alan R Hevner and Nilmini Wickramasinghe. “Design science research opportunities in health care”. In: *Theories to inform superior health informatics research and practice* (2018), pp. 3–18.

[39] Austin Himes et al. “Why nature matters: A systematic review of intrinsic, instrumental, and relational values”. In: *BioScience* 74.1 (2024), pp. 25–43.

[40] Oselen J Imafidon, David SK Ting, and Rupp Carriveau. "Thermal modelling of a passive style net-zero greenhouse in Alberta: The effect of ground parameters and the solar to air fraction". In: *Journal of Cleaner Production* 416 (2023), p. 137840.

[41] International Energy Agency. *Energy system of Canada*. 2022. URL: `https://www.iea.org/countries/canada` (visited on 09/05/2024).

[42] Uzair Jamil, Abigail Bonnington, and Joshua M Pearce. "The agrivoltaic potential of Canada". In: *Sustainability* 15.4 (2023), p. 3228.

[43] Sven Erik Jorgensen and Brian D Fath. *Encyclopedia of ecology*. Elsevier BV, 2008.

[44] Martin Kaltschmitt, Wolfgang Streicher, and Andreas Wiese. *Renewable energy: technology, economics and environment*. Springer Science & Business Media, 2007.

[45] Robin Kimmerer. "Restoration and reciprocity: the contributions of traditional ecological knowledge". In: *Human dimensions of ecological restoration: Integrating science, nature, and culture* (2011), pp. 257–276.

[46] Robin Wall Kimmerer. *Robin Wall Kimmerer*. 2020. URL: `https://www.robinwallkimmerer.com/about` (visited on 10/12/2024).

[47] Verna J Kirkness and Ray Barnhardt. "First Nations and higher education: The four R's—Respect, relevance, reciprocity, responsibility". In: *Journal of American Indian Education* (1991), pp. 1–15.

[48] LANDMARC. *About Our Project*. URL: `https://www.landmarc2020.eu/about` (visited on 09/05/2024).

[49] Fuqi Liang, Matteo Brunelli, and Jafar Rezaei. "Consistency issues in the best worst method: Measurements and thresholds". In: *Omega* 96 (2020), p. 102175.

[50] José Lobillo-Eguíbar et al. "Economic sustainability of small-scale aquaponic systems for food self-production". In: *Agronomy* 10.10 (2020), p. 1468.

[51] Chrysanthos Maraveas et al. "Agricultural greenhouses: Resource management technologies and perspectives for zero greenhouse gas emissions". In: *Agriculture* 13.7 (2023), p. 1464.

[52] Mafalda Miranda, Jasmin Raymond, and Chrystel Dezayes. "Uncertainty and risk evaluation of deep geothermal energy source for heat production and electricity generation in remote northern regions". In: *Energies* 13.16 (2020), p. 4221.

[53] Mafalda Miranda et al. "Are engineered geothermal energy systems a viable solution for arctic off-grid communities? A techno-economic study". In: *Water* 13.24 (2021), p. 3526.

[54] Alan V Morgan. "The Changing Atmosphere Conference". In: *Geoscience Canada* (1988).

[55] Niek Mouter, Paul Koster, and Thijs Dekker. *An introduction to participatory value evaluation*. Tech. rep. Tinbergen Institute Discussion Paper, 2019.

[56] David Natcher et al. "Seeking indigenous consensus on the impacts of oil sands development in Alberta, Canada". In: *The Extractive Industries and Society* 7.4 (2020), pp. 1330–1337.

[57] Krishna Nemali. "History of controlled environment horticulture: Greenhouses". In: *HortScience* 57.2 (2022), pp. 239–246.

[58] Lisa A Neville et al. "Biogeographic variation in Thecamoebian (Testate amoeba) assemblages in lakes within various vegetation zones of Alberta, Canada". In: *International Journal of Biodiversity and Conservation* 2.8 (2010), pp. 215–224.

[59] OpenAI. *Temporary Chat FAQ*. URL: `https://help.openai.com/en/articles/8914046-temporary-chat-faq` (visited on 01/20/2025).

[60] Samvid Parajuli et al. "Assessment of potential renewable energy alternatives for a typical greenhouse aquaponics in Himalayan Region of Nepal". In: *Applied Energy* 344 (2023), p. 121270.

[61] BinBin Pearce, Irina Dallo, and Hammond Sarpong. *Handbook - Interdisciplinary and transdisciplinary research*. 2024. URL: `https://itd-alliance.org/wp-content/uploads/2024/03/Handbook-ITD-and-TD-research_March-2024.pdf`.

[62] Paul Piché et al. "Design, construction and analysis of a thermal energy storage system adapted to greenhouse cultivation in isolated northern communities". In: *Solar Energy* 204 (2020), pp. 90–105.

[63] John Pourdehnad, Erica R Wexler, and Dennis V Wilson. “Integrating systems thinking and design thinking”. In: *The Systems Thinker* 22.9 (2011), pp. 2–6.

[64] Tazrin Jahan Priyanka et al. “Techno-economic analysis of a renewable-based hybrid energy system for utility and transportation facilities in a remote community of Northern Alberta”. In: *Cleaner Energy Systems* 6 (2023), p. 100073.

[65] Hamid Rahmanifard and Tatyana Plaksina. “Hybrid compressed air energy storage, wind and geothermal energy systems in Alberta: Feasibility simulation and economic assessment”. In: *Renewable energy* 143 (2019), pp. 453–470.

[66] Graeme Reed and Jesse Donovan. *Indigenous Peoples: A Guide to Terminology*. 2024. URL: `https://www.iwgia.org/en/canada/5395-iw-2024-canada.html` (visited on 11/03/2024).

[67] Jafar Rezaei. “Best-worst multi-criteria decision-making method”. In: *Omega* 53 (2015), pp. 49–57.

[68] Jafar Rezaei. “Best-worst multi-criteria decision-making method: Some properties and a linear model”. In: *Omega* 64 (2016), pp. 126–130.

[69] Jafar Rezaei, Alireza Arab, and Mohammadreza Mehregan. “Analyzing anchoring bias in attribute weight elicitation of SMART, Swing, and best-worst method”. In: *International Transactions in Operational Research* 31.2 (2024), pp. 918–948.

[70] Jafar Rezaei, Alireza Arab, and Mohammadreza Mehregan. “Equalizing bias in eliciting attribute weights in multiattribute decision-making: experimental research”. In: *Journal of Behavioral Decision Making* 35.2 (2022), e2262.

[71] Mohsen Rezaei. “A multi-criteria decision-making approach for sustainable energy prioritization”. In: *Environmental Energy and Economic Research* 6.1 (2022), pp. 1–19.

[72] Hannah Ritchie. “Who has contributed most to global CO2 emissions?” In: *Our World in Data* (2019).

[73] Erin V Satterthwaite et al. “CENTERING KNOWLEDGE CO-PRODUCTION IN SUSTAINABILITY SCIENCE”. In: *Oceanography* 37.1 (2024), pp. 26–37.

[74] Rebekka Schnitter and Peter Berry. “The climate change, food security and human health nexus in Canada: A framework to protect population health”. In: *International journal of environmental research and public health* 16.14 (2019), p. 2531.

[75] Annette Schultz et al. “Historical and continued colonial impacts on heart health of Indigenous Peoples in Canada: what’s reconciliation got to do with it?” In: *CJC open* 3.12 (2021), S149–S164.

[76] Hillary Sillitto et al. “Systems engineering and system definitions”. In: *INCOSE–International Council on Systems Engineering* (2019).

[77] Kelly Skinner et al. “Implementation of a community greenhouse in a remote, sub-Arctic First Nations community in Ontario, Canada: a descriptive case study”. In: *Rural and remote health* 14.2 (2014), pp. 79–96.

[78] David Spink and Ryan Abel. “Development of Alberta’s oil sands: The Fort McKay First Nation’s perspective on environmental management”. In: *Edited by* (2015), p. 227.

[79] Amanda Stephenson. *First Nation in northern Alberta signs oilsands lease development MOU with Suncor*. 2024. URL: `https://www.cbc.ca/news/canada/edmonton/alberta-first-nation-signs-oilsands-lease-development-mou-with-suncor-1.7137002` (visited on 09/26/2024).

[80] Town of Inuvik. *Inuvik Community Greenhouse*. URL: `https://www.inuvik.ca/en/discovering-inuvik/Inuvik-Community-Greenhouse.asp` (visited on 09/25/2024).

[81] United Nations. *What Is Climate Change?* URL: `https://www.un.org/en/climatechange/what-is-climate-change` (visited on 09/03/2022).

[82] United Nations. *What is renewable energy?* URL: `https://www.un.org/en/climatechange/what-is-renewable-energy` (visited on 09/05/2024).

[83] University of Alberta. *Canadian Renewable Energy Project Map*. 2024. URL: https://www.futureenergysystems.ca/resources/renewable-energy-projects-canada (visited on 01/24/2025).

[84] University of Alberta. *Community-Based Research and Evaluation*. 2025. URL: https://www.ualberta.ca/en/graduate-programs/community-based-research-and-evaluation.html (visited on 01/14/2025).

[85] Berna Uzun et al. "Theoretical aspects of multi-criteria decision-making (MCDM) methods". In: *Applications of multi-criteria decision-making theories in healthcare and biomedical engineering*. Elsevier, 2021, pp. 3–40.

[86] Jan Vom Brocke, Alan Hevner, and Alexander Maedche. "Introduction to design science research". In: *Design science research. Cases* (2020), pp. 1–13.

[87] Abeer Al-Wahaibi et al. "Techno-economic evaluation of biogas production from food waste via anaerobic digestion". In: *Scientific reports* 10.1 (2020), p. 15719.

[88] Alex Wilkinson et al. "Controlled environment agriculture and containerized food production in northern North America". In: *Journal of Agriculture, Food Systems, and Community Development* 10.4 (2021), pp. 127–142.

[89] Kun Xie and Kurt Rosentrater. "Life cycle assessment (LCA) and Techno-economic analysis (TEA) of tilapia-basil aquaponics". In: *2015 ASABE Annual International Meeting*. American Society of Agricultural and Biological Engineers. 2015, p. 1.

[90] Margaret Zafiriou, Elisabeta Lika, and Al Mussell. *Competing Pressures on Land Use in Canadian Agriculture: To Intensify Or Not to Intensify-that is the Question*. Canadian Agri-Food Policy Institute, 2023.

[91] Natalia Zappernick et al. "Techno-economic analysis of a recirculating tilapia-lettuce aquaponics system". In: *Journal of Cleaner Production* 365 (2022), p. 132753.

[92] Ruosi Zhang et al. "Systems approaches for sustainable fisheries: A comprehensive review and future perspectives". In: *Sustainable production and consumption* (2023).

A

Appendix

A.1. Literature review

Table A.1: List of literature reviewed

Nr.	Title	Year	Author	Journal
1	Are Engineered Geothermal Energy Systems a Viable Solution for Arctic Off-Grid Communities? A Techno-Economic Study	2021	Miranda et al.	Water
2	Evaluation of technology, economics and emissions impacts of community-scale bioenergy systems for a forest-based community in Ontario	2020	Blair and Mabee	Renewable Energy
3	Techno-economic analysis of a renewable-based hybrid energy system for utility and transportation facilities in a remote community of Northern Alberta	2023	Priyanka et al.	Cleaner Energy Systems
4	Techno-economic evaluation of a tandem dry batch, garage-style digestion-compost process for remote work camp environments	2016	Hayes et al.	Waste Management
5	Hybrid compressed air energy storage, wind and geothermal energy systems in Alberta: Feasibility simulation and economic assessment	2019	Rahmanifard and Plaksina	Renewable Energy
6	Thermal modelling of a passive style net-zero greenhouse in Alberta: The effect of ground parameters and the solar to air fraction	2023	Imafidon, Ting, and Carriveau	Journal of Cleaner Production
7	Uncertainty and Risk Evaluation of Deep Geothermal Energy Source for Heat Production and Electricity Generation in Remote Northern Regions	2020	Miranda, Raymond, and Dezayes	Energies
8	The Agrivoltaic Potential of Canada	2023	Jamil, Bonnington, and Pearce	Sustainability
9	Controlled environment agriculture and containerized food production in northern North America	2021	Wilkinson et al.	Journal of Agriculture, Food Systems, and Community Development
10	Design, construction and analysis of a thermal energy storage system adapted to greenhouse cultivation in isolated northern communities	2020	Piché et al.	Solar Energy
11	The renewable energy landscape in Canada: A spatial analysis	2017	Barrington-Leigh and Ouliaris	Renewable and Sustainable Energy Reviews

Nr.	Title	Year	Author	Journal
12	Implementation of a community greenhouse in a remote, sub-Arctic First Nations community in Ontario, Canada: a descriptive case study	2014	Skinner et al.	Rural and remote health
13	Assessment of potential renewable energy alternatives for a typical greenhouse aquaponics in Himalayan Region of Nepal	2023	Parajuli et al.	Applied Energy
14	Techno-Economic Feasibility Analysis of a Stand-Alone Photovoltaic System for Combined Aquaponics on Drylands	2020	Baiyin, Tagawa, and Gutierrez	Sustainability
15	Life cycle assessment (LCA) and Techno-economic analysis (TEA) of tilapia-basil aquaponics	2015	Xie and Rosentrater	ASABE Meeting Presentation
16	Techno-economic analysis of a recirculating tilapia-lettuce aquaponics system	2022	Zappernick et al.	Journal of Cleaner Production
17	Economic Sustainability of Small-Scale Aquaponic Systems for Food Self-Production	2020	Lobillo-Eguíbar et al.	Agronomy
18	Systems approaches for sustainable fisheries: A comprehensive review and future perspectives	2023	Zhang et al.	Sustainable Production and Consumption
19	A review on opportunities for implementation of solar energy technologies in agricultural greenhouses	2021	Gorjian et al.	Journal of Cleaner Production
20	Performance evaluation of stand alone, grid connected and hybrid renewable energy systems for rural application: A comparative review	2017	Goel and Sharma	Renewable and Sustainable Energy Reviews

A.2. Applying the concept of bricolage

Figure A.1: Asking a multiplicity of questions

A.3. LANDMARC: Protection of Personal Data

POPD - REQUIREMENT NUMBER 1

D9.1

TUD

STATUS: CONFIDENTIAL

This project has received funding from the European Unions' Horizon2020 Grant Agreement No 869367

LANDMARC

Land-use based Mitigation for Resilient Climate Pathways

GA No. 869367 [RIA]

Deliverable number	*D9.1*
Deliverable name	*POPD - REQUIREMENT NUMBER 1*
WP / WP number	*9*
Delivery due date	*30/09/2020*
Actual date of submission	*25/11/2020*
Dissemination level	*Confidential*
Lead beneficiary	*TUD*
Responsible scientist / administrator	*Jenny Lieu*
Contributor(s)	*Ed Dearnley, SPRU*
Reviewer(s)	*Eise Spijker, JIN*
Changes with respect to the DoA	*None*
Dissemination and uptake	*Internal use only*

Short Summary of results
This Deliverable describes the project's approach to the Ethics Requirements of our grant agreement. Specifically, it names our Data Protection Officer and outlines our approach to ethics and data sharing in our case studies. This document should be read alongside our forthcoming Data Management Plan, which is due in month 6 (December 2020).
Evidence of accomplishment
This report

Preface

Negative emission solutions are expected to play a pivotal role in future climate actions and net zero emissions policy scenarios. To date most climate actions have focussed on phasing out fossil fuels and reducing greenhouse gas emissions in, for example, industry, electricity, and transport. While zero emission trajectories in these sectors will remain a priority for decades to come, it is expected that residual GHG emissions will remain. To be able to fulfil the Paris Agreement and meet the world's climate goals research, policy and markets are increasingly looking at negative emission solutions.

This is why the nineteen LANDMARC consortium partners work together in order to:

- Estimate the climate impact of land-based negative emission solutions, in agriculture, forestry, and other land-use sectors
- Assess the potential for regional and global upscaling of negative emission solutions
- Map their potential environmental, economic, and social co-benefits and trade-offs

LANDMARC is an interdisciplinary consortium with expertise from ecology, engineering, climate sciences, global carbon cycle, soil sciences, satellite earth observation sciences, agronomy, economics, social sciences, and business. There is a balanced representation of partners from academia, SMEs, and NGOs from the EU, Africa, Asia and the Americas, which ensures a wide coverage of LMTs operating in different contexts (e.g. climates, land-use practices, socio-economic etc.) and spatial scales.

The LANDMARC project consortium:

Table of Contents

Acknowledgements

This report has been produced as part of the LANDMARC project.

Disclaimer:

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 869367 (LANDMARC).

Executive Summary

This Deliverable describes the project's approach to the Ethics Requirements of our grant agreement. Specifically, it names our Data Protection Officer and outlines our approach to ethics and data sharing in our case studies. This document should be read alongside our forthcoming Data Management Plan, which is due in month 6 (December 2020).

Introduction

D9.1 is described in the LANDMARC grant agreement as follows:

'The beneficiary/beneficiaries must confirm that it has appointed a Data Protection Officer (DPO) and the contact details of the DPO are made available to all data subjects involved in the research. For host institutions not required to appoint a DPO under the GDPR a detailed data protection policy for the project must be kept on file. A description of the technical and organisational measures that will be implemented to safeguard the rights and freedoms of the data subjects/research participants must be submitted as a deliverable. For instances when personal data are transferred from the EU to a non-EU country or international organisation, confirmation that such transfers are in accordance with Chapter V of the General Data Protection Regulation 2016/679, must be submitted as a deliverable. For instances when personal data are transferred from a non-EU country to the EU (or another third state), confirmation that such transfers comply with the laws of the country in which the data was collected must be submitted as a deliverable. If applicable, for further processing of previously collected personal data, an explicit confirmation that the beneficiary has lawful basis for the data processing and that the appropriate technical and organisational measures are in place to safeguard the rights of the data subjects must be submitted as a deliverable. Data Processing Agreement/Addendum (or equivalent) with data processors (i.e. LinkedIn, Twitter, etc.) who store or process personal data, must be kept on file.'

To meet these requirements, in this Deliverable we:

- Name our Data Protection Officer.
- Outline ethics requirements of our case studies and provide brief details of data transfer between countries and partners. Note that we will expand upon this in our Data Management Plan, due in month 6 (December 2020).

Data Protection Officer

The data protection officer for LANDMARC will be:

- Erik van Leeuwen (Data Protection Officer, TU Delft)

Department: Universiteitsdienst, Directie Legal Services, Legal Affairs

Address: Stevinweg nr. 1, Postbus 5, 2600 AA Delft

The Data Protection Officer will be named on relevant project documents, alongside the case study lead(s) and other key LANDMARC contacts.

Safeguarding the Rights of Research Participants

1.1 Research Participants Interaction with LANDMARC

Research participants will interact with LANDMARC via interviews, surveys and workshops. Our project plan foresees most of these activities taking place in person, however due to the current COVID-19 pandemic we may make greater use of online technologies. If this is the case, we will update this Deliverable to detail the systems we are using, and how we will check their compliance with GDPR and other applicable data protection regulations.

1.2 Safeguarding Measures

LANDMARC will implement the following safeguarding measures:

- The project as a whole will follow the ethical research procedures of the coordinating institution, TU-Delft.
- Informed consent will be used to engage research participants. Participants will be provided with information sheets detailing how their data will be used, how their data will be stored and their rights. Examples of these sheets are shown in Appendix A – Consent Form Template for Participant Interviews.
- Personal data will be stored securely on institutional servers, encrypted media and in locked filing cabinets. Personal data can be stored securely on Bitrix24 the centralised LANDMARC file sharing system at TU Delft but accessible only to the researcher who collected the data. We have set up customised feature in Bitrix24 to ensure personal data is protected. This enables researchers to have secure backup of the data particularly for smaller organisations without additional back-up systems. However, the researcher collecting the data may also chose not to store the information on Bitrix24 if they have secure backup in their own institution. Only anonymised data resulting from the case studies will be shared.
- We have no plans to transfer data that is not already publicly available between EU and non-EU countries. Please see section 1.3 for details of our process for any unforeseen data sharing need.

1.3 Unforeseen Data Sharing

In the event of a currently unforeseen need for data sharing later in the project, the co-ordinator will a) review the need for data sharing, b) determine whether data sharing is allowable under the consents that research participants have provided and c) broker legally binding data sharing agreements between the relevant parties.

1.4 Data Management Plan

The LANDMARC data management plan will be completed by December 2020 and updated regularly throughout the project. The plan will detail procedures for data collection, storage and sharing.

Appendix A – Consent Form Template for Participant Interviews

LANDMARC: Land-use based Mitigation for Resilient Climate Pathways XXXX Country Case Study Research

CONSENT FORM FOR PROJECT PARTICIPANTS

Sponsor(s): European Union HORIZON 2020: The EU Framework Programme for Research and Innovation and xxx

Researcher: xxx

Researcher contact details: xxx

Interviewee name: xxx

Interviewee contact details: xxx

Date: xxx

---

1. Background purpose of the study:

Land-based negative emission solutions are expected to play a pivotal role in future climate actions and policy scenarios. To date most climate actions have focussed on phasing out fossil fuels and reducing greenhouse gas emissions in, for example, industry, electricity, and transport. While zero emission trajectories in these sectors will remain a priority for decades to come, it is expected that some residual GHG emissions will remain. To be able to fulfil the Paris Agreement and meet the world's climate goals research, policy and markets are increasingly looking at land-based negative emission solutions.

This is why the nineteen LANDMARC consortium partners work together in order to:

- Estimate the climate impact of land-based negative emission solutions, for example in agriculture, forestry, and other land-use sectors
- Assess the potential for regional and global upscaling of negative emission solutions
- Map their potential environmental, economic, and social co-benefits and trade-offs

2. What will I be asked to do?

We anticipate that the interview will last for approximately between 30-60 minutes. We will take written notes and will be making a digital recording of the interview. We may be accompanied by a research-assistant who will also takes notes to ensure the accuracy and completeness of the information we use. The following precautions will be taken to protect your anonymity and confidentiality.

You are under no pressure to participate in the interview. You are free to decline to answer questions on topics that you do not wish to discuss. You are free to break off the interview at any time or to withdraw from the interview altogether at any point of time. Any information collected to that point will be destroyed if you do not wish of us to use the information.

3. What type of information will be collected?

You will not be identified in the research findings either directly or indirectly unless we have your permission to do so. Even after receiving your permission, we will not identify or quote you in any publication (e.g. direct quote or paraphrase your comment) without allowing you to verify the accuracy of quotes that are being used. Information collected will be restricted to questions relevant to your official role (length of time in this position, responsibilities, prior relevant experience).

Please put a check mark on the line corresponding to your willingness to be identified:

You may quote me and use my name: Yes____ No____

4. Can we contact you for further research?

You may contact me in the future for further research related to the LANDMARC project:

Yes____ No____

4. What are the possible risk and benefits of taking part?

Since confidentiality is being provided, there are no risks are foreseen in relation to participation. Benefits would include potential contribution to developing low-carbon scenarios that could feed into the decision making process including the contribution to the knowledge base informing the policy-making process in XXX country, which may have the potential to improve the quality of policy-making.

5. What happens to the information provided?

All information collected will be kept in institutional servers (where available), or if institutional servers are not available, in password-protected electronic files on the hard drive of their secured computers. Data collected will be retained in secure filing cabinets for 3 years after the completing of the project. All data with your personal information (e.g. full name and contact details) will be destroyed after the research study is completed unless you have agreed for us to contact you at a later date. Summaries of some interview content may be provided to other researchers in the team, but this will be provided in a format that will ensure that your identity cannot be ascertained.

6. What will happen to the results of the research study?

The results of the survey/workshops will be used to help formulate assumptions and what-if conditions for the quantitative models to assess *the extent* of synergies, conflicts, and risks associated with different low-carbon technological pathways.

7. Who is organising and funding the research?

LANDMARC has received funding from the European Union under the Horizon 2020 programme through Grant Agreement No 869367.

The co-ordinating institution, has approved the study and XXXX researcher will be carrying out the research for the XXX country case study.

9. Signatures (written consent):

Your signature on this form indicates that you:

1) Understand to your satisfaction the information provided to you about your participation in this research project,

2) Understand that your participation is voluntary, that you can choose not to participate in part or all of the project, and that you can withdraw at any stage of the project without being penalised or disadvantaged in any way

3) Consent to the processing of your personal information for the purposes of this research study. You understand that such information will be treated as strictly confidential and handled in accordance with the General Data Protection Regulation, the co-ordinating institutions' country requirements and the relevant ethics approval process.

Participant's Name: (please print)

____

Participant's Signature

____

Date:

____

Researcher's Name: (please print)

____

Researcher's Signature:

____

Date:

____

8. Contact for further information, questions or concerns

If you have any further questions or want clarification regarding this research and/or your participation, please contact:

LANDMARC's Coordinator:

- Dr Jenny Lieu; j.lieu-1@tudelf.nl at Delft University of Technology or the Co-coordinator
- Eise Spijker; eise@jin.ngo at JIN Climate and Sustainability

Appendix B – Consent Form Template for Participant Surveys and Workshops

LANDMARC: Land-use based Mitigation for Resilient Climate Pathways XXXX Country Case Study Research

PARTICIPANT INFORMATION SHEET TEMPLATE FOR SURVEYS AND WORKSHOP PARTICIPANTS

Sponsor(s): European Union HORIZON 2020: The EU Framework Programme for Research and Innovation and xxx

Researcher: xxx

Researcher contact details: xxx

Interviewee name: xxx

Interviewee contact details: xxx

Date: xxx

---

1. Background purpose of the study:

Land-based negative emission solutions are expected to play a pivotal role in future climate actions and policy scenarios. To date most climate actions have focussed on phasing out fossil fuels and reducing greenhouse gas emissions in, for example, industry, electricity, and transport. While zero emission trajectories in these sectors will remain a priority for decades to come, it is expected that some residual GHG emissions will remain. To be able to fulfil the Paris Agreement and meet the world’s climate goals research, policy and markets are increasingly looking at land-based negative emission solutions.

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- Assess the potential for regional and global upscaling of negative emission solutions
- Map their potential environmental, economic, and social co-benefits and trade-offs

2. Invitation to participate in LANDMARC:

You have been selected to participate in the study due to your expertise about relevant issues and/or because you had personal involvement with the specified case (either directly or indirectly) allowing you to provide first-hand knowledge of subject area or current events. A total of XXX people have been invited to participate in the XXX country/regional case study and XXX in the whole project.

3. Do I have to take part?

You are under no pressure to participate in the research. *If you decide to take part, you can proceed to fill out the survey provided in the link: XXXXXXXXX or respond to invitation to attend the workshop(s). The survey will take around XXX minutes/the workshop will take place on XXX date from XXX to XXX*

When filling out the survey/attending the workshop, you are free to decline to answer questions on topics and questions that you do not wish to answer/discuss.

You will also be asked if you can be contacted for follow up questions, clarifications or further participation over the duration of the project.

4. What are the possible risk and benefits of taking part?

Since confidentiality is being provided, there are no risks are foreseen in relation to participation. Benefits would include potential contribution to developing low-carbon scenarios that could feed into the decision making process including the contribution to the knowledge base informing the policy-making process in XXX Country, which may have the potential to improve the quality of policy-making.

5. What happens to the information provided?

All information collected will be kept in institutional servers (where available), or if institutional servers are not available, in password-protected electronic files on the hard drive of their secured computers. Data collected will be retained in secure filing cabinets for 3 years after the completing of the project. All data with your personal information (e.g. full name and contact details) will be destroyed after the research study is completed unless you have agreed for us to contact you at a later date. Summaries of some interview content may be provided to other researchers in the team, but this will be provided in a format that will ensure that your identity cannot be ascertained.

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8. Contact for further information, questions or concerns

If you have any further questions or want clarification regarding this research and/or your participation, please contact:

LANDMARC's Coordinator:

- Dr Jenny Lieu; j.lieu-1@tudelf.nl at Delft University of Technology or the Co-coordinator
- Eise Spijker; eise@jin.ngo at JIN Climate and Sustainability

B

Appendix

B.1. Aquaponic Greenhouse process

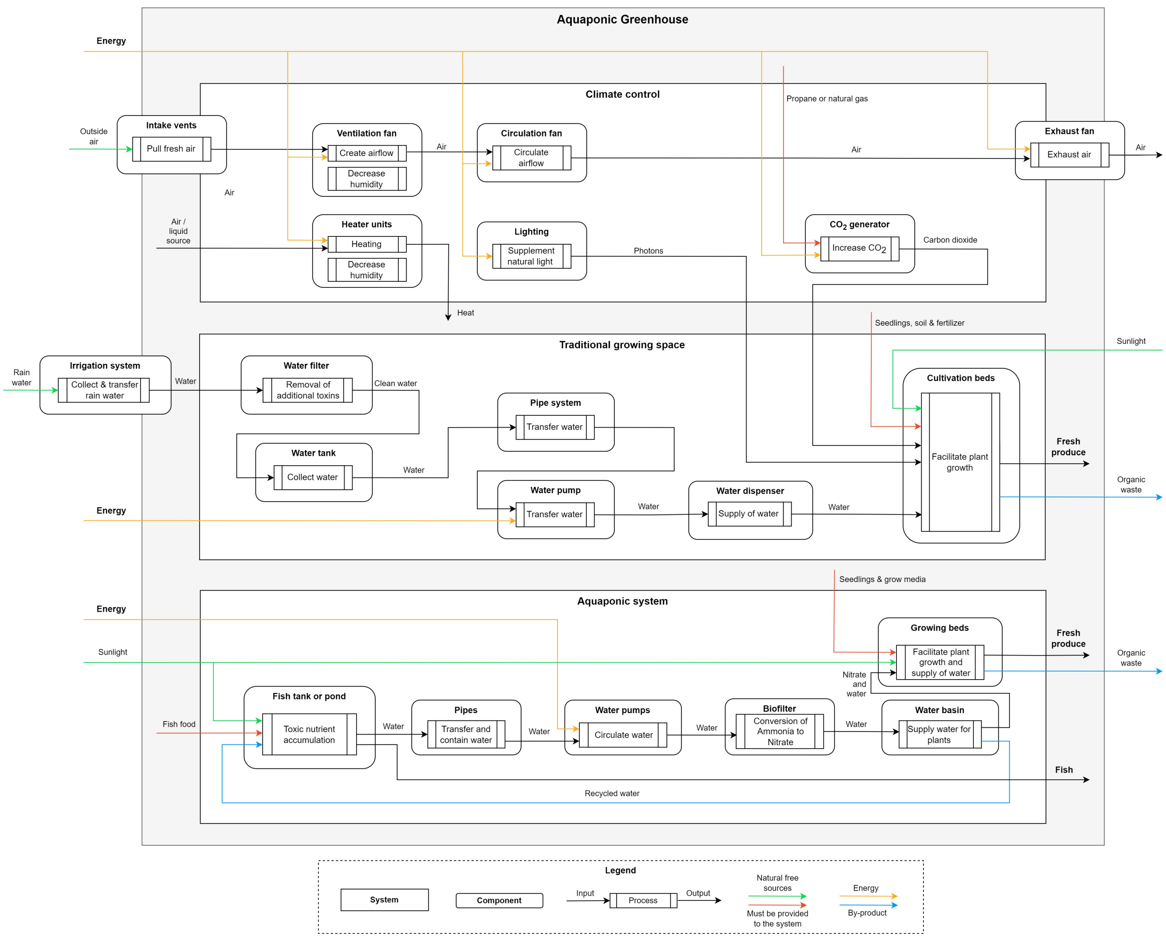


Figure B.1: AG IPO diagram

B.2. Climate data

B.2.1. Mildred Lake

RETScreen - Location **Subscriber: Viewer**

Site reference conditions

Climate data location: Canada - Alberta - Mildred Lake   Facility location: Canada - AB - Wood Buffalo

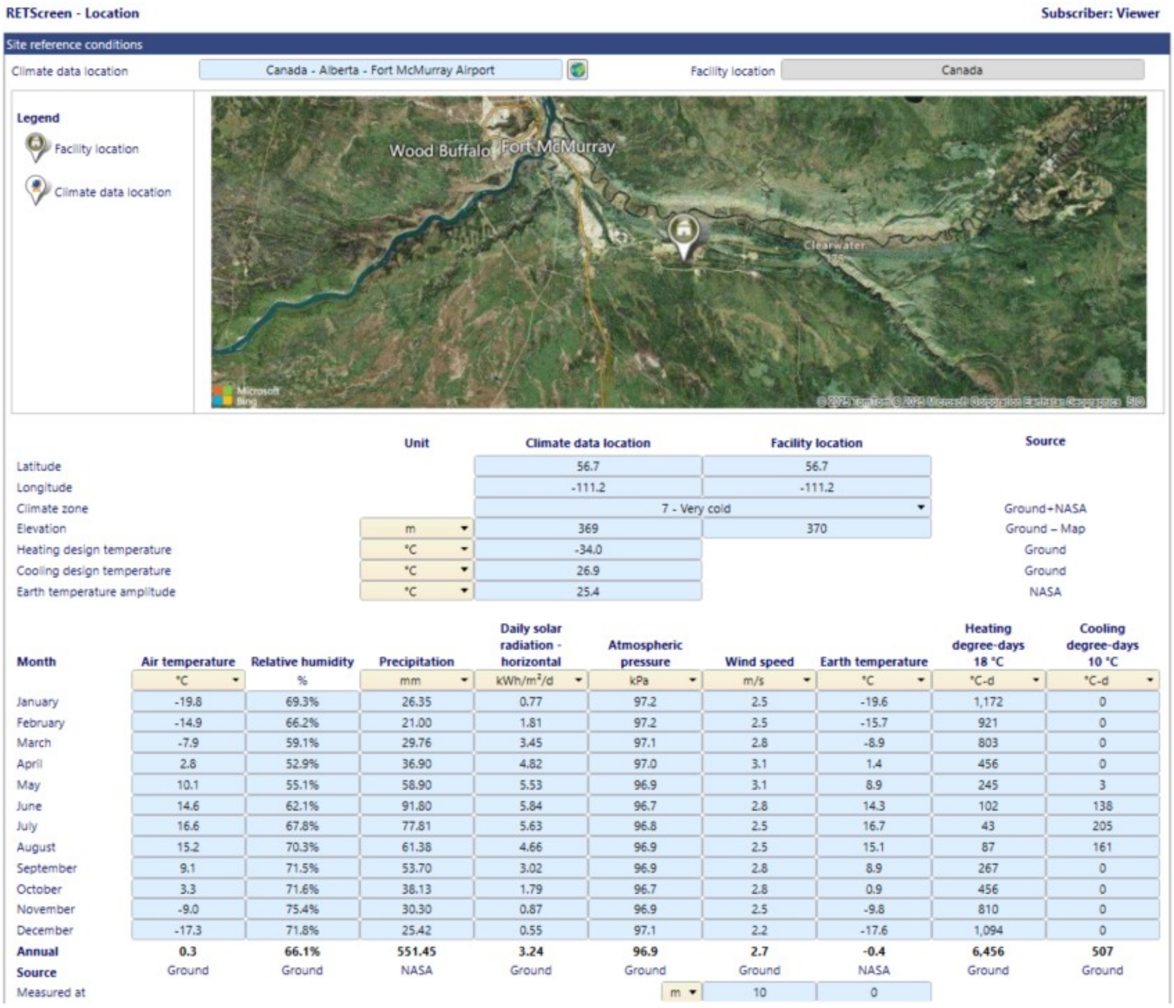
Legend
Facility location
Climate data location

	Unit	Climate data location	Facility location	Source
Latitude		57.0	57.0	
Longitude		-111.6	-111.6	
Climate zone		7 - Very cold		Ground+NASA
Elevation	m	310	309	Ground – Map
Heating design temperature	°C	-32.5		Ground
Cooling design temperature	°C	27.3		Ground
Earth temperature amplitude	°C	25.5		NASA

Month	Air temperature	Relative humidity	Precipitation	Daily solar radiation - horizontal	Atmospheric pressure	Wind speed	Earth temperature	Heating degree-days 18 °C	Cooling degree-days 10 °C
	°C	%	mm	kWh/m²/d	kPa	m/s	°C	°C-d	°C-d
January	-17.7	79.8%	24.18	0.58	96.1	2.5	-20.8	1,107	0
February	-12.3	77.3%	19.60	1.44	96.2	2.6	-16.6	848	0
March	-6.2	66.8%	29.45	2.92	96.2	3.1	-9.9	750	0
April	3.8	56.0%	35.40	4.59	96.2	3.5	0.9	426	0
May	10.2	58.4%	58.28	5.48	96.1	3.4	8.6	242	6
June	15.9	63.5%	84.90	5.68	95.9	3.2	14.1	63	177
July	18.2	68.4%	73.47	5.55	96.0	3.1	16.7	0	254
August	16.4	71.3%	58.59	4.59	96.0	3.0	15.1	50	198
September	10.8	73.4%	51.90	3.06	96.0	3.2	8.7	216	24
October	3.0	75.5%	36.58	1.67	96.0	3.2	0.5	465	0
November	-6.9	82.4%	28.50	0.80	95.9	2.8	-10.7	747	0
December	-13.5	82.7%	23.25	0.36	96.0	2.6	-18.7	977	0
Annual	**1.9**	**71.3%**	**524.10**	**3.07**	**96.1**	**3.0**	**-0.9**	**5,890**	**660**
Source	Ground	Ground	NASA	NASA	NASA	Ground	NASA	Ground	Ground
Measured at					m	10	0		

Figure B.2: RETScreen climate data: Mildred Lake

B.2.2. Fort McMurray Airport


RETScreen - Location | Subscriber: Viewer

Site reference conditions

Climate data location: Canada - Alberta - Fort McMurray Airport | Facility location: Canada

	Unit	Climate data location	Facility location	Source
Latitude		56.7	56.7	
Longitude		-111.2	-111.2	
Climate zone		7 - Very cold		Ground+NASA
Elevation	m	369	370	Ground – Map
Heating design temperature	°C	-34.0		Ground
Cooling design temperature	°C	26.9		Ground
Earth temperature amplitude	°C	25.4		NASA

Month	Air temperature	Relative humidity	Precipitation	Daily solar radiation - horizontal	Atmospheric pressure	Wind speed	Earth temperature	Heating degree-days 18 °C	Cooling degree-days 10 °C
	°C	%	mm	kWh/m²/d	kPa	m/s	°C	°C-d	°C-d
January	-19.8	69.3%	26.35	0.77	97.2	2.5	-19.6	1,172	0
February	-14.9	66.2%	21.00	1.81	97.2	2.5	-15.7	921	0
March	-7.9	59.1%	29.76	3.45	97.1	2.8	-8.9	803	0
April	2.8	52.9%	36.90	4.82	97.0	3.1	1.4	456	0
May	10.1	55.1%	58.90	5.53	96.9	3.1	8.9	245	3
June	14.6	62.1%	91.80	5.84	96.7	2.8	14.3	102	138
July	16.6	67.8%	77.81	5.63	96.8	2.5	16.7	43	205
August	15.2	70.3%	61.38	4.66	96.9	2.5	15.1	87	161
September	9.1	71.5%	53.70	3.02	96.9	2.8	8.9	267	0
October	3.3	71.6%	38.13	1.79	96.7	2.8	0.9	456	0
November	-9.0	75.4%	30.30	0.87	96.9	2.5	-9.8	810	0
December	-17.3	71.8%	25.42	0.55	97.1	2.2	-17.6	1,094	0
Annual	**0.3**	**66.1%**	**551.45**	**3.24**	**96.9**	**2.7**	**-0.4**	**6,456**	**507**
Source	Ground	Ground	NASA	Ground	Ground	Ground	NASA	Ground	Ground
Measured at					m	10	0		

Figure B.3: RETScreen climate data: Fort McMurray Airport

B.3. Sensitivity analysis: Hybrid options

B.3.1. Hybrid-1BN

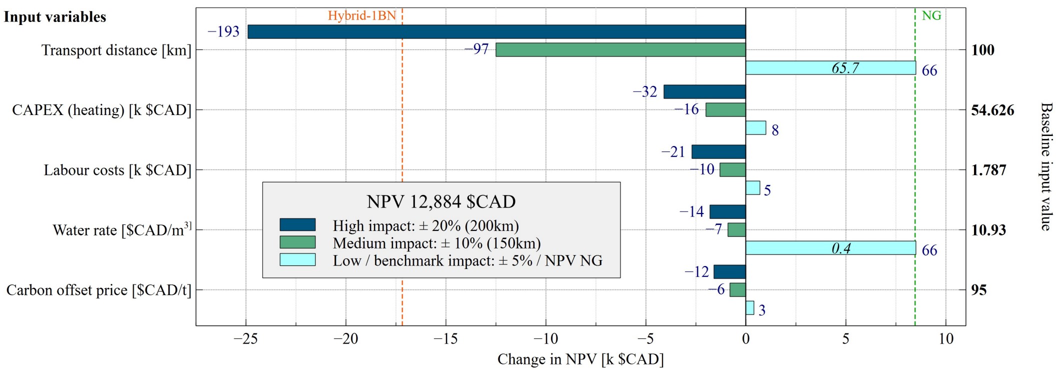


Figure B.4: Sensitivity analysis: Hybrid-1BN 392m²

B.3.2. Hybrid-2GB

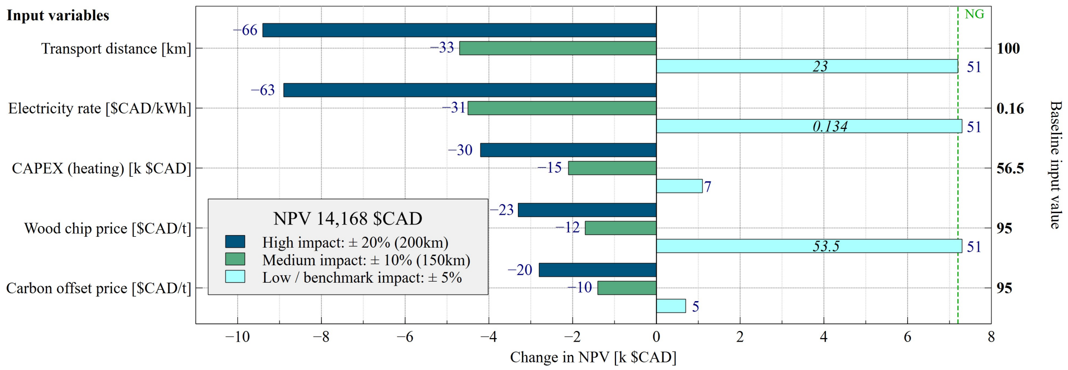


Figure B.5: Sensitivity analysis: Hybrid-2GB 392m²

B.4. Linear BWM Questionnaire

Criteria Number = 6	Criterion 1	Criterion 2	Criterion 3	Criterion 4	Criterion 5	Criterion 6
Names of Criteria	Reliable	Easy to	Climate-	Waste	Off-grid	Affordable

Select the Best	Affordable

Select the Worst	Easy to

Best to Others	Reliable	Easy to	Climate-	Waste	Off-grid	Affordable
Affordable	2	9	3	2	2	1

Others to the Worst	Easy to
Reliable	7
Easy to operate	1
Climate-friendly	5
Waste recycling	7
Off-grid	7
Affordable	9

Weights	Reliable	Easy to	Climate-	Waste	Off-grid	Affordable
	0.1778351	0.0309278	0.1185567	0.1778351	0.1778351	0.3170103

Input-Based CR	0.0833333	The pairwise comparison consistency level is acceptable
Associated Threshold	0.3337	

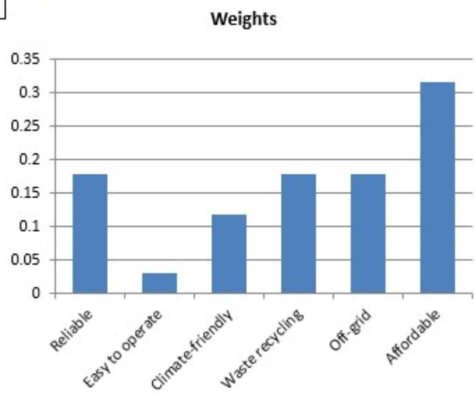


Figure B.6: BWM criteria weighting: Project developer response

C
Appendix

C.1. Cash flow statements from TEA

C.1.1. Base case: Natural gas boiler

Increasing greenhouse size per page.

Discount rate 12 [%]

BASE CASE: NATURAL GAS

260 [m2] 5000 [l]

Lifespan		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Years		**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**	**2036**	**2037**	**2038**	**2039**	**2040**	**2041**	**2042**	**2043**	**2044**	**2045**
Gas price [CAD/kWh]		0.0134	0.0139	0.0145	0.0151	0.0157	0.0163	0.0168	0.0174	0.0180	0.0186	0.0192	0.0198	0.0203	0.0209	0.0215	0.0221	0.0227	0.0232	0.0238	0.0244	0.0250
Electricity rates [CAD/kWh]		0.104	0.160	0.167	0.175	0.182	0.189	0.197	0.204	0.212	0.219	0.226	0.234	0.241	0.248	0.256	0.263	0.271	0.278	0.285	0.293	0.300
CAPEX_Heating																						
Hydronic radiant heating		10,930.51	-546.53	-546.53	-546.53	-546.53	-546.53	-546.53	-546.53	-546.53	-546.53	-546.53	-546.53	-546.53	-546.53	-546.53	-546.53	-546.53	-546.53	-546.53	-546.53	-546.53
Hot water boiler		6,713.33	-335.67	-335.67	-335.67	-335.67	-335.67	-335.67	-335.67	-335.67	-335.67	-335.67	-335.67	-335.67	-335.67	-335.67	-335.67	-335.67	-335.67	-335.67	-335.67	-335.67
Buffer tank		1,420.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00
Grid access		3,000.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00
	Total:	**22,063.84**	1,103.19	1,103.19	1,103.19	1,103.19	1,103.19	1,103.19	1,103.19	1,103.19	1,103.19	1,103.19	1,103.19	1,103.19	1,103.19	1,103.19	1,103.19	1,103.19	1,103.19	1,103.19	1,103.19	1,103.19
		8,240.23	**-984.99**	**-879.46**	**-785.23**	**-701.10**	**-625.98**	**-558.91**	**-499.03**	**-445.56**	**-397.82**	**-355.20**	**-317.14**	**-283.16**	**-252.82**	**-225.73**	**-201.55**	**-179.95**	**-160.67**	**-143.46**	**-128.09**	**-114.36**
OPEX_Heating																						
Fuel (Natural gas)			-1,417.05	-1,476.17	-1,535.29	-1,594.41	-1,653.52	-1,712.64	-1,771.76	-1,830.87	-1,889.99	-1,949.11	-2,008.23	-2,067.34	-2,126.46	-2,185.58	-2,244.69	-2,303.81	-2,362.93	-2,422.05	-2,481.16	-2,540.28
Maintenance			-182.95	-182.95	-182.95	-182.95	-182.95	-182.95	-182.95	-182.95	-182.95	-182.95	-182.95	-182.95	-182.95	-182.95	-182.95	-182.95	-182.95	-182.95	-182.95	-182.95
Cooling		0.30	-328.75	-327.51	-341.93	-356.35	-370.77	-385.19	-399.60	-414.02	-428.44	-442.86	-457.28	-471.70	-486.12	-500.54	-514.95	-529.37	-543.79	-558.21	-572.63	-587.05
	Total:		1,928.76	-1,986.64	-2,060.17	-2,133.71	-2,207.25	-2,280.78	-2,354.32	-2,427.85	-2,501.39	-2,574.92	-2,648.46	-2,722.00	-2,795.53	-2,869.07	-2,942.60	-3,016.14	-3,089.68	-3,163.21	-3,236.75	-3,310.28
Direct CO2 emissions		[t CO2]	18.13	18.13	18.13	18.13	18.13	18.13	18.13	18.13	18.13	18.13	18.13	18.13	18.13	18.13	18.13	18.13	18.13	18.13	18.13	18.13
Net emissions impact		[t CO2]	18.13	18.13	18.13	18.13	18.13	18.13	18.13	18.13	18.13	18.13	18.13	18.13	18.13	18.13	18.13	18.13	18.13	18.13	18.13	18.13
		17,610.52	**-1,722.11**	**-1,583.74**	**-1,466.39**	**-1,356.01**	**-1,252.45**	**-1,155.51**	**-1,064.97**	**-980.57**	**-902.03**	**-829.06**	**-761.37**	**-698.67**	**-640.66**	**-587.07**	**-537.60**	**-492.00**	**-449.99**	**-411.34**	**-375.81**	**-343.17**
NPC Heating		**-25,850.75**	-2,707.10	-2,463.19	-2,251.62	-2,057.11	-1,878.43	-1,714.43	-1,564.00	-1,426.13	-1,299.85	-1,184.26	-1,078.51	-981.83	-893.49	-812.80	-739.15	-671.95	-610.67	-554.80	-503.90	-457.53
CAPEX_Non-Heating																						
Building																						
	Material	42,069.34	-2,103.47	-2,103.47	-2,103.47	-2,103.47	-2,103.47	-2,103.47	-2,103.47	-2,103.47	-2,103.47	-2,103.47	-2,103.47	-2,103.47	-2,103.47	-2,103.47	-2,103.47	-2,103.47	-2,103.47	-2,103.47	-2,103.47	-2,103.47
	Labour	37,362.98	-1,868.15	-1,868.15	-1,868.15	-1,868.15	-1,868.15	-1,868.15	-1,868.15	-1,868.15	-1,868.15	-1,868.15	-1,868.15	-1,868.15	-1,868.15	-1,868.15	-1,868.15	-1,868.15	-1,868.15	-1,868.15	-1,868.15	-1,868.15
	Total:	**79,432.33**	3,971.62	3,971.62	3,971.62	3,971.62	3,971.62	3,971.62	3,971.62	3,971.62	3,971.62	3,971.62	3,971.62	3,971.62	3,971.62	3,971.62	3,971.62	3,971.62	3,971.62	3,971.62	3,971.62	3,971.62
Aquaponics																						
	Aquaculture system	8,825.00	-441.25	-441.25	-441.25	-441.25	-441.25	-441.25	-441.25	-441.25	-441.25	-441.25	-441.25	-441.25	-441.25	-441.25	-441.25	-441.25	-441.25	-441.25	-441.25	-441.25
	NFT system: Horizontal	11,477.08	-573.85	-573.85	-573.85	-573.85	-573.85	-573.85	-573.85	-573.85	-573.85	-573.85	-573.85	-573.85	-573.85	-573.85	-573.85	-573.85	-573.85	-573.85	-573.85	-573.85
	NFT system : Vertical	22,820.83	-1,141.04	-1,141.04	-1,141.04	-1,141.04	-1,141.04	-1,141.04	-1,141.04	-1,141.04	-1,141.04	-1,141.04	-1,141.04	-1,141.04	-1,141.04	-1,141.04	-1,141.04	-1,141.04	-1,141.04	-1,141.04	-1,141.04	-1,141.04
	Growing lights	20,630.16	-1,031.51	-1,031.51	-1,031.51	-1,031.51	-1,031.51	-1,031.51	-1,031.51	-1,031.51	-1,031.51	-1,031.51	-1,031.51	-1,031.51	-1,031.51	-1,031.51	-1,031.51	-1,031.51	-1,031.51	-1,031.51	-1,031.51	-1,031.51
	Water	138.19	-6.91	-6.91	-6.91	-6.91	-6.91	-6.91	-6.91	-6.91	-6.91	-6.91	-6.91	-6.91	-6.91	-6.91	-6.91	-6.91	-6.91	-6.91	-6.91	-6.91
	Total:	**63,891.27**	3,194.56	3,194.56	3,194.56	3,194.56	3,194.56	3,194.56	3,194.56	3,194.56	3,194.56	3,194.56	3,194.56	3,194.56	3,194.56	3,194.56	3,194.56	3,194.56	3,194.56	3,194.56	3,194.56	3,194.56
Soil-based cultivation																						
	Growing beds	1,031.25	-51.56	-51.56	-51.56	-51.56	-51.56	-51.56	-51.56	-51.56	-51.56	-51.56	-51.56	-51.56	-51.56	-51.56	-51.56	-51.56	-51.56	-51.56	-51.56	-51.56
	Soil	2,062.50	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13
	Total:	**3,093.75**	154.69	154.69	154.69	154.69	154.69	154.69	154.69	154.69	154.69	154.69	154.69	154.69	154.69	154.69	154.69	154.69	154.69	154.69	154.69	154.69
		54,682.80	**-6,536.49**	**-5,836.15**	**-5,210.85**	**-4,652.54**	**-4,154.06**	**-3,708.98**	**-3,311.59**	**-2,956.78**	**-2,639.98**	**-2,357.12**	**-2,104.57**	**-1,879.08**	**-1,677.75**	**-1,497.99**	**-1,337.50**	**-1,194.19**	**-1,066.24**	**-952.00**	**-850.00**	**-758.93**
OPEX_Non-Heating																						
Electricity	Grow lights		-1,859.83	-1,945.48	-2,031.13	-2,116.78	-2,202.43	-2,288.08	-2,373.73	-2,459.38	-2,545.03	-2,630.68	-2,716.33	-2,801.98	-2,887.63	-2,973.28	-3,058.93	-3,144.58	-3,230.23	-3,315.88	-3,401.53	-3,487.18
	Pumps		-265.16	-277.37	-289.58	-301.79	-314.00	-326.22	-338.43	-350.64	-362.85	-375.06	-387.27	-399.48	-411.70	-423.91	-436.12	-448.33	-460.54	-472.75	-484.96	-497.17
Labor			-2,290.00	-2,290.00	-2,290.00	-2,290.00	-2,290.00	-2,290.00	-2,290.00	-2,290.00	-2,290.00	-2,290.00	-2,290.00	-2,290.00	-2,290.00	-2,290.00	-2,290.00	-2,290.00	-2,290.00	-2,290.00	-2,290.00	-2,290.00
Fish feed			-3,019.50	-3,019.50	-3,019.50	-3,019.50	-3,019.50	-3,019.50	-3,019.50	-3,019.50	-3,019.50	-3,019.50	-3,019.50	-3,019.50	-3,019.50	-3,019.50	-3,019.50	-3,019.50	-3,019.50	-3,019.50	-3,019.50	-3,019.50
Maintenance	Building		-897.20	-897.20	-897.20	-897.20	-897.20	-897.20	-897.20	-897.20	-897.20	-897.20	-897.20	-897.20	-897.20	-897.20	-897.20	-897.20	-897.20	-897.20	-897.20	-897.20
	Aquaponics		-1,300.00	-1,300.00	-1,300.00	-1,300.00	-1,300.00	-1,300.00	-1,300.00	-1,300.00	-1,300.00	-1,300.00	-1,300.00	-1,300.00	-1,300.00	-1,300.00	-1,300.00	-1,300.00	-1,300.00	-1,300.00	-1,300.00	-1,300.00
		76,343.93	**-8,599.72**	**-7,756.34**	**-6,994.96**	**-6,307.69**	**-5,687.39**	**-5,127.61**	**-4,622.49**	**-4,166.75**	**-3,755.60**	**-3,384.72**	**-3,050.21**	**-2,748.52**	**-2,476.46**	**-2,231.15**	**-2,009.98**	**-1,810.59**	**-1,630.85**	**-1,468.84**	**-1,322.83**	**-1,191.24**
NPC Total		**-156,877.49**	-17,843.31	-16,055.68	-14,457.43	-13,017.34	-11,719.88	-10,551.02	-9,498.08	-8,549.65	-7,695.43	-6,926.10	-6,233.29	-5,609.43	-5,047.70	-4,541.95	-4,086.62	-3,676.73	-3,307.76	-2,975.64	-2,676.73	-2,407.70
AG yield																						
Fish [CAD/kg]		8.8	2,200.00	2,200.00	2,200.00	2,200.00	2,200.00	2,200.00	2,200.00	2,200.00	2,200.00	2,200.00	2,200.00	2,200.00	2,200.00	2,200.00	2,200.00	2,200.00	2,200.00	2,200.00	2,200.00	2,200.00
Basil: NFT [CAD/kg]		7.5	14,850.00	14,850.00	14,850.00	14,850.00	14,850.00	14,850.00	14,850.00	14,850.00	14,850.00	14,850.00	14,850.00	14,850.00	14,850.00	14,850.00	14,850.00	14,850.00	14,850.00	14,850.00	14,850.00	14,850.00
Lettuce: Soil [CAD/kg]		5	4,950.00	4,950.00	4,950.00	4,950.00	4,950.00	4,950.00	4,950.00	4,950.00	4,950.00	4,950.00	4,950.00	4,950.00	4,950.00	4,950.00	4,950.00	4,950.00	4,950.00	4,950.00	4,950.00	4,950.00
		164,327.76	**19,642.86**	**17,538.27**	**15,659.17**	**13,981.40**	**12,483.39**	**11,145.88**	**9,951.68**	**8,885.43**	**7,933.42**	**7,083.41**	**6,324.47**	**5,646.85**	**5,041.83**	**4,501.64**	**4,019.32**	**3,588.68**	**3,204.18**	**2,860.87**	**2,554.35**	**2,280.67**
NPV Total		**7,450.27**	1,799.55	1,482.58	1,201.74	964.06	763.51	594.87	453.60	335.78	237.99	157.31	91.18	37.42	-5.87	-40.31	-67.31	-88.05	-103.58	-114.77	-122.38	-127.03
		Cumulative	1,799.55	3,282.13	4,483.87	5,447.93	6,211.43	6,806.30	7,259.90	7,595.68	7,833.67	7,990.98	8,082.16	8,119.58	8,113.71	8,073.40	8,006.09	7,918.04	7,814.45	7,699.68	7,577.30	7,450.27
Output																						
Fish waste [kg]		453	453	453	453	453	453	453	453	453	453	453	453	453	453	453	453	453	453	453	453	453
Biomass [kg]		495	495	495	495	495	495	495	495	495	495	495	495	495	495	495	495	495	495	495	495	495

Discount rate 12 [%]

BASE CASE: NATURAL GAS

304 [m2] 6000 [l]

Lifespan	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Years	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**	**2036**	**2037**	**2038**	**2039**	**2040**	**2041**	**2042**	**2043**	**2044**	**2045**
Gas price [CAD/kWh]	0.0134	0.0139	0.0145	0.0151	0.0157	0.0163	0.0168	0.0174	0.0180	0.0186	0.0192	0.0198	0.0203	0.0209	0.0215	0.0221	0.0227	0.0232	0.0238	0.0244	0.0250
Electricity rates [CAD/kWh]	0.104	0.160	0.167	0.175	0.182	0.189	0.197	0.204	0.212	0.219	0.226	0.234	0.241	0.248	0.256	0.263	0.271	0.278	0.285	0.293	0.300
CAPEX_Heating																					
Hydronic radiant heating	12,792.51	- 639.63	- 639.63	- 639.63	- 639.63	- 639.63	- 639.63	- 639.63	- 639.63	- 639.63	- 639.63	- 639.63	- 639.63	- 639.63	- 639.63	- 639.63	- 639.63	- 639.63	- 639.63	- 639.63	- 639.63
Hot water boiler	7,333.33	- 366.67	- 366.67	- 366.67	- 366.67	- 366.67	- 366.67	- 366.67	- 366.67	- 366.67	- 366.67	- 366.67	- 366.67	- 366.67	- 366.67	- 366.67	- 366.67	- 366.67	- 366.67	- 366.67	- 366.67
Buffer tank	1,420.00	- 71.00	- 71.00	- 71.00	- 71.00	- 71.00	- 71.00	- 71.00	- 71.00	- 71.00	- 71.00	- 71.00	- 71.00	- 71.00	- 71.00	- 71.00	- 71.00	- 71.00	- 71.00	- 71.00	- 71.00
Grid access	3,000.00	- 150.00	- 150.00	- 150.00	- 150.00	- 150.00	- 150.00	- 150.00	- 150.00	- 150.00	- 150.00	- 150.00	- 150.00	- 150.00	- 150.00	- 150.00	- 150.00	- 150.00	- 150.00	- 150.00	- 150.00
Total:	**24,545.84**	1,227.29	1,227.29	1,227.29	1,227.29	1,227.29	1,227.29	1,227.29	1,227.29	1,227.29	1,227.29	1,227.29	1,227.29	1,227.29	1,227.29	1,227.29	1,227.29	1,227.29	1,227.29	1,227.29	1,227.29
	9,167.19	**- 1,095.80**	**- 978.39**	**- 873.56**	**- 779.97**	**- 696.40**	**- 621.78**	**- 555.16**	**- 495.68**	**- 442.57**	**- 395.16**	**- 352.82**	**- 315.02**	**- 281.26**	**- 251.13**	**- 224.22**	**- 200.20**	**- 178.75**	**- 159.60**	**- 142.50**	**- 127.23**
OPEX_Heating																					
Fuel (Natural gas)		- 1,612.71	- 1,679.99	- 1,747.27	- 1,814.55	- 1,881.83	- 1,949.11	- 2,016.39	- 2,083.67	- 2,150.95	- 2,218.23	- 2,285.51	- 2,352.79	- 2,420.07	- 2,487.35	- 2,554.63	- 2,621.91	- 2,689.19	- 2,756.47	- 2,823.75	- 2,891.03
Maintenance		- 208.22	- 208.22	- 208.22	- 208.22	- 208.22	- 208.22	- 208.22	- 208.22	- 208.22	- 208.22	- 208.22	- 208.22	- 208.22	- 208.22	- 208.22	- 208.22	- 208.22	- 208.22	- 208.22	- 208.22
Cooling	0.30	- 434.95	- 432.79	- 451.84	- 470.90	- 489.95	- 509.01	- 528.06	- 547.11	- 566.17	- 585.22	- 604.27	- 623.33	- 642.38	- 661.43	- 680.49	- 699.54	- 718.60	- 737.65	- 756.70	- 775.76
Total:		2,255.88	- 2,321.00	- 2,407.33	- 2,493.66	- 2,580.00	- 2,666.33	- 2,752.66	- 2,839.00	- 2,925.33	- 3,011.66	- 3,098.00	- 3,184.33	- 3,270.66	- 3,357.00	- 3,443.33	- 3,529.66	- 3,616.00	- 3,702.33	- 3,788.66	- 3,875.00
Direct CO2 emissions	[t CO2e]	20.63	20.63	20.63	20.63	20.63	20.63	20.63	20.63	20.63	20.63	20.63	20.63	20.63	20.63	20.63	20.63	20.63	20.63	20.63	20.63
Net emissions impact	[t CO2e]	20.63	20.63	20.63	20.63	20.63	20.63	20.63	20.63	20.63	20.63	20.63	20.63	20.63	20.63	20.63	20.63	20.63	20.63	20.63	20.63
	20,592.85	**- 2,014.18**	**- 1,850.29**	**- 1,713.49**	**- 1,584.77**	**- 1,463.96**	**- 1,350.85**	**- 1,245.17**	**- 1,146.62**	**- 1,054.90**	**- 969.68**	**- 890.60**	**- 817.34**	**- 749.55**	**- 686.91**	**- 629.08**	**- 575.76**	**- 526.65**	**- 481.45**	**- 439.89**	**- 401.71**
NPC Heating	**- 29,760.04**	- 3,109.98	- 2,828.68	- 2,587.05	- 2,364.74	- 2,160.36	- 1,972.63	- 1,800.33	- 1,642.31	- 1,497.48	- 1,364.83	- 1,243.42	- 1,132.35	- 1,030.82	- 938.04	- 853.31	- 775.96	- 705.40	- 641.05	- 582.39	- 528.94
CAPEX_Non-Heating																					
Building																					
Material	48,687.79	- 2,434.39	- 2,434.39	- 2,434.39	- 2,434.39	- 2,434.39	- 2,434.39	- 2,434.39	- 2,434.39	- 2,434.39	- 2,434.39	- 2,434.39	- 2,434.39	- 2,434.39	- 2,434.39	- 2,434.39	- 2,434.39	- 2,434.39	- 2,434.39	- 2,434.39	- 2,434.39
Labour	43,396.53	- 2,169.83	- 2,169.83	- 2,169.83	- 2,169.83	- 2,169.83	- 2,169.83	- 2,169.83	- 2,169.83	- 2,169.83	- 2,169.83	- 2,169.83	- 2,169.83	- 2,169.83	- 2,169.83	- 2,169.83	- 2,169.83	- 2,169.83	- 2,169.83	- 2,169.83	- 2,169.83
Total:	**92,084.32**	4,604.22	4,604.22	4,604.22	4,604.22	4,604.22	4,604.22	4,604.22	4,604.22	4,604.22	4,604.22	4,604.22	4,604.22	4,604.22	4,604.22	4,604.22	4,604.22	4,604.22	4,604.22	4,604.22	4,604.22
Aquaponics																					
Aquaculture system	10,590.00	- 529.50	- 529.50	- 529.50	- 529.50	- 529.50	- 529.50	- 529.50	- 529.50	- 529.50	- 529.50	- 529.50	- 529.50	- 529.50	- 529.50	- 529.50	- 529.50	- 529.50	- 529.50	- 529.50	- 529.50
NFT system: Horizontal	13,772.50	- 688.63	- 688.63	- 688.63	- 688.63	- 688.63	- 688.63	- 688.63	- 688.63	- 688.63	- 688.63	- 688.63	- 688.63	- 688.63	- 688.63	- 688.63	- 688.63	- 688.63	- 688.63	- 688.63	- 688.63
NFT system : Vertical	27,385.00	- 1,369.25	- 1,369.25	- 1,369.25	- 1,369.25	- 1,369.25	- 1,369.25	- 1,369.25	- 1,369.25	- 1,369.25	- 1,369.25	- 1,369.25	- 1,369.25	- 1,369.25	- 1,369.25	- 1,369.25	- 1,369.25	- 1,369.25	- 1,369.25	- 1,369.25	- 1,369.25
Growing lights	24,756.19	- 1,237.81	- 1,237.81	- 1,237.81	- 1,237.81	- 1,237.81	- 1,237.81	- 1,237.81	- 1,237.81	- 1,237.81	- 1,237.81	- 1,237.81	- 1,237.81	- 1,237.81	- 1,237.81	- 1,237.81	- 1,237.81	- 1,237.81	- 1,237.81	- 1,237.81	- 1,237.81
Water	165.83	- 8.29	- 8.29	- 8.29	- 8.29	- 8.29	- 8.29	- 8.29	- 8.29	- 8.29	- 8.29	- 8.29	- 8.29	- 8.29	- 8.29	- 8.29	- 8.29	- 8.29	- 8.29	- 8.29	- 8.29
Total:	**76,669.52**	3,833.48	3,833.48	3,833.48	3,833.48	3,833.48	3,833.48	3,833.48	3,833.48	3,833.48	3,833.48	3,833.48	3,833.48	3,833.48	3,833.48	3,833.48	3,833.48	3,833.48	3,833.48	3,833.48	3,833.48
Soil-based cultivation																					
Growing beds	1,237.50	- 61.88	- 61.88	- 61.88	- 61.88	- 61.88	- 61.88	- 61.88	- 61.88	- 61.88	- 61.88	- 61.88	- 61.88	- 61.88	- 61.88	- 61.88	- 61.88	- 61.88	- 61.88	- 61.88	- 61.88
Soil	2,475.00	- 123.75	- 123.75	- 123.75	- 123.75	- 123.75	- 123.75	- 123.75	- 123.75	- 123.75	- 123.75	- 123.75	- 123.75	- 123.75	- 123.75	- 123.75	- 123.75	- 123.75	- 123.75	- 123.75	- 123.75
Total:	**3,712.50**	185.63	185.63	185.63	185.63	185.63	185.63	185.63	185.63	185.63	185.63	185.63	185.63	185.63	185.63	185.63	185.63	185.63	185.63	185.63	185.63
	64,411.38	**- 7,699.39**	**- 6,874.46**	**- 6,137.91**	**- 5,480.27**	**- 4,893.10**	**- 4,368.84**	**- 3,900.75**	**- 3,482.81**	**- 3,109.65**	**- 2,776.48**	**- 2,479.00**	**- 2,213.39**	**- 1,976.24**	**- 1,764.50**	**- 1,575.45**	**- 1,406.65**	**- 1,255.94**	**- 1,121.37**	**- 1,001.23**	**- 893.95**
OPEX_Non-Heating																					
Electricity Grow lights		- 2,231.80	- 2,334.58	- 2,437.36	- 2,540.14	- 2,642.92	- 2,745.70	- 2,848.48	- 2,951.26	- 3,054.04	- 3,156.82	- 3,259.60	- 3,362.38	- 3,465.16	- 3,567.94	- 3,670.72	- 3,773.50	- 3,876.28	- 3,979.06	- 4,081.84	- 4,184.62
Pumps		- 318.19	- 332.85	- 347.50	- 362.15	- 376.81	- 391.46	- 406.11	- 420.77	- 435.42	- 450.07	- 464.73	- 479.38	- 494.03	- 508.69	- 523.34	- 538.00	- 552.65	- 567.30	- 581.96	- 596.61
Labor		- 2,748.00	- 2,748.00	- 2,748.00	- 2,748.00	- 2,748.00	- 2,748.00	- 2,748.00	- 2,748.00	- 2,748.00	- 2,748.00	- 2,748.00	- 2,748.00	- 2,748.00	- 2,748.00	- 2,748.00	- 2,748.00	- 2,748.00	- 2,748.00	- 2,748.00	- 2,748.00
Fish feed		- 3,623.40	- 3,623.40	- 3,623.40	- 3,623.40	- 3,623.40	- 3,623.40	- 3,623.40	- 3,623.40	- 3,623.40	- 3,623.40	- 3,623.40	- 3,623.40	- 3,623.40	- 3,623.40	- 3,623.40	- 3,623.40	- 3,623.40	- 3,623.40	- 3,623.40	- 3,623.40
Maintenance Building		- 1,050.03	- 1,050.03	- 1,050.03	- 1,050.03	- 1,050.03	- 1,050.03	- 1,050.03	- 1,050.03	- 1,050.03	- 1,050.03	- 1,050.03	- 1,050.03	- 1,050.03	- 1,050.03	- 1,050.03	- 1,050.03	- 1,050.03	- 1,050.03	- 1,050.03	- 1,050.03
Aquaponics		- 1,560.00	- 1,560.00	- 1,560.00	- 1,560.00	- 1,560.00	- 1,560.00	- 1,560.00	- 1,560.00	- 1,560.00	- 1,560.00	- 1,560.00	- 1,560.00	- 1,560.00	- 1,560.00	- 1,560.00	- 1,560.00	- 1,560.00	- 1,560.00	- 1,560.00	- 1,560.00
	91,414.01	**- 10,295.91**	**- 9,286.40**	**- 8,375.01**	**- 7,552.32**	**- 6,809.78**	**- 6,139.65**	**- 5,534.96**	**- 4,989.35**	**- 4,497.13**	**- 4,053.10**	**- 3,652.60**	**- 3,291.39**	**- 2,965.66**	**- 2,671.94**	**- 2,407.11**	**- 2,168.36**	**- 1,953.14**	**- 1,759.15**	**- 1,584.30**	**- 1,426.73**
NPC Total	**-185,585.42**	- 21,105.28	- 18,989.53	- 17,099.97	- 15,397.33	- 13,863.24	- 12,481.13	- 11,236.04	- 10,114.47	- 9,104.26	- 8,194.41	- 7,375.02	- 6,637.14	- 5,972.71	- 5,374.48	- 4,835.87	- 4,350.98	- 3,914.48	- 3,521.57	- 3,167.92	- 2,849.62
AG yield																					
Fish [CAD/kg]	8.8	2,640.00	2,640.00	2,640.00	2,640.00	2,640.00	2,640.00	2,640.00	2,640.00	2,640.00	2,640.00	2,640.00	2,640.00	2,640.00	2,640.00	2,640.00	2,640.00	2,640.00	2,640.00	2,640.00	2,640.00
Basil: NFT [CAD/kg]	7.5	17,820.00	17,820.00	17,820.00	17,820.00	17,820.00	17,820.00	17,820.00	17,820.00	17,820.00	17,820.00	17,820.00	17,820.00	17,820.00	17,820.00	17,820.00	17,820.00	17,820.00	17,820.00	17,820.00	17,820.00
Lettuce: Soil [CAD/kg]	5	5,940.00	5,940.00	5,940.00	5,940.00	5,940.00	5,940.00	5,940.00	5,940.00	5,940.00	5,940.00	5,940.00	5,940.00	5,940.00	5,940.00	5,940.00	5,940.00	5,940.00	5,940.00	5,940.00	5,940.00
	197,193.31	**23,571.43**	**21,045.92**	**18,791.00**	**16,777.68**	**14,980.07**	**13,375.06**	**11,942.02**	**10,662.52**	**9,520.10**	**8,500.09**	**7,589.37**	**6,776.22**	**6,050.20**	**5,401.96**	**4,823.18**	**4,306.41**	**3,845.01**	**3,433.05**	**3,065.22**	**2,736.80**
NPV Total	**11,607.89**	2,466.15	2,056.39	1,691.03	1,380.35	1,116.83	893.94	705.98	548.04	415.84	305.68	214.35	139.08	77.48	27.49	- 12.69	- 44.56	- 69.47	- 88.52	- 102.70	- 112.82
Cumulative		2,466.15	4,522.54	6,213.57	7,593.92	8,710.75	9,604.68	10,310.66	10,858.71	11,274.55	11,580.23	11,794.59	11,933.67	12,011.16	12,038.64	12,025.96	11,981.39	11,911.93	11,823.40	11,720.71	11,607.89
Output																					
Fish waste [kg]	544	544	544	544	544	544	544	544	544	544	544	544	544	544	544	544	544	544	544	544	544
Biomass [kg]	594	594	594	594	594	594	594	594	594	594	594	594	594	594	594	594	594	594	594	594	594

Discount rate 12 [%]

BASE CASE: NATURAL GAS 348 [m2] 7000 [l]

Lifespan		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Years		**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**	**2036**	**2037**	**2038**	**2039**	**2040**	**2041**	**2042**	**2043**	**2044**	**2045**
Gas price [CAD/kWh]		0.0134	0.0139	0.0145	0.0151	0.0157	0.0163	0.0168	0.0174	0.0180	0.0186	0.0192	0.0198	0.0203	0.0209	0.0215	0.0221	0.0227	0.0232	0.0238	0.0244	0.0250
Electricity rates [CAD/kWh]		0.104	0.160	0.167	0.175	0.182	0.189	0.197	0.204	0.212	0.219	0.226	0.234	0.241	0.248	0.256	0.263	0.271	0.278	0.285	0.293	0.300
CAPEX_Heating																						
Hydronic radiant heating		14,654.50	-732.73	-732.73	-732.73	-732.73	-732.73	-732.73	-732.73	-732.73	-732.73	-732.73	-732.73	-732.73	-732.73	-732.73	-732.73	-732.73	-732.73	-732.73	-732.73	-732.73
Hot water boiler		7,333.33	-366.67	-366.67	-366.67	-366.67	-366.67	-366.67	-366.67	-366.67	-366.67	-366.67	-366.67	-366.67	-366.67	-366.67	-366.67	-366.67	-366.67	-366.67	-366.67	-366.67
Buffer tank		1,420.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00
Grid access		3,000.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00
	Total:	**26,407.84**	1,320.39	1,320.39	1,320.39	1,320.39	1,320.39	1,320.39	1,320.39	1,320.39	1,320.39	1,320.39	1,320.39	1,320.39	1,320.39	1,320.39	1,320.39	1,320.39	1,320.39	1,320.39	1,320.39	1,320.39
		9,862.59	**-1,178.92**	**-1,052.61**	**-939.83**	**-839.13**	**-749.23**	**-668.95**	**-597.28**	**-533.28**	**-476.15**	**-425.13**	**-379.58**	**-338.91**	**-302.60**	**-270.18**	**-241.23**	**-215.38**	**-192.31**	**-171.70**	**-153.31**	**-136.88**
OPEX_Heating																						
Fuel (Natural gas)			-1,808.37	-1,883.81	-1,959.25	-2,034.70	-2,110.14	-2,185.58	-2,261.02	-2,336.46	-2,411.91	-2,487.35	-2,562.79	-2,638.23	-2,713.68	-2,789.12	-2,864.56	-2,940.00	-3,015.44	-3,090.89	-3,166.33	-3,241.77
Maintenance			-233.48	-233.48	-233.48	-233.48	-233.48	-233.48	-233.48	-233.48	-233.48	-233.48	-233.48	-233.48	-233.48	-233.48	-233.48	-233.48	-233.48	-233.48	-233.48	-233.48
Cooling		0.30	-541.16	-538.07	-561.76	-585.45	-609.14	-632.82	-656.51	-680.20	-703.89	-727.58	-751.27	-774.96	-798.64	-822.33	-846.02	-869.71	-893.40	-917.09	-940.78	-964.46
		Total:	2,583.00	-2,655.36	-2,754.49	-2,853.62	-2,952.75	-3,051.88	-3,151.01	-3,250.14	-3,349.27	-3,448.40	-3,547.54	-3,646.67	-3,745.80	-3,844.93	-3,944.06	-4,043.19	-4,142.32	-4,241.45	-4,340.58	-4,439.71
Direct CO2 emissions		[t CO2e]	23.14	23.14	23.14	23.14	23.14	23.14	23.14	23.14	23.14	23.14	23.14	23.14	23.14	23.14	23.14	23.14	23.14	23.14	23.14	23.14
Net emissions impact		[t CO2e]	23.14	23.14	23.14	23.14	23.14	23.14	23.14	23.14	23.14	23.14	23.14	23.14	23.14	23.14	23.14	23.14	23.14	23.14	23.14	23.14
		23,575.17	**-2,306.25**	**-2,116.84**	**-1,960.59**	**-1,813.53**	**-1,675.47**	**-1,546.18**	**-1,425.36**	**-1,312.68**	**-1,207.78**	**-1,110.29**	**-1,019.83**	**-936.01**	**-858.44**	**-786.75**	**-720.56**	**-659.53**	**-603.31**	**-551.56**	**-503.97**	**-460.25**
NPC Heating		**-33,437.77**	-3,485.17	-3,169.44	-2,900.42	-2,652.66	-2,424.70	-2,215.13	-2,022.64	-1,845.96	-1,683.93	-1,535.42	-1,399.41	-1,274.92	-1,161.04	-1,056.93	-961.80	-874.92	-795.61	-723.26	-657.28	-597.13
CAPEX_Non-Heating																						
Building																						
	Material	52,233.67	-2,611.68	-2,611.68	-2,611.68	-2,611.68	-2,611.68	-2,611.68	-2,611.68	-2,611.68	-2,611.68	-2,611.68	-2,611.68	-2,611.68	-2,611.68	-2,611.68	-2,611.68	-2,611.68	-2,611.68	-2,611.68	-2,611.68	-2,611.68
	Labour	49,430.08	-2,471.50	-2,471.50	-2,471.50	-2,471.50	-2,471.50	-2,471.50	-2,471.50	-2,471.50	-2,471.50	-2,471.50	-2,471.50	-2,471.50	-2,471.50	-2,471.50	-2,471.50	-2,471.50	-2,471.50	-2,471.50	-2,471.50	-2,471.50
	Total:	**101,663.75**	5,083.19	5,083.19	5,083.19	5,083.19	5,083.19	5,083.19	5,083.19	5,083.19	5,083.19	5,083.19	5,083.19	5,083.19	5,083.19	5,083.19	5,083.19	5,083.19	5,083.19	5,083.19	5,083.19	5,083.19
Aquaponics																						
	Aquaculture system	12,355.00	-617.75	-617.75	-617.75	-617.75	-617.75	-617.75	-617.75	-617.75	-617.75	-617.75	-617.75	-617.75	-617.75	-617.75	-617.75	-617.75	-617.75	-617.75	-617.75	-617.75
	NFT system: Horizontal	16,067.92	-803.40	-803.40	-803.40	-803.40	-803.40	-803.40	-803.40	-803.40	-803.40	-803.40	-803.40	-803.40	-803.40	-803.40	-803.40	-803.40	-803.40	-803.40	-803.40	-803.40
	NFT system : Vertical	31,949.17	-1,597.46	-1,597.46	-1,597.46	-1,597.46	-1,597.46	-1,597.46	-1,597.46	-1,597.46	-1,597.46	-1,597.46	-1,597.46	-1,597.46	-1,597.46	-1,597.46	-1,597.46	-1,597.46	-1,597.46	-1,597.46	-1,597.46	-1,597.46
	Growing lights	28,882.22	-1,444.11	-1,444.11	-1,444.11	-1,444.11	-1,444.11	-1,444.11	-1,444.11	-1,444.11	-1,444.11	-1,444.11	-1,444.11	-1,444.11	-1,444.11	-1,444.11	-1,444.11	-1,444.11	-1,444.11	-1,444.11	-1,444.11	-1,444.11
	Water	193.47	-9.67	-9.67	-9.67	-9.67	-9.67	-9.67	-9.67	-9.67	-9.67	-9.67	-9.67	-9.67	-9.67	-9.67	-9.67	-9.67	-9.67	-9.67	-9.67	-9.67
	Total:	**89,447.77**	4,472.39	4,472.39	4,472.39	4,472.39	4,472.39	4,472.39	4,472.39	4,472.39	4,472.39	4,472.39	4,472.39	4,472.39	4,472.39	4,472.39	4,472.39	4,472.39	4,472.39	4,472.39	4,472.39	4,472.39
Soil-based cultivation																						
	Growing beds	1,443.75	-72.19	-72.19	-72.19	-72.19	-72.19	-72.19	-72.19	-72.19	-72.19	-72.19	-72.19	-72.19	-72.19	-72.19	-72.19	-72.19	-72.19	-72.19	-72.19	-72.19
	Soil	2,887.50	-144.38	-144.38	-144.38	-144.38	-144.38	-144.38	-144.38	-144.38	-144.38	-144.38	-144.38	-144.38	-144.38	-144.38	-144.38	-144.38	-144.38	-144.38	-144.38	-144.38
	Total:	**4,331.25**	216.56	216.56	216.56	216.56	216.56	216.56	216.56	216.56	216.56	216.56	216.56	216.56	216.56	216.56	216.56	216.56	216.56	216.56	216.56	216.56
		72,992.44	**-8,725.12**	**-7,790.29**	**-6,955.62**	**-6,210.37**	**-5,544.97**	**-4,950.87**	**-4,420.42**	**-3,946.80**	**-3,523.93**	**-3,146.37**	**-2,809.26**	**-2,508.26**	**-2,239.52**	**-1,999.57**	**-1,785.33**	**-1,594.05**	**-1,423.26**	**-1,270.76**	**-1,134.61**	**-1,013.05**
OPEX_Non-Heating																						
Electricity	Grow lights		-2,603.76	-2,723.67	-2,843.58	-2,963.49	-3,083.40	-3,203.31	-3,323.22	-3,443.13	-3,563.04	-3,682.95	-3,802.86	-3,922.77	-4,042.68	-4,162.59	-4,282.50	-4,402.41	-4,522.32	-4,642.23	-4,762.14	-4,882.06
	Pumps		-371.22	-388.32	-405.42	-422.51	-439.61	-456.70	-473.80	-490.89	-507.99	-525.09	-542.18	-559.28	-576.37	-593.47	-610.57	-627.66	-644.76	-661.85	-678.95	-696.04
Labor			-3,206.00	-3,206.00	-3,206.00	-3,206.00	-3,206.00	-3,206.00	-3,206.00	-3,206.00	-3,206.00	-3,206.00	-3,206.00	-3,206.00	-3,206.00	-3,206.00	-3,206.00	-3,206.00	-3,206.00	-3,206.00	-3,206.00	-3,206.00
Fish feed			-4,227.30	-4,227.30	-4,227.30	-4,227.30	-4,227.30	-4,227.30	-4,227.30	-4,227.30	-4,227.30	-4,227.30	-4,227.30	-4,227.30	-4,227.30	-4,227.30	-4,227.30	-4,227.30	-4,227.30	-4,227.30	-4,227.30	-4,227.30
Maintenance	Building		-1,202.87	-1,202.87	-1,202.87	-1,202.87	-1,202.87	-1,202.87	-1,202.87	-1,202.87	-1,202.87	-1,202.87	-1,202.87	-1,202.87	-1,202.87	-1,202.87	-1,202.87	-1,202.87	-1,202.87	-1,202.87	-1,202.87	-1,202.87
	Aquaponics		-1,820.00	-1,820.00	-1,820.00	-1,820.00	-1,820.00	-1,820.00	-1,820.00	-1,820.00	-1,820.00	-1,820.00	-1,820.00	-1,820.00	-1,820.00	-1,820.00	-1,820.00	-1,820.00	-1,820.00	-1,820.00	-1,820.00	-1,820.00
		106,484.08	**-11,992.10**	**-10,816.46**	**-9,755.07**	**-8,796.95**	**-7,932.16**	**-7,151.70**	**-6,447.42**	**-5,811.96**	**-5,238.65**	**-4,721.48**	**-4,255.00**	**-3,834.27**	**-3,454.85**	**-3,112.72**	**-2,804.25**	**-2,526.14**	**-2,275.44**	**-2,049.46**	**-1,845.78**	**-1,662.22**
NPC Total		**-212,914.29**	-24,202.40	-21,776.19	-19,611.10	-17,659.98	-15,901.83	-14,317.70	-12,890.47	-11,604.72	-10,446.51	-9,403.27	-8,463.66	-7,617.45	-6,855.41	-6,169.22	-5,551.38	-4,995.11	-4,494.31	-4,043.48	-3,637.67	-3,272.40
AG yield																						
Fish [CAD/kg]		8.8	3,080.00	3,080.00	3,080.00	3,080.00	3,080.00	3,080.00	3,080.00	3,080.00	3,080.00	3,080.00	3,080.00	3,080.00	3,080.00	3,080.00	3,080.00	3,080.00	3,080.00	3,080.00	3,080.00	3,080.00
Basil: NFT [CAD/kg]		7.5	20,790.00	20,790.00	20,790.00	20,790.00	20,790.00	20,790.00	20,790.00	20,790.00	20,790.00	20,790.00	20,790.00	20,790.00	20,790.00	20,790.00	20,790.00	20,790.00	20,790.00	20,790.00	20,790.00	20,790.00
Lettuce: Soil [CAD/kg]		5	6,930.00	6,930.00	6,930.00	6,930.00	6,930.00	6,930.00	6,930.00	6,930.00	6,930.00	6,930.00	6,930.00	6,930.00	6,930.00	6,930.00	6,930.00	6,930.00	6,930.00	6,930.00	6,930.00	6,930.00
		230,058.86	**27,500.00**	**24,553.57**	**21,922.83**	**19,573.96**	**17,476.75**	**15,604.24**	**13,932.36**	**12,439.60**	**11,106.79**	**9,916.78**	**8,854.26**	**7,905.59**	**7,058.57**	**6,302.29**	**5,627.04**	**5,024.15**	**4,485.85**	**4,005.22**	**3,576.09**	**3,192.94**
NPV Total		**17,144.58**	3,297.60	2,777.38	2,311.73	1,913.97	1,574.92	1,286.54	1,041.88	834.88	660.27	513.50	390.60	288.14	203.15	133.07	75.67	29.04	-8.46	-38.26	-61.58	-79.46
		Cumulative	3,297.60	6,074.98	8,386.71	10,300.69	11,875.60	13,162.14	14,204.02	15,038.90	15,699.18	16,212.68	16,603.28	16,891.42	17,094.57	17,227.63	17,303.30	17,332.34	17,323.88	17,285.62	17,224.04	17,144.58
Output																						
Fish waste [kg]		634	634	634	634	634	634	634	634	634	634	634	634	634	634	634	634	634	634	634	634	634
Biomass [kg]		693	693	693	693	693	693	693	693	693	693	693	693	693	693	693	693	693	693	693	693	693

Discount rate 12 [%]

BASE CASE: NATURAL GAS

392 [m2] 8000 [l]

Lifespan	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Years	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**	**2036**	**2037**	**2038**	**2039**	**2040**	**2041**	**2042**	**2043**	**2044**	**2045**
Gas price [CAD/kWh]	0.0134	0.0139	0.0145	0.0151	0.0157	0.0163	0.0168	0.0174	0.0180	0.0186	0.0192	0.0198	0.0203	0.0209	0.0215	0.0221	0.0227	0.0232	0.0238	0.0244	0.0250
Electricity rates [CAD/kWh]	0.104	0.160	0.167	0.175	0.182	0.189	0.197	0.204	0.212	0.219	0.226	0.234	0.241	0.248	0.256	0.263	0.271	0.278	0.285	0.293	0.300
CAPEX_Heating																					
Hydronic radiant heating	16,516.50	-825.82	-825.82	-825.82	-825.82	-825.82	-825.82	-825.82	-825.82	-825.82	-825.82	-825.82	-825.82	-825.82	-825.82	-825.82	-825.82	-825.82	-825.82	-825.82	-825.82
Hot water boiler	8,033.33	-401.67	-401.67	-401.67	-401.67	-401.67	-401.67	-401.67	-401.67	-401.67	-401.67	-401.67	-401.67	-401.67	-401.67	-401.67	-401.67	-401.67	-401.67	-401.67	-401.67
Buffer tank	1,420.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00
Grid access	3,000.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00
Total:	**28,969.83**	1,448.49	1,448.49	1,448.49	1,448.49	1,448.49	1,448.49	1,448.49	1,448.49	1,448.49	1,448.49	1,448.49	1,448.49	1,448.49	1,448.49	1,448.49	1,448.49	1,448.49	1,448.49	1,448.49	1,448.49
	10,819.43	**-1,293.30**	**-1,154.73**	**-1,031.01**	**-920.54**	**-821.91**	**-733.85**	**-655.22**	**-585.02**	**-522.34**	**-466.38**	**-416.41**	**-371.79**	**-331.96**	**-296.39**	**-264.63**	**-236.28**	**-210.96**	**-188.36**	**-168.18**	**-150.16**
OPEX_Heating																					
Fuel (Natural gas)		-2,005.90	-2,089.59	-2,173.27	-2,256.95	-2,340.64	-2,424.32	-2,508.00	-2,591.68	-2,675.37	-2,759.05	-2,842.73	-2,926.42	-3,010.10	-3,093.78	-3,177.47	-3,261.15	-3,344.83	-3,428.51	-3,512.20	-3,595.88
Maintenance		-258.98	-258.98	-258.98	-258.98	-258.98	-258.98	-258.98	-258.98	-258.98	-258.98	-258.98	-258.98	-258.98	-258.98	-258.98	-258.98	-258.98	-258.98	-258.98	-258.98
Cooling	0.30	-648.89	-646.56	-675.03	-703.49	-731.95	-760.42	-788.88	-817.35	-845.81	-874.28	-902.74	-931.21	-959.67	-988.14	-1,016.60	-1,045.07	-1,073.53	-1,102.00	-1,130.46	-1,158.93
Total:		2,913.78	-2,995.13	-3,107.28	-3,219.42	-3,331.57	-3,443.72	-3,555.87	-3,668.02	-3,780.16	-3,892.31	-4,004.46	-4,116.61	-4,228.75	-4,340.90	-4,453.05	-4,565.20	-4,677.35	-4,789.49	-4,901.64	-5,013.79
Direct CO2 emissions	[t CO2e]	25.67	25.67	25.67	25.67	25.67	25.67	25.67	25.67	25.67	25.67	25.67	25.67	25.67	25.67	25.67	25.67	25.67	25.67	25.67	25.67
Net emissions impact	[t CO2e]	25.67	25.67	25.67	25.67	25.67	25.67	25.67	25.67	25.67	25.67	25.67	25.67	25.67	25.67	25.67	25.67	25.67	25.67	25.67	25.67
	26,604.77	**-2,601.59**	**-2,387.70**	**-2,211.70**	**-2,046.00**	**-1,890.42**	**-1,744.70**	**-1,608.49**	**-1,481.45**	**-1,363.16**	**-1,253.22**	**-1,151.19**	**-1,056.63**	**-969.12**	**-888.23**	**-813.56**	**-744.68**	**-681.23**	**-622.82**	**-569.11**	**-519.76**
NPC Heating	**-37,424.20**	-3,894.88	-3,542.43	-3,242.71	-2,966.54	-2,712.34	-2,478.55	-2,263.72	-2,066.47	-1,885.51	-1,719.60	-1,567.59	-1,428.42	-1,301.08	-1,184.62	-1,078.19	-980.96	-892.19	-811.19	-737.29	-669.92
CAPEX_Non-Heating																					
Building																					
Material	58,484.42	-2,924.22	-2,924.22	-2,924.22	-2,924.22	-2,924.22	-2,924.22	-2,924.22	-2,924.22	-2,924.22	-2,924.22	-2,924.22	-2,924.22	-2,924.22	-2,924.22	-2,924.22	-2,924.22	-2,924.22	-2,924.22	-2,924.22	-2,924.22
Labour	55,463.63	-2,773.18	-2,773.18	-2,773.18	-2,773.18	-2,773.18	-2,773.18	-2,773.18	-2,773.18	-2,773.18	-2,773.18	-2,773.18	-2,773.18	-2,773.18	-2,773.18	-2,773.18	-2,773.18	-2,773.18	-2,773.18	-2,773.18	-2,773.18
Total:	**113,948.05**	5,697.40	5,697.40	5,697.40	5,697.40	5,697.40	5,697.40	5,697.40	5,697.40	5,697.40	5,697.40	5,697.40	5,697.40	5,697.40	5,697.40	5,697.40	5,697.40	5,697.40	5,697.40	5,697.40	5,697.40
Aquaponics																					
Aquaculture system	14,120.00	-706.00	-706.00	-706.00	-706.00	-706.00	-706.00	-706.00	-706.00	-706.00	-706.00	-706.00	-706.00	-706.00	-706.00	-706.00	-706.00	-706.00	-706.00	-706.00	-706.00
NFT system: Horizontal	18,363.33	-918.17	-918.17	-918.17	-918.17	-918.17	-918.17	-918.17	-918.17	-918.17	-918.17	-918.17	-918.17	-918.17	-918.17	-918.17	-918.17	-918.17	-918.17	-918.17	-918.17
NFT system : Vertical	36,513.33	-1,825.67	-1,825.67	-1,825.67	-1,825.67	-1,825.67	-1,825.67	-1,825.67	-1,825.67	-1,825.67	-1,825.67	-1,825.67	-1,825.67	-1,825.67	-1,825.67	-1,825.67	-1,825.67	-1,825.67	-1,825.67	-1,825.67	-1,825.67
Growing lights	33,008.25	-1,650.41	-1,650.41	-1,650.41	-1,650.41	-1,650.41	-1,650.41	-1,650.41	-1,650.41	-1,650.41	-1,650.41	-1,650.41	-1,650.41	-1,650.41	-1,650.41	-1,650.41	-1,650.41	-1,650.41	-1,650.41	-1,650.41	-1,650.41
Water	221.11	-11.06	-11.06	-11.06	-11.06	-11.06	-11.06	-11.06	-11.06	-11.06	-11.06	-11.06	-11.06	-11.06	-11.06	-11.06	-11.06	-11.06	-11.06	-11.06	-11.06
Total:	**102,226.03**	5,111.30	5,111.30	5,111.30	5,111.30	5,111.30	5,111.30	5,111.30	5,111.30	5,111.30	5,111.30	5,111.30	5,111.30	5,111.30	5,111.30	5,111.30	5,111.30	5,111.30	5,111.30	5,111.30	5,111.30
Soil-based cultivation																					
Growing beds	1,650.00	-82.50	-82.50	-82.50	-82.50	-82.50	-82.50	-82.50	-82.50	-82.50	-82.50	-82.50	-82.50	-82.50	-82.50	-82.50	-82.50	-82.50	-82.50	-82.50	-82.50
Soil	3,300.00	-165.00	-165.00	-165.00	-165.00	-165.00	-165.00	-165.00	-165.00	-165.00	-165.00	-165.00	-165.00	-165.00	-165.00	-165.00	-165.00	-165.00	-165.00	-165.00	-165.00
Total:	**4,950.00**	247.50	247.50	247.50	247.50	247.50	247.50	247.50	247.50	247.50	247.50	247.50	247.50	247.50	247.50	247.50	247.50	247.50	247.50	247.50	247.50
	82,583.69	**-9,871.61**	**-8,813.94**	**-7,869.59**	**-7,026.42**	**-6,273.59**	**-5,601.42**	**-5,001.27**	**-4,465.42**	**-3,986.98**	**-3,559.80**	**-3,178.39**	**-2,837.85**	**-2,533.80**	**-2,262.32**	**-2,019.93**	**-1,803.51**	**-1,610.27**	**-1,437.74**	**-1,283.70**	**-1,146.16**
OPEX_Non-Heating																					
Electricity	Grow lights	-2,975.73	-3,112.77	-3,249.81	-3,386.85	-3,523.89	-3,660.93	-3,797.97	-3,935.01	-4,072.05	-4,209.09	-4,346.13	-4,483.17	-4,620.21	-4,757.25	-4,894.29	-5,031.33	-5,168.37	-5,305.41	-5,442.45	-5,579.49
	Pumps	-424.26	-443.79	-463.33	-482.87	-502.41	-521.95	-541.48	-561.02	-580.56	-600.10	-619.64	-639.17	-658.71	-678.25	-697.79	-717.33	-736.86	-756.40	-775.94	-795.48
Labor		-3,664.00	-3,664.00	-3,664.00	-3,664.00	-3,664.00	-3,664.00	-3,664.00	-3,664.00	-3,664.00	-3,664.00	-3,664.00	-3,664.00	-3,664.00	-3,664.00	-3,664.00	-3,664.00	-3,664.00	-3,664.00	-3,664.00	-3,664.00
Fish feed		-4,831.20	-4,831.20	-4,831.20	-4,831.20	-4,831.20	-4,831.20	-4,831.20	-4,831.20	-4,831.20	-4,831.20	-4,831.20	-4,831.20	-4,831.20	-4,831.20	-4,831.20	-4,831.20	-4,831.20	-4,831.20	-4,831.20	-4,831.20
Maintenance	Building	-1,355.71	-1,355.71	-1,355.71	-1,355.71	-1,355.71	-1,355.71	-1,355.71	-1,355.71	-1,355.71	-1,355.71	-1,355.71	-1,355.71	-1,355.71	-1,355.71	-1,355.71	-1,355.71	-1,355.71	-1,355.71	-1,355.71	-1,355.71
	Aquaponics	-2,080.00	-2,080.00	-2,080.00	-2,080.00	-2,080.00	-2,080.00	-2,080.00	-2,080.00	-2,080.00	-2,080.00	-2,080.00	-2,080.00	-2,080.00	-2,080.00	-2,080.00	-2,080.00	-2,080.00	-2,080.00	-2,080.00	-2,080.00
	121,554.16	**-13,688.29**	**-12,346.51**	**-11,135.12**	**-10,041.58**	**-9,054.55**	**-8,163.74**	**-7,359.88**	**-6,634.56**	**-5,980.18**	**-5,389.86**	**-4,857.39**	**-4,377.14**	**-3,944.05**	**-3,553.51**	**-3,201.38**	**-2,883.92**	**-2,597.73**	**-2,339.77**	**-2,107.26**	**-1,897.71**
NPC Total	**-241,562.05**	-27,454.79	-24,702.88	-22,247.42	-20,034.54	-18,040.47	-16,243.71	-14,624.87	-13,166.45	-11,852.66	-10,669.26	-9,603.38	-8,643.42	-7,778.92	-7,000.45	-6,299.50	-5,668.39	-5,100.20	-4,588.70	-4,128.25	-3,713.80
AG yield																					
Fish [CAD/kg]	8.8	3,520.00	3,520.00	3,520.00	3,520.00	3,520.00	3,520.00	3,520.00	3,520.00	3,520.00	3,520.00	3,520.00	3,520.00	3,520.00	3,520.00	3,520.00	3,520.00	3,520.00	3,520.00	3,520.00	3,520.00
Basil: NFT [CAD/kg]	7.5	23,760.00	23,760.00	23,760.00	23,760.00	23,760.00	23,760.00	23,760.00	23,760.00	23,760.00	23,760.00	23,760.00	23,760.00	23,760.00	23,760.00	23,760.00	23,760.00	23,760.00	23,760.00	23,760.00	23,760.00
Lettuce: Soil [CAD/kg]	5	7,920.00	7,920.00	7,920.00	7,920.00	7,920.00	7,920.00	7,920.00	7,920.00	7,920.00	7,920.00	7,920.00	7,920.00	7,920.00	7,920.00	7,920.00	7,920.00	7,920.00	7,920.00	7,920.00	7,920.00
	262,924.42	**31,428.57**	**28,061.22**	**25,054.66**	**22,370.24**	**19,973.43**	**17,833.42**	**15,922.69**	**14,216.69**	**12,693.47**	**11,333.46**	**10,119.16**	**9,034.96**	**8,066.93**	**7,202.62**	**6,430.91**	**5,741.88**	**5,126.68**	**4,577.39**	**4,086.96**	**3,649.07**
NPV Total	**21,362.37**	3,973.78	3,358.35	2,807.25	2,335.69	1,932.96	1,589.71	1,297.83	1,050.24	840.81	664.20	515.78	391.54	288.01	202.16	131.41	73.49	26.48	-11.30	-41.29	-64.73
	Cumulative	3,973.78	7,332.13	10,139.38	12,475.07	14,408.03	15,997.74	17,295.56	18,345.80	19,186.61	19,850.81	20,366.59	20,758.13	21,046.14	21,248.31	21,379.71	21,453.21	21,479.69	21,468.39	21,427.09	21,362.37
Output																					
Fish waste [kg]	725	725	725	725	725	725	725	725	725	725	725	725	725	725	725	725	725	725	725	725	725
Biomass [kg]	792	792	792	792	792	792	792	792	792	792	792	792	792	792	792	792	792	792	792	792	792

Discount rate 12 [%]

BASE CASE: NATURAL GAS

436 [m2] 9000 [l]

Lifespan		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Years		**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**	**2036**	**2037**	**2038**	**2039**	**2040**	**2041**	**2042**	**2043**	**2044**	**2045**
Gas price [CAD/kWh]		0.0134	0.0139	0.0145	0.0151	0.0157	0.0163	0.0168	0.0174	0.0180	0.0186	0.0192	0.0198	0.0203	0.0209	0.0215	0.0221	0.0227	0.0232	0.0238	0.0244	0.0250
Electricity rates [CAD/kWh]		0.104	0.160	0.167	0.175	0.182	0.189	0.197	0.204	0.212	0.219	0.226	0.234	0.241	0.248	0.256	0.263	0.271	0.278	0.285	0.293	0.300
CAPEX_Heating																						
Hydronic radiant heating		18,378.49	-918.92	-918.92	-918.92	-918.92	-918.92	-918.92	-918.92	-918.92	-918.92	-918.92	-918.92	-918.92	-918.92	-918.92	-918.92	-918.92	-918.92	-918.92	-918.92	-918.92
Hot water boiler		8,033.33	-401.67	-401.67	-401.67	-401.67	-401.67	-401.67	-401.67	-401.67	-401.67	-401.67	-401.67	-401.67	-401.67	-401.67	-401.67	-401.67	-401.67	-401.67	-401.67	-401.67
Buffer tank		1,775.00	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75
Grid access		3,000.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00
	Total:	**31,186.83**	1,559.34	1,559.34	1,559.34	1,559.34	1,559.34	1,559.34	1,559.34	1,559.34	1,559.34	1,559.34	1,559.34	1,559.34	1,559.34	1,559.34	1,559.34	1,559.34	1,559.34	1,559.34	1,559.34	1,559.34
		11,647.41	**-1,392.27**	**-1,243.10**	**-1,109.91**	**-990.99**	**-884.81**	**-790.01**	**-705.37**	**-629.79**	**-562.31**	**-502.07**	**-448.27**	**-400.24**	**-357.36**	**-319.07**	**-284.89**	**-254.36**	**-227.11**	**-202.78**	**-181.05**	**-161.65**
OPEX_Heating																						
Fuel (Natural gas)			-2,204.47	-2,296.43	-2,388.40	-2,480.37	-2,572.33	-2,664.30	-2,756.27	-2,848.23	-2,940.20	-3,032.17	-3,124.13	-3,216.10	-3,308.07	-3,400.03	-3,492.00	-3,583.97	-3,675.93	-3,767.90	-3,859.87	-3,951.83
Maintenance			-284.62	-284.62	-284.62	-284.62	-284.62	-284.62	-284.62	-284.62	-284.62	-284.62	-284.62	-284.62	-284.62	-284.62	-284.62	-284.62	-284.62	-284.62	-284.62	-284.62
Cooling		0.30	-757.47	-756.81	-790.13	-823.45	-856.76	-890.08	-923.40	-956.72	-990.04	-1,023.36	-1,056.68	-1,090.00	-1,123.31	-1,156.63	-1,189.95	-1,223.27	-1,256.59	-1,289.91	-1,323.23	-1,356.54
	Total:		3,246.56	-3,337.86	-3,463.14	-3,588.43	-3,713.71	-3,839.00	-3,964.28	-4,089.57	-4,214.86	-4,340.14	-4,465.43	-4,590.71	-4,716.00	-4,841.28	-4,966.57	-5,091.85	-5,217.14	-5,342.42	-5,467.71	-5,592.99
Direct CO2 emissions		[t CO2e]	28.21	28.21	28.21	28.21	28.21	28.21	28.21	28.21	28.21	28.21	28.21	28.21	28.21	28.21	28.21	28.21	28.21	28.21	28.21	28.21
Net emissions impact		[t CO2e]	28.21	28.21	28.21	28.21	28.21	28.21	28.21	28.21	28.21	28.21	28.21	28.21	28.21	28.21	28.21	28.21	28.21	28.21	28.21	28.21
		29,660.25	**-2,898.71**	**-2,660.92**	**-2,465.00**	**-2,280.51**	**-2,107.26**	**-1,944.96**	**-1,793.24**	**-1,651.71**	**-1,519.92**	**-1,397.41**	**-1,283.70**	**-1,178.32**	**-1,080.78**	**-990.62**	**-907.37**	**-830.59**	**-759.85**	**-694.73**	**-634.84**	**-579.81**
NPC Heating		**-41,307.66**	-4,290.98	-3,904.02	-3,574.91	-3,271.50	-2,992.07	-2,734.97	-2,498.61	-2,281.50	-2,082.23	-1,899.48	-1,731.98	-1,578.57	-1,438.15	-1,309.69	-1,192.26	-1,084.95	-986.96	-897.50	-815.89	-741.46
CAPEX_Non-Heating																						
Building																						
	Material	60,927.23	-3,046.36	-3,046.36	-3,046.36	-3,046.36	-3,046.36	-3,046.36	-3,046.36	-3,046.36	-3,046.36	-3,046.36	-3,046.36	-3,046.36	-3,046.36	-3,046.36	-3,046.36	-3,046.36	-3,046.36	-3,046.36	-3,046.36	-3,046.36
	Labour	61,497.18	-3,074.86	-3,074.86	-3,074.86	-3,074.86	-3,074.86	-3,074.86	-3,074.86	-3,074.86	-3,074.86	-3,074.86	-3,074.86	-3,074.86	-3,074.86	-3,074.86	-3,074.86	-3,074.86	-3,074.86	-3,074.86	-3,074.86	-3,074.86
	Total:	**122,424.40**	6,121.22	6,121.22	6,121.22	6,121.22	6,121.22	6,121.22	6,121.22	6,121.22	6,121.22	6,121.22	6,121.22	6,121.22	6,121.22	6,121.22	6,121.22	6,121.22	6,121.22	6,121.22	6,121.22	6,121.22
Aquaponics																						
	Aquaculture system	15,885.00	-794.25	-794.25	-794.25	-794.25	-794.25	-794.25	-794.25	-794.25	-794.25	-794.25	-794.25	-794.25	-794.25	-794.25	-794.25	-794.25	-794.25	-794.25	-794.25	-794.25
	NFT system: Horizontal	20,658.75	-1,032.94	-1,032.94	-1,032.94	-1,032.94	-1,032.94	-1,032.94	-1,032.94	-1,032.94	-1,032.94	-1,032.94	-1,032.94	-1,032.94	-1,032.94	-1,032.94	-1,032.94	-1,032.94	-1,032.94	-1,032.94	-1,032.94	-1,032.94
	NFT system : Vertical	41,077.50	-2,053.88	-2,053.88	-2,053.88	-2,053.88	-2,053.88	-2,053.88	-2,053.88	-2,053.88	-2,053.88	-2,053.88	-2,053.88	-2,053.88	-2,053.88	-2,053.88	-2,053.88	-2,053.88	-2,053.88	-2,053.88	-2,053.88	-2,053.88
	Growing lights	37,134.28	-1,856.71	-1,856.71	-1,856.71	-1,856.71	-1,856.71	-1,856.71	-1,856.71	-1,856.71	-1,856.71	-1,856.71	-1,856.71	-1,856.71	-1,856.71	-1,856.71	-1,856.71	-1,856.71	-1,856.71	-1,856.71	-1,856.71	-1,856.71
	Water	248.74	-12.44	-12.44	-12.44	-12.44	-12.44	-12.44	-12.44	-12.44	-12.44	-12.44	-12.44	-12.44	-12.44	-12.44	-12.44	-12.44	-12.44	-12.44	-12.44	-12.44
	Total:	**115,004.28**	5,750.21	5,750.21	5,750.21	5,750.21	5,750.21	5,750.21	5,750.21	5,750.21	5,750.21	5,750.21	5,750.21	5,750.21	5,750.21	5,750.21	5,750.21	5,750.21	5,750.21	5,750.21	5,750.21	5,750.21
Soil-based cultivation																						
	Growing beds	1,856.25	-92.81	-92.81	-92.81	-92.81	-92.81	-92.81	-92.81	-92.81	-92.81	-92.81	-92.81	-92.81	-92.81	-92.81	-92.81	-92.81	-92.81	-92.81	-92.81	-92.81
	Soil	3,712.50	-185.63	-185.63	-185.63	-185.63	-185.63	-185.63	-185.63	-185.63	-185.63	-185.63	-185.63	-185.63	-185.63	-185.63	-185.63	-185.63	-185.63	-185.63	-185.63	-185.63
	Total:	**5,568.75**	278.44	278.44	278.44	278.44	278.44	278.44	278.44	278.44	278.44	278.44	278.44	278.44	278.44	278.44	278.44	278.44	278.44	278.44	278.44	278.44
		90,752.78	**-10,848.10**	**-9,685.80**	**-8,648.04**	**-7,721.46**	**-6,894.16**	**-6,155.50**	**-5,495.98**	**-4,907.13**	**-4,381.37**	**-3,911.93**	**-3,492.80**	**-3,118.57**	**-2,784.44**	**-2,486.10**	**-2,219.74**	**-1,981.91**	**-1,769.56**	**-1,579.96**	**-1,410.68**	**-1,259.54**
OPEX_Non-Heating																						
Electricity	Grow lights		-3,347.69	-3,501.87	-3,656.04	-3,810.21	-3,964.38	-4,118.55	-4,272.72	-4,426.89	-4,581.06	-4,735.23	-4,889.40	-5,043.57	-5,197.74	-5,351.91	-5,506.08	-5,660.25	-5,814.42	-5,968.59	-6,122.76	-6,276.93
	Pumps		-477.29	-499.27	-521.25	-543.23	-565.21	-587.19	-609.17	-631.15	-653.13	-675.11	-697.09	-719.07	-741.05	-763.03	-785.01	-806.99	-828.97	-850.95	-872.93	-894.91
Labor			-4,122.00	-4,122.00	-4,122.00	-4,122.00	-4,122.00	-4,122.00	-4,122.00	-4,122.00	-4,122.00	-4,122.00	-4,122.00	-4,122.00	-4,122.00	-4,122.00	-4,122.00	-4,122.00	-4,122.00	-4,122.00	-4,122.00	-4,122.00
Fish feed			-5,435.10	-5,435.10	-5,435.10	-5,435.10	-5,435.10	-5,435.10	-5,435.10	-5,435.10	-5,435.10	-5,435.10	-5,435.10	-5,435.10	-5,435.10	-5,435.10	-5,435.10	-5,435.10	-5,435.10	-5,435.10	-5,435.10	-5,435.10
Maintenance	Building		-1,508.54	-1,508.54	-1,508.54	-1,508.54	-1,508.54	-1,508.54	-1,508.54	-1,508.54	-1,508.54	-1,508.54	-1,508.54	-1,508.54	-1,508.54	-1,508.54	-1,508.54	-1,508.54	-1,508.54	-1,508.54	-1,508.54	-1,508.54
	Aquaponics		-2,340.00	-2,340.00	-2,340.00	-2,340.00	-2,340.00	-2,340.00	-2,340.00	-2,340.00	-2,340.00	-2,340.00	-2,340.00	-2,340.00	-2,340.00	-2,340.00	-2,340.00	-2,340.00	-2,340.00	-2,340.00	-2,340.00	-2,340.00
		136,624.23	**-15,384.49**	**-13,876.57**	**-12,515.18**	**-11,286.21**	**-10,176.93**	**-9,175.79**	**-8,272.35**	**-7,457.17**	**-6,721.71**	**-6,058.24**	**-5,459.78**	**-4,920.02**	**-4,433.24**	**-3,994.30**	**-3,598.52**	**-3,241.70**	**-2,920.03**	**-2,630.07**	**-2,368.73**	**-2,133.20**
NPC Total		**-268,684.67**	-30,523.56	-27,466.39	-24,738.12	-22,279.18	-20,063.17	-18,066.26	-16,266.94	-14,645.80	-13,185.31	-11,869.65	-10,684.56	-9,617.15	-8,655.83	-7,790.10	-7,010.51	-6,308.56	-5,676.54	-5,107.54	-4,595.30	-4,134.20
AG yield																						
Fish [CAD/kg]		8.8	3,960.00	3,960.00	3,960.00	3,960.00	3,960.00	3,960.00	3,960.00	3,960.00	3,960.00	3,960.00	3,960.00	3,960.00	3,960.00	3,960.00	3,960.00	3,960.00	3,960.00	3,960.00	3,960.00	3,960.00
Basil: NFT [CAD/kg]		7.5	26,730.00	26,730.00	26,730.00	26,730.00	26,730.00	26,730.00	26,730.00	26,730.00	26,730.00	26,730.00	26,730.00	26,730.00	26,730.00	26,730.00	26,730.00	26,730.00	26,730.00	26,730.00	26,730.00	26,730.00
Lettuce: Soil [CAD/kg]		5	8,910.00	8,910.00	8,910.00	8,910.00	8,910.00	8,910.00	8,910.00	8,910.00	8,910.00	8,910.00	8,910.00	8,910.00	8,910.00	8,910.00	8,910.00	8,910.00	8,910.00	8,910.00	8,910.00	8,910.00
		295,789.97	**35,357.14**	**31,568.88**	**28,186.50**	**25,166.52**	**22,470.10**	**20,062.59**	**17,913.03**	**15,993.78**	**14,280.16**	**12,750.14**	**11,384.05**	**10,164.33**	**9,075.30**	**8,102.94**	**7,234.77**	**6,459.62**	**5,767.52**	**5,149.57**	**4,597.83**	**4,105.20**
NPV Total		**27,105.29**	4,833.58	4,102.48	3,448.38	2,887.34	2,406.94	1,996.34	1,646.09	1,347.98	1,094.85	880.49	699.50	547.18	419.47	312.85	224.26	151.06	90.97	42.03	2.52	-28.99
		Cumulative	4,833.58	8,936.06	12,384.44	15,271.77	17,678.71	19,675.05	21,321.14	22,669.11	23,763.96	24,644.45	25,343.95	25,891.13	26,310.60	26,623.45	26,847.71	26,998.76	27,089.74	27,131.76	27,134.29	27,105.29
Output																						
Fish waste [kg]		815	815	815	815	815	815	815	815	815	815	815	815	815	815	815	815	815	815	815	815	815
Biomass [kg]		891	891	891	891	891	891	891	891	891	891	891	891	891	891	891	891	891	891	891	891	891

Discount rate 12 [%]

BASE CASE: NATURAL GAS

481 [m2] 10000 [l]

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Lifespan	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Years	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**	**2036**	**2037**	**2038**	**2039**	**2040**	**2041**	**2042**	**2043**	**2044**	**2045**
Gas price [CAD/kWh]	0.0134	0.0139	0.0145	0.0151	0.0157	0.0163	0.0168	0.0174	0.0180	0.0186	0.0192	0.0198	0.0203	0.0209	0.0215	0.0221	0.0227	0.0232	0.0238	0.0244	0.0250
Electricity rates [CAD/kWh]	0.104	0.160	0.167	0.175	0.182	0.189	0.197	0.204	0.212	0.219	0.226	0.234	0.241	0.248	0.256	0.263	0.271	0.278	0.285	0.293	0.300
CAPEX_Heating																					
Hydronic radiant heating	20,240.49	-1,012.02	-1,012.02	-1,012.02	-1,012.02	-1,012.02	-1,012.02	-1,012.02	-1,012.02	-1,012.02	-1,012.02	-1,012.02	-1,012.02	-1,012.02	-1,012.02	-1,012.02	-1,012.02	-1,012.02	-1,012.02	-1,012.02	-1,012.02
Hot water boiler	9,082.91	-454.15	-454.15	-454.15	-454.15	-454.15	-454.15	-454.15	-454.15	-454.15	-454.15	-454.15	-454.15	-454.15	-454.15	-454.15	-454.15	-454.15	-454.15	-454.15	-454.15
Buffer tank	1,775.00	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75
Grid access	3,000.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00
Total:	**34,098.40**	1,704.92	1,704.92	1,704.92	1,704.92	1,704.92	1,704.92	1,704.92	1,704.92	1,704.92	1,704.92	1,704.92	1,704.92	1,704.92	1,704.92	1,704.92	1,704.92	1,704.92	1,704.92	1,704.92	1,704.92
	12,734.81	**-1,522.25**	**-1,359.15**	**-1,213.53**	**-1,083.51**	**-967.42**	**-863.77**	**-771.22**	**-688.59**	**-614.81**	**-548.94**	**-490.12**	**-437.61**	**-390.72**	**-348.86**	**-311.48**	**-278.11**	**-248.31**	**-221.71**	**-197.95**	**-176.74**
OPEX_Heating																					
Fuel (Natural gas)		-2,412.93	-2,513.60	-2,614.26	-2,714.92	-2,815.59	-2,916.25	-3,016.91	-3,117.58	-3,218.24	-3,318.90	-3,419.57	-3,520.23	-3,620.89	-3,721.56	-3,822.22	-3,922.89	-4,023.55	-4,124.21	-4,224.88	-4,325.54
Maintenance		-311.53	-311.53	-311.53	-311.53	-311.53	-311.53	-311.53	-311.53	-311.53	-311.53	-311.53	-311.53	-311.53	-311.53	-311.53	-311.53	-311.53	-311.53	-311.53	-311.53
Cooling	0.30	-1,018.39	-1,024.67	-1,069.78	-1,114.89	-1,160.00	-1,205.11	-1,250.23	-1,295.34	-1,340.45	-1,385.56	-1,430.67	-1,475.78	-1,520.89	-1,566.00	-1,611.12	-1,656.23	-1,701.34	-1,746.45	-1,791.56	-1,836.67
Total:		3,742.86	-3,849.80	-3,995.57	-4,141.35	-4,287.12	-4,432.90	-4,578.67	-4,724.45	-4,870.22	-5,016.00	-5,161.77	-5,307.55	-5,453.32	-5,599.09	-5,744.87	-5,890.64	-6,036.42	-6,182.19	-6,327.97	-6,473.74
Direct CO2 emissions	[t CO2e]	30.87	30.87	30.87	30.87	30.87	30.87	30.87	30.87	30.87	30.87	30.87	30.87	30.87	30.87	30.87	30.87	30.87	30.87	30.87	30.87
Net emissions impact	[t CO2e]	30.87	30.87	30.87	30.87	30.87	30.87	30.87	30.87	30.87	30.87	30.87	30.87	30.87	30.87	30.87	30.87	30.87	30.87	30.87	30.87
	34,256.80	**-3,341.84**	**-3,069.04**	**-2,843.97**	**-2,631.90**	**-2,432.63**	**-2,245.84**	**-2,071.16**	**-1,908.12**	**-1,756.25**	**-1,615.02**	**-1,483.89**	**-1,362.31**	**-1,249.76**	**-1,145.69**	**-1,049.57**	**-960.89**	**-879.17**	**-803.93**	**-734.72**	**-671.11**
NPC Heating	**-46,991.61**	-4,864.09	-4,428.19	-4,057.50	-3,715.41	-3,400.05	-3,109.61	-2,842.38	-2,596.71	-2,371.06	-2,163.96	-1,974.01	-1,799.93	-1,640.48	-1,494.55	-1,361.05	-1,239.00	-1,127.48	-1,025.64	-932.67	-847.86
CAPEX_Non-Heating																					
Building																					
Material	69,137.60	-3,456.88	-3,456.88	-3,456.88	-3,456.88	-3,456.88	-3,456.88	-3,456.88	-3,456.88	-3,456.88	-3,456.88	-3,456.88	-3,456.88	-3,456.88	-3,456.88	-3,456.88	-3,456.88	-3,456.88	-3,456.88	-3,456.88	-3,456.88
Labour	69,801.60	-3,490.08	-3,490.08	-3,490.08	-3,490.08	-3,490.08	-3,490.08	-3,490.08	-3,490.08	-3,490.08	-3,490.08	-3,490.08	-3,490.08	-3,490.08	-3,490.08	-3,490.08	-3,490.08	-3,490.08	-3,490.08	-3,490.08	-3,490.08
Total:	**138,939.19**	6,946.96	6,946.96	6,946.96	6,946.96	6,946.96	6,946.96	6,946.96	6,946.96	6,946.96	6,946.96	6,946.96	6,946.96	6,946.96	6,946.96	6,946.96	6,946.96	6,946.96	6,946.96	6,946.96	6,946.96
Aquaponics																					
Aquaculture system	17,650.00	-882.50	-882.50	-882.50	-882.50	-882.50	-882.50	-882.50	-882.50	-882.50	-882.50	-882.50	-882.50	-882.50	-882.50	-882.50	-882.50	-882.50	-882.50	-882.50	-882.50
NFT system: Horizontal	22,954.17	-1,147.71	-1,147.71	-1,147.71	-1,147.71	-1,147.71	-1,147.71	-1,147.71	-1,147.71	-1,147.71	-1,147.71	-1,147.71	-1,147.71	-1,147.71	-1,147.71	-1,147.71	-1,147.71	-1,147.71	-1,147.71	-1,147.71	-1,147.71
NFT system : Vertical	45,641.67	-2,282.08	-2,282.08	-2,282.08	-2,282.08	-2,282.08	-2,282.08	-2,282.08	-2,282.08	-2,282.08	-2,282.08	-2,282.08	-2,282.08	-2,282.08	-2,282.08	-2,282.08	-2,282.08	-2,282.08	-2,282.08	-2,282.08	-2,282.08
Growing lights	41,260.32	-2,063.02	-2,063.02	-2,063.02	-2,063.02	-2,063.02	-2,063.02	-2,063.02	-2,063.02	-2,063.02	-2,063.02	-2,063.02	-2,063.02	-2,063.02	-2,063.02	-2,063.02	-2,063.02	-2,063.02	-2,063.02	-2,063.02	-2,063.02
Water	276.38	-13.82	-13.82	-13.82	-13.82	-13.82	-13.82	-13.82	-13.82	-13.82	-13.82	-13.82	-13.82	-13.82	-13.82	-13.82	-13.82	-13.82	-13.82	-13.82	-13.82
Total:	**127,782.53**	6,389.13	6,389.13	6,389.13	6,389.13	6,389.13	6,389.13	6,389.13	6,389.13	6,389.13	6,389.13	6,389.13	6,389.13	6,389.13	6,389.13	6,389.13	6,389.13	6,389.13	6,389.13	6,389.13	6,389.13
Soil-based cultivation																					
Growing beds	2,062.50	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13
Soil	4,125.00	-206.25	-206.25	-206.25	-206.25	-206.25	-206.25	-206.25	-206.25	-206.25	-206.25	-206.25	-206.25	-206.25	-206.25	-206.25	-206.25	-206.25	-206.25	-206.25	-206.25
Total:	**6,187.50**	309.38	309.38	309.38	309.38	309.38	309.38	309.38	309.38	309.38	309.38	309.38	309.38	309.38	309.38	309.38	309.38	309.38	309.38	309.38	309.38
	101,924.00	**-12,183.45**	**-10,878.08**	**-9,712.57**	**-8,671.94**	**-7,742.80**	**-6,913.22**	**-6,172.51**	**-5,511.17**	**-4,920.69**	**-4,393.47**	**-3,922.74**	**-3,502.45**	**-3,127.19**	**-2,792.13**	**-2,492.97**	**-2,225.87**	**-1,987.38**	**-1,774.45**	**-1,584.33**	**-1,414.58**
OPEX_Non-Heating																					
Electricity: Grow lights		-3,719.66	-3,890.96	-4,062.26	-4,233.56	-4,404.86	-4,576.16	-4,747.46	-4,918.76	-5,090.06	-5,261.36	-5,432.66	-5,603.96	-5,775.26	-5,946.56	-6,117.86	-6,289.16	-6,460.46	-6,631.76	-6,803.06	-6,974.36
Pumps		-530.32	-554.74	-579.16	-603.59	-628.01	-652.43	-676.85	-701.28	-725.70	-750.12	-774.55	-798.97	-823.39	-847.81	-872.24	-896.66	-921.08	-945.50	-969.93	-994.35
Labor		-4,580.00	-4,580.00	-4,580.00	-4,580.00	-4,580.00	-4,580.00	-4,580.00	-4,580.00	-4,580.00	-4,580.00	-4,580.00	-4,580.00	-4,580.00	-4,580.00	-4,580.00	-4,580.00	-4,580.00	-4,580.00	-4,580.00	-4,580.00
Fish feed		-6,039.00	-6,039.00	-6,039.00	-6,039.00	-6,039.00	-6,039.00	-6,039.00	-6,039.00	-6,039.00	-6,039.00	-6,039.00	-6,039.00	-6,039.00	-6,039.00	-6,039.00	-6,039.00	-6,039.00	-6,039.00	-6,039.00	-6,039.00
Maintenance: Building		-1,661.38	-1,661.38	-1,661.38	-1,661.38	-1,661.38	-1,661.38	-1,661.38	-1,661.38	-1,661.38	-1,661.38	-1,661.38	-1,661.38	-1,661.38	-1,661.38	-1,661.38	-1,661.38	-1,661.38	-1,661.38	-1,661.38	-1,661.38
Aquaponics		-2,600.00	-2,600.00	-2,600.00	-2,600.00	-2,600.00	-2,600.00	-2,600.00	-2,600.00	-2,600.00	-2,600.00	-2,600.00	-2,600.00	-2,600.00	-2,600.00	-2,600.00	-2,600.00	-2,600.00	-2,600.00	-2,600.00	-2,600.00
	151,694.31	**-17,080.68**	**-15,406.63**	**-13,895.23**	**-12,530.84**	**-11,299.31**	**-10,187.83**	**-9,184.81**	**-8,279.77**	**-7,463.24**	**-6,726.62**	**-6,062.18**	**-5,462.90**	**-4,922.44**	**-4,435.08**	**-3,995.65**	**-3,599.48**	**-3,242.32**	**-2,920.38**	**-2,630.21**	**-2,368.69**
NPC Total	**-300,609.92**	-34,128.21	-30,712.90	-27,665.30	-24,918.19	-22,442.16	-20,210.66	-18,199.70	-16,387.66	-14,754.99	-13,284.05	-11,958.93	-10,765.27	-9,690.11	-8,721.76	-7,849.68	-7,064.35	-6,357.19	-5,720.47	-5,147.21	-4,631.13
AG yield																					
Fish [CAD/kg]	8.8	4,400.00	4,400.00	4,400.00	4,400.00	4,400.00	4,400.00	4,400.00	4,400.00	4,400.00	4,400.00	4,400.00	4,400.00	4,400.00	4,400.00	4,400.00	4,400.00	4,400.00	4,400.00	4,400.00	4,400.00
Basil: NFT [CAD/kg]	7.5	29,700.00	29,700.00	29,700.00	29,700.00	29,700.00	29,700.00	29,700.00	29,700.00	29,700.00	29,700.00	29,700.00	29,700.00	29,700.00	29,700.00	29,700.00	29,700.00	29,700.00	29,700.00	29,700.00	29,700.00
Lettuce: Soil [CAD/kg]	5	9,900.00	9,900.00	9,900.00	9,900.00	9,900.00	9,900.00	9,900.00	9,900.00	9,900.00	9,900.00	9,900.00	9,900.00	9,900.00	9,900.00	9,900.00	9,900.00	9,900.00	9,900.00	9,900.00	9,900.00
	328,655.52	**39,285.71**	**35,076.53**	**31,318.33**	**27,962.80**	**24,966.78**	**22,291.77**	**19,903.37**	**17,770.86**	**15,866.84**	**14,166.82**	**12,648.95**	**11,293.70**	**10,083.66**	**9,003.27**	**8,038.64**	**7,177.35**	**6,408.35**	**5,721.74**	**5,108.70**	**4,561.34**
NPV Total	**28,045.60**	5,157.50	4,363.63	3,653.03	3,044.60	2,524.62	2,081.11	1,703.66	1,383.20	1,111.85	882.77	690.02	528.43	393.55	281.51	188.96	113.01	51.16	1.27	-38.51	-69.79
Cumulative		5,157.50	9,521.14	13,174.16	16,218.77	18,743.39	20,824.51	22,528.17	23,911.37	25,023.22	25,906.00	26,596.01	27,124.45	27,518.00	27,799.51	27,988.47	28,101.47	28,152.64	28,153.91	28,115.39	28,045.60
Output																					
Fish waste [kg]	906	906	906	906	906	906	906	906	906	906	906	906	906	906	906	906	906	906	906	906	906
Biomass [kg]	990	990	990	990	990	990	990	990	990	990	990	990	990	990	990	990	990	990	990	990	990

Discount rate 12 [%]

BASE CASE: NATURAL GAS

525 [m2] 11000 [l]

Lifespan	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Years	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**	**2036**	**2037**	**2038**	**2039**	**2040**	**2041**	**2042**	**2043**	**2044**	**2045**
Gas price [CAD/kWh]	0.0134	0.0139	0.0145	0.0151	0.0157	0.0163	0.0168	0.0174	0.0180	0.0186	0.0192	0.0198	0.0203	0.0209	0.0215	0.0221	0.0227	0.0232	0.0238	0.0244	0.0250
Electricity rates [CAD/kWh]	0.104	0.160	0.167	0.175	0.182	0.189	0.197	0.204	0.212	0.219	0.226	0.234	0.241	0.248	0.256	0.263	0.271	0.278	0.285	0.293	0.300
CAPEX_Heating																					
Hydronic radiant heating	22,102.48	- 1,105.12	- 1,105.12	- 1,105.12	- 1,105.12	- 1,105.12	- 1,105.12	- 1,105.12	- 1,105.12	- 1,105.12	- 1,105.12	- 1,105.12	- 1,105.12	- 1,105.12	- 1,105.12	- 1,105.12	- 1,105.12	- 1,105.12	- 1,105.12	- 1,105.12	- 1,105.12
Hot water boiler	9,082.91	- 454.15	- 454.15	- 454.15	- 454.15	- 454.15	- 454.15	- 454.15	- 454.15	- 454.15	- 454.15	- 454.15	- 454.15	- 454.15	- 454.15	- 454.15	- 454.15	- 454.15	- 454.15	- 454.15	- 454.15
Buffer tank	1,775.00	- 88.75	- 88.75	- 88.75	- 88.75	- 88.75	- 88.75	- 88.75	- 88.75	- 88.75	- 88.75	- 88.75	- 88.75	- 88.75	- 88.75	- 88.75	- 88.75	- 88.75	- 88.75	- 88.75	- 88.75
Grid access	3,000.00	- 150.00	- 150.00	- 150.00	- 150.00	- 150.00	- 150.00	- 150.00	- 150.00	- 150.00	- 150.00	- 150.00	- 150.00	- 150.00	- 150.00	- 150.00	- 150.00	- 150.00	- 150.00	- 150.00	- 150.00
Total:	**35,960.40**	1,798.02	1,798.02	1,798.02	1,798.02	1,798.02	1,798.02	1,798.02	1,798.02	1,798.02	1,798.02	1,798.02	1,798.02	1,798.02	1,798.02	1,798.02	1,798.02	1,798.02	1,798.02	1,798.02	1,798.02
	13,430.21	**- 1,605.37**	**- 1,433.37**	**- 1,279.80**	**- 1,142.67**	**- 1,020.24**	**- 910.93**	**- 813.33**	**- 726.19**	**- 648.38**	**- 578.91**	**- 516.89**	**- 461.51**	**- 412.06**	**- 367.91**	**- 328.49**	**- 293.30**	**- 261.87**	**- 233.81**	**- 208.76**	**- 186.39**
OPEX_Heating																					
Fuel (Natural gas)		- 2,618.47	- 2,727.71	- 2,836.94	- 2,946.18	- 3,055.42	- 3,164.66	- 3,273.90	- 3,383.14	- 3,492.37	- 3,601.61	- 3,710.85	- 3,820.09	- 3,929.33	- 4,038.56	- 4,147.80	- 4,257.04	- 4,366.28	- 4,475.52	- 4,584.75	- 4,693.99
Maintenance		- 338.07	- 338.07	- 338.07	- 338.07	- 338.07	- 338.07	- 338.07	- 338.07	- 338.07	- 338.07	- 338.07	- 338.07	- 338.07	- 338.07	- 338.07	- 338.07	- 338.07	- 338.07	- 338.07	- 338.07
Cooling	0.30	- 1,147.96	- 1,156.88	- 1,207.81	- 1,258.74	- 1,309.68	- 1,360.61	- 1,411.54	- 1,462.47	- 1,513.40	- 1,564.34	- 1,615.27	- 1,666.20	- 1,717.13	- 1,768.06	- 1,819.00	- 1,869.93	- 1,920.86	- 1,971.79	- 2,022.72	- 2,073.65
	Total:	4,104.50	- 4,222.66	- 4,382.83	- 4,543.00	- 4,703.17	- 4,863.34	- 5,023.51	- 5,183.68	- 5,343.85	- 5,504.02	- 5,664.19	- 5,824.36	- 5,984.53	- 6,144.69	- 6,304.86	- 6,465.03	- 6,625.20	- 6,785.37	- 6,945.54	- 7,105.71
Direct CO2 emissions	[t CO2e]	33.50	33.50	33.50	33.50	33.50	33.50	33.50	33.50	33.50	33.50	33.50	33.50	33.50	33.50	33.50	33.50	33.50	33.50	33.50	33.50
Net emissions impact	[t CO2e]	33.50	33.50	33.50	33.50	33.50	33.50	33.50	33.50	33.50	33.50	33.50	33.50	33.50	33.50	33.50	33.50	33.50	33.50	33.50	33.50
	37,584.47	**- 3,664.73**	**- 3,366.28**	**- 3,119.61**	**- 2,887.16**	**- 2,668.70**	**- 2,463.92**	**- 2,272.38**	**- 2,093.60**	**- 1,927.04**	**- 1,772.15**	**- 1,628.32**	**- 1,494.97**	**- 1,371.50**	**- 1,257.33**	**- 1,151.88**	**- 1,054.59**	**- 964.92**	**- 882.37**	**- 806.42**	**- 736.63**
NPC Heating	**- 51,014.68**	- 5,270.11	- 4,799.65	- 4,399.40	- 4,029.83	- 3,688.95	- 3,374.85	- 3,085.71	- 2,819.79	- 2,575.43	- 2,351.06	- 2,145.21	- 1,956.47	- 1,783.56	- 1,625.24	- 1,480.37	- 1,347.88	- 1,226.80	- 1,116.18	- 1,015.19	- 923.02
CAPEX_Non-Heating																					
Building																					
Material	70,527.84	- 3,526.39	- 3,526.39	- 3,526.39	- 3,526.39	- 3,526.39	- 3,526.39	- 3,526.39	- 3,526.39	- 3,526.39	- 3,526.39	- 3,526.39	- 3,526.39	- 3,526.39	- 3,526.39	- 3,526.39	- 3,526.39	- 3,526.39	- 3,526.39	- 3,526.39	- 3,526.39
Labour	76,036.14	- 3,801.81	- 3,801.81	- 3,801.81	- 3,801.81	- 3,801.81	- 3,801.81	- 3,801.81	- 3,801.81	- 3,801.81	- 3,801.81	- 3,801.81	- 3,801.81	- 3,801.81	- 3,801.81	- 3,801.81	- 3,801.81	- 3,801.81	- 3,801.81	- 3,801.81	- 3,801.81
Total:	**146,563.98**	7,328.20	7,328.20	7,328.20	7,328.20	7,328.20	7,328.20	7,328.20	7,328.20	7,328.20	7,328.20	7,328.20	7,328.20	7,328.20	7,328.20	7,328.20	7,328.20	7,328.20	7,328.20	7,328.20	7,328.20
Aquaponics																					
Aquaculture system	19,415.00	- 970.75	- 970.75	- 970.75	- 970.75	- 970.75	- 970.75	- 970.75	- 970.75	- 970.75	- 970.75	- 970.75	- 970.75	- 970.75	- 970.75	- 970.75	- 970.75	- 970.75	- 970.75	- 970.75	- 970.75
NFT system: Horizontal	25,249.58	- 1,262.48	- 1,262.48	- 1,262.48	- 1,262.48	- 1,262.48	- 1,262.48	- 1,262.48	- 1,262.48	- 1,262.48	- 1,262.48	- 1,262.48	- 1,262.48	- 1,262.48	- 1,262.48	- 1,262.48	- 1,262.48	- 1,262.48	- 1,262.48	- 1,262.48	- 1,262.48
NFT system : Vertical	50,205.83	- 2,510.29	- 2,510.29	- 2,510.29	- 2,510.29	- 2,510.29	- 2,510.29	- 2,510.29	- 2,510.29	- 2,510.29	- 2,510.29	- 2,510.29	- 2,510.29	- 2,510.29	- 2,510.29	- 2,510.29	- 2,510.29	- 2,510.29	- 2,510.29	- 2,510.29	- 2,510.29
Growing lights	45,386.35	- 2,269.32	- 2,269.32	- 2,269.32	- 2,269.32	- 2,269.32	- 2,269.32	- 2,269.32	- 2,269.32	- 2,269.32	- 2,269.32	- 2,269.32	- 2,269.32	- 2,269.32	- 2,269.32	- 2,269.32	- 2,269.32	- 2,269.32	- 2,269.32	- 2,269.32	- 2,269.32
Water	304.02	- 15.20	- 15.20	- 15.20	- 15.20	- 15.20	- 15.20	- 15.20	- 15.20	- 15.20	- 15.20	- 15.20	- 15.20	- 15.20	- 15.20	- 15.20	- 15.20	- 15.20	- 15.20	- 15.20	- 15.20
Total:	**140,560.78**	7,028.04	7,028.04	7,028.04	7,028.04	7,028.04	7,028.04	7,028.04	7,028.04	7,028.04	7,028.04	7,028.04	7,028.04	7,028.04	7,028.04	7,028.04	7,028.04	7,028.04	7,028.04	7,028.04	7,028.04
Soil-based cultivation																					
Growing beds	2,268.75	- 113.44	- 113.44	- 113.44	- 113.44	- 113.44	- 113.44	- 113.44	- 113.44	- 113.44	- 113.44	- 113.44	- 113.44	- 113.44	- 113.44	- 113.44	- 113.44	- 113.44	- 113.44	- 113.44	- 113.44
Soil	4,537.50	- 226.88	- 226.88	- 226.88	- 226.88	- 226.88	- 226.88	- 226.88	- 226.88	- 226.88	- 226.88	- 226.88	- 226.88	- 226.88	- 226.88	- 226.88	- 226.88	- 226.88	- 226.88	- 226.88	- 226.88
Total:	**6,806.25**	340.31	340.31	340.31	340.31	340.31	340.31	340.31	340.31	340.31	340.31	340.31	340.31	340.31	340.31	340.31	340.31	340.31	340.31	340.31	340.31
	109,775.06	**- 13,121.92**	**- 11,716.00**	**- 10,460.71**	**- 9,339.92**	**- 8,339.22**	**- 7,445.73**	**- 6,647.97**	**- 5,935.69**	**- 5,299.72**	**- 4,731.90**	**- 4,224.91**	**- 3,772.24**	**- 3,368.07**	**- 3,007.21**	**- 2,685.00**	**- 2,397.33**	**- 2,140.47**	**- 1,911.13**	**- 1,706.37**	**- 1,523.54**
OPEX_Non-Heating																					
Electricity	Grow lights	- 4,091.63	- 4,280.06	- 4,468.49	- 4,656.92	- 4,845.35	- 5,033.78	- 5,222.21	- 5,410.64	- 5,599.07	- 5,787.50	- 5,975.93	- 6,164.36	- 6,352.79	- 6,541.22	- 6,729.65	- 6,918.08	- 7,106.51	- 7,294.94	- 7,483.37	- 7,671.80
	Pumps	- 583.35	- 610.22	- 637.08	- 663.95	- 690.81	- 717.68	- 744.54	- 771.41	- 798.27	- 825.14	- 852.00	- 878.86	- 905.73	- 932.59	- 959.46	- 986.32	- 1,013.19	- 1,040.05	- 1,066.92	- 1,093.78
Labor		- 5,038.00	- 5,038.00	- 5,038.00	- 5,038.00	- 5,038.00	- 5,038.00	- 5,038.00	- 5,038.00	- 5,038.00	- 5,038.00	- 5,038.00	- 5,038.00	- 5,038.00	- 5,038.00	- 5,038.00	- 5,038.00	- 5,038.00	- 5,038.00	- 5,038.00	- 5,038.00
Fish feed		- 6,642.90	- 6,642.90	- 6,642.90	- 6,642.90	- 6,642.90	- 6,642.90	- 6,642.90	- 6,642.90	- 6,642.90	- 6,642.90	- 6,642.90	- 6,642.90	- 6,642.90	- 6,642.90	- 6,642.90	- 6,642.90	- 6,642.90	- 6,642.90	- 6,642.90	- 6,642.90
Maintenance	Building	- 1,814.21	- 1,814.21	- 1,814.21	- 1,814.21	- 1,814.21	- 1,814.21	- 1,814.21	- 1,814.21	- 1,814.21	- 1,814.21	- 1,814.21	- 1,814.21	- 1,814.21	- 1,814.21	- 1,814.21	- 1,814.21	- 1,814.21	- 1,814.21	- 1,814.21	- 1,814.21
	Aquaponics	- 2,860.00	- 2,860.00	- 2,860.00	- 2,860.00	- 2,860.00	- 2,860.00	- 2,860.00	- 2,860.00	- 2,860.00	- 2,860.00	- 2,860.00	- 2,860.00	- 2,860.00	- 2,860.00	- 2,860.00	- 2,860.00	- 2,860.00	- 2,860.00	- 2,860.00	- 2,860.00
	166,764.38	**- 18,776.87**	**- 16,936.69**	**- 15,275.29**	**- 13,775.48**	**- 12,421.70**	**- 11,199.87**	**- 10,097.28**	**- 9,102.38**	**- 8,204.76**	**- 7,395.00**	**- 6,664.57**	**- 6,005.77**	**- 5,411.64**	**- 4,875.87**	**- 4,392.79**	**- 3,957.25**	**- 3,564.62**	**- 3,210.69**	**- 2,891.69**	**- 2,604.18**
NPC Total	**-327,554.12**	- 37,168.89	- 33,452.34	- 30,135.41	- 27,145.23	- 24,449.86	- 22,020.45	- 19,830.96	- 17,857.86	- 16,079.91	- 14,477.96	- 13,034.68	- 11,734.48	- 10,563.26	- 9,508.31	- 8,558.16	- 7,702.46	- 6,931.88	- 6,238.01	- 5,613.24	- 5,050.75
AG yield																					
Fish [CAD/kg]	8.8	4,840.00	4,840.00	4,840.00	4,840.00	4,840.00	4,840.00	4,840.00	4,840.00	4,840.00	4,840.00	4,840.00	4,840.00	4,840.00	4,840.00	4,840.00	4,840.00	4,840.00	4,840.00	4,840.00	4,840.00
Basil: NFT [CAD/kg]	7.5	32,670.00	32,670.00	32,670.00	32,670.00	32,670.00	32,670.00	32,670.00	32,670.00	32,670.00	32,670.00	32,670.00	32,670.00	32,670.00	32,670.00	32,670.00	32,670.00	32,670.00	32,670.00	32,670.00	32,670.00
Lettuce: Soil [CAD/kg]	5	10,890.00	10,890.00	10,890.00	10,890.00	10,890.00	10,890.00	10,890.00	10,890.00	10,890.00	10,890.00	10,890.00	10,890.00	10,890.00	10,890.00	10,890.00	10,890.00	10,890.00	10,890.00	10,890.00	10,890.00
	361,521.07	**43,214.29**	**38,584.18**	**34,450.16**	**30,759.07**	**27,463.46**	**24,520.95**	**21,893.70**	**19,547.95**	**17,453.53**	**15,583.50**	**13,913.84**	**12,423.07**	**11,092.03**	**9,903.60**	**8,842.50**	**7,895.09**	**7,049.19**	**6,293.92**	**5,619.57**	**5,017.47**
NPV Total	**33,966.95**	6,045.39	5,131.85	4,314.76	3,613.85	3,013.60	2,500.49	2,062.74	1,690.09	1,373.61	1,105.55	879.16	688.59	528.77	395.29	284.34	192.63	117.30	55.91	6.33	- 33.28
	Cumulative	6,045.39	11,177.24	15,491.99	19,105.84	22,119.44	24,619.93	26,682.67	28,372.76	29,746.37	30,851.92	31,731.08	32,419.67	32,948.44	33,343.72	33,628.06	33,820.69	33,937.99	33,993.90	34,000.23	33,966.95
Output																					
Fish waste [kg]	996	996	996	996	996	996	996	996	996	996	996	996	996	996	996	996	996	996	996	996	996
Biomass [kg]	1089	1089	1089	1089	1089	1089	1089	1089	1089	1089	1089	1089	1089	1089	1089	1089	1089	1089	1089	1089	1089

C.1.2. Biomass boiler

Increasing greenhouse size per page.

Discount rate 12 [%]

BIOMASS BOILER

260 [m2] 5000 [l]

Lifespan	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Years	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**	**2036**	**2037**	**2038**	**2039**	**2040**	**2041**	**2042**	**2043**	**2044**	**2045**
Wood chip price [CAD/t]	95.0	97	99	101	103	105	107	109	111	114	116	118	120	123	125	128	130	133	136	138	141
Electricity rates [CAD/kWh]	0.104	0.160	0.167	0.175	0.182	0.189	0.197	0.204	0.212	0.219	0.226	0.234	0.241	0.248	0.256	0.263	0.271	0.278	0.285	0.293	0.300
Carbon offset price [CAD/t]	95	110	125	140	155	170	172	174	176	178	180	182	184	186	188	190	192	194	196	198	200
CAPEX_Heating																					
Hydronic radiant heating	10,930.51	-546.53	-546.53	-546.53	-546.53	-546.53	-546.53	-546.53	-546.53	-546.53	-546.53	-546.53	-546.53	-546.53	-546.53	-546.53	-546.53	-546.53	-546.53	-546.53	-546.53
Biomass boiler	10,300.00	-515.00	-515.00	-515.00	-515.00	-515.00	-515.00	-515.00	-515.00	-515.00	-515.00	-515.00	-515.00	-515.00	-515.00	-515.00	-515.00	-515.00	-515.00	-515.00	-515.00
Buffer tank	3,900.00	-195.00	-195.00	-195.00	-195.00	-195.00	-195.00	-195.00	-195.00	-195.00	-195.00	-195.00	-195.00	-195.00	-195.00	-195.00	-195.00	-195.00	-195.00	-195.00	-195.00
Total:	**25,130.51**	1,256.53	1,256.53	1,256.53	1,256.53	1,256.53	1,256.53	1,256.53	1,256.53	1,256.53	1,256.53	1,256.53	1,256.53	1,256.53	1,256.53	1,256.53	1,256.53	1,256.53	1,256.53	1,256.53	1,256.53
	9,385.55	**-1,121.90**	**-1,001.69**	**-894.37**	**-798.54**	**-712.99**	**-636.59**	**-568.39**	**-507.49**	**-453.12**	**-404.57**	**-361.22**	**-322.52**	**-287.96**	**-257.11**	**-229.56**	**-204.97**	**-183.01**	**-163.40**	**-145.89**	**-130.26**
OPEX_Heating																					
Fuel (biomass) [t]	23.35	-2,262.56	-2,307.82	-2,353.97	-2,401.05	-2,449.07	-2,498.05	-2,548.01	-2,598.97	-2,650.95	-2,703.97	-2,758.05	-2,813.21	-2,869.48	-2,926.87	-2,985.41	-3,045.11	-3,106.02	-3,168.14	-3,231.50	-3,296.13
Maintenance		-643.80	-643.80	-643.80	-643.80	-643.80	-643.80	-643.80	-643.80	-643.80	-643.80	-643.80	-643.80	-643.80	-643.80	-643.80	-643.80	-643.80	-643.80	-643.80	-643.80
Cooling	0.30	-328.75	-327.51	-341.93	-356.35	-370.77	-385.19	-399.60	-414.02	-428.44	-442.86	-457.28	-471.70	-486.12	-500.54	-514.95	-529.37	-543.79	-558.21	-572.63	-587.05
Transport		-1,192.23	-1,192.23	-1,192.23	-1,192.23	-1,192.23	-1,192.23	-1,192.23	-1,192.23	-1,192.23	-1,192.23	-1,192.23	-1,192.23	-1,192.23	-1,192.23	-1,192.23	-1,192.23	-1,192.23	-1,192.23	-1,192.23	-1,192.23
Labour		-389.46	-389.46	-389.46	-389.46	-389.46	-389.46	-389.46	-389.46	-389.46	-389.46	-389.46	-389.46	-389.46	-389.46	-389.46	-389.46	-389.46	-389.46	-389.46	-389.46
Total:		4,816.81	4,860.82	4,921.40	4,982.89	5,045.33	5,108.73	5,173.11	5,238.49	5,304.89	5,372.33	5,440.83	5,510.41	5,581.09	5,652.90	5,725.85	5,799.98	5,875.30	5,951.84	6,029.62	6,108.67
Net emissions impact	[t CO2e]	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58
	38,764.49	**-4,300.72**	**-3,875.02**	**-3,502.95**	**-3,166.72**	**-2,862.86**	**-2,588.24**	**-2,340.05**	**-2,115.74**	**-1,913.00**	**-1,729.75**	**-1,564.11**	**-1,414.38**	**-1,279.04**	**-1,156.69**	**-1,046.09**	**-946.10**	**-855.70**	**-773.97**	**-700.08**	**-633.27**
NPC Heating	**-48,150.04**	-5,422.62	-4,876.71	-4,397.32	-3,965.26	-3,575.84	-3,224.84	-2,908.44	-2,623.23	-2,366.11	-2,134.31	-1,925.33	-1,736.90	-1,567.00	-1,413.80	-1,275.65	-1,151.07	-1,038.71	-937.37	-845.97	-763.53
CAPEX_Non-Heating																					
Building																					
Material	42,069.34	-2,103.47	-2,103.47	-2,103.47	-2,103.47	-2,103.47	-2,103.47	-2,103.47	-2,103.47	-2,103.47	-2,103.47	-2,103.47	-2,103.47	-2,103.47	-2,103.47	-2,103.47	-2,103.47	-2,103.47	-2,103.47	-2,103.47	-2,103.47
Labour	37,362.98	-1,868.15	-1,868.15	-1,868.15	-1,868.15	-1,868.15	-1,868.15	-1,868.15	-1,868.15	-1,868.15	-1,868.15	-1,868.15	-1,868.15	-1,868.15	-1,868.15	-1,868.15	-1,868.15	-1,868.15	-1,868.15	-1,868.15	-1,868.15
Total:	**79,432.33**	3,971.62	3,971.62	3,971.62	3,971.62	3,971.62	3,971.62	3,971.62	3,971.62	3,971.62	3,971.62	3,971.62	3,971.62	3,971.62	3,971.62	3,971.62	3,971.62	3,971.62	3,971.62	3,971.62	3,971.62
Aquaponics																					
Aquaculture system	8,825.00	-441.25	-441.25	-441.25	-441.25	-441.25	-441.25	-441.25	-441.25	-441.25	-441.25	-441.25	-441.25	-441.25	-441.25	-441.25	-441.25	-441.25	-441.25	-441.25	-441.25
NFT system 1: Horizontal	11,477.08	-573.85	-573.85	-573.85	-573.85	-573.85	-573.85	-573.85	-573.85	-573.85	-573.85	-573.85	-573.85	-573.85	-573.85	-573.85	-573.85	-573.85	-573.85	-573.85	-573.85
NFT system 2: Vertical	22,820.83	-1,141.04	-1,141.04	-1,141.04	-1,141.04	-1,141.04	-1,141.04	-1,141.04	-1,141.04	-1,141.04	-1,141.04	-1,141.04	-1,141.04	-1,141.04	-1,141.04	-1,141.04	-1,141.04	-1,141.04	-1,141.04	-1,141.04	-1,141.04
Growing lights	20,630.16	-1,031.51	-1,031.51	-1,031.51	-1,031.51	-1,031.51	-1,031.51	-1,031.51	-1,031.51	-1,031.51	-1,031.51	-1,031.51	-1,031.51	-1,031.51	-1,031.51	-1,031.51	-1,031.51	-1,031.51	-1,031.51	-1,031.51	-1,031.51
Water	138.19	-6.91	-6.91	-6.91	-6.91	-6.91	-6.91	-6.91	-6.91	-6.91	-6.91	-6.91	-6.91	-6.91	-6.91	-6.91	-6.91	-6.91	-6.91	-6.91	-6.91
Total:	**63,891.27**	3,194.56	3,194.56	3,194.56	3,194.56	3,194.56	3,194.56	3,194.56	3,194.56	3,194.56	3,194.56	3,194.56	3,194.56	3,194.56	3,194.56	3,194.56	3,194.56	3,194.56	3,194.56	3,194.56	3,194.56
Soil-based cultivation																					
Growing beds	1,031.25	-51.56	-51.56	-51.56	-51.56	-51.56	-51.56	-51.56	-51.56	-51.56	-51.56	-51.56	-51.56	-51.56	-51.56	-51.56	-51.56	-51.56	-51.56	-51.56	-51.56
Soil	2,062.50	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13
Total:	**3,093.75**	154.69	154.69	154.69	154.69	154.69	154.69	154.69	154.69	154.69	154.69	154.69	154.69	154.69	154.69	154.69	154.69	154.69	154.69	154.69	154.69
	54,682.80	**-6,536.49**	**-5,836.15**	**-5,210.85**	**-4,652.54**	**-4,154.06**	**-3,708.98**	**-3,311.59**	**-2,956.78**	**-2,639.98**	**-2,357.12**	**-2,104.57**	**-1,879.08**	**-1,677.75**	**-1,497.99**	**-1,337.50**	**-1,194.19**	**-1,066.24**	**-952.00**	**-850.00**	**-758.93**
OPEX_Non-Heating																					
Electricity: Grow lights		-1,859.83	-1,945.48	-2,031.13	-2,116.78	-2,202.43	-2,288.08	-2,373.73	-2,459.38	-2,545.03	-2,630.68	-2,716.33	-2,801.98	-2,887.63	-2,973.28	-3,058.93	-3,144.58	-3,230.23	-3,315.88	-3,401.53	-3,487.18
Pumps		-265.16	-277.37	-289.58	-301.79	-314.00	-326.22	-338.43	-350.64	-362.85	-375.06	-387.27	-399.48	-411.70	-423.91	-436.12	-448.33	-460.54	-472.75	-484.96	-497.17
Labor		-2,290.00	-2,290.00	-2,290.00	-2,290.00	-2,290.00	-2,290.00	-2,290.00	-2,290.00	-2,290.00	-2,290.00	-2,290.00	-2,290.00	-2,290.00	-2,290.00	-2,290.00	-2,290.00	-2,290.00	-2,290.00	-2,290.00	-2,290.00
Fish feed		-3,019.50	-3,019.50	-3,019.50	-3,019.50	-3,019.50	-3,019.50	-3,019.50	-3,019.50	-3,019.50	-3,019.50	-3,019.50	-3,019.50	-3,019.50	-3,019.50	-3,019.50	-3,019.50	-3,019.50	-3,019.50	-3,019.50	-3,019.50
Maintenance: Building		-897.20	-897.20	-897.20	-897.20	-897.20	-897.20	-897.20	-897.20	-897.20	-897.20	-897.20	-897.20	-897.20	-897.20	-897.20	-897.20	-897.20	-897.20	-897.20	-897.20
Aquaponics		-1,300.00	-1,300.00	-1,300.00	-1,300.00	-1,300.00	-1,300.00	-1,300.00	-1,300.00	-1,300.00	-1,300.00	-1,300.00	-1,300.00	-1,300.00	-1,300.00	-1,300.00	-1,300.00	-1,300.00	-1,300.00	-1,300.00	-1,300.00
	76,343.93	**-8,599.72**	**-7,756.34**	**-6,994.96**	**-6,307.69**	**-5,687.39**	**-5,127.61**	**-4,622.49**	**-4,166.75**	**-3,755.60**	**-3,384.72**	**-3,050.21**	**-2,748.52**	**-2,476.46**	**-2,231.15**	**-2,009.98**	**-1,810.59**	**-1,630.85**	**-1,468.84**	**-1,322.83**	**-1,191.24**
NPC Total	**-179,176.78**	-20,558.83	-18,469.20	-16,603.13	-14,925.50	-13,417.30	-12,061.43	-10,842.52	-9,746.75	-8,761.69	-7,876.16	-7,080.11	-6,364.51	-5,721.22	-5,142.95	-4,623.13	-4,155.85	-3,735.80	-3,358.22	-3,018.80	-2,713.70
AG yield																					
Fish [CAD/kg]	8.8	2,200.00	2,200.00	2,200.00	2,200.00	2,200.00	2,200.00	2,200.00	2,200.00	2,200.00	2,200.00	2,200.00	2,200.00	2,200.00	2,200.00	2,200.00	2,200.00	2,200.00	2,200.00	2,200.00	2,200.00
Basil: NFT [CAD/kg]	7.5	14,850.00	14,850.00	14,850.00	14,850.00	14,850.00	14,850.00	14,850.00	14,850.00	14,850.00	14,850.00	14,850.00	14,850.00	14,850.00	14,850.00	14,850.00	14,850.00	14,850.00	14,850.00	14,850.00	14,850.00
Lettuce: Soil [CAD/kg]	5	4,950.00	4,950.00	4,950.00	4,950.00	4,950.00	4,950.00	4,950.00	4,950.00	4,950.00	4,950.00	4,950.00	4,950.00	4,950.00	4,950.00	4,950.00	4,950.00	4,950.00	4,950.00	4,950.00	4,950.00
Additional income																					
Carbon offsets		1,931.05	2,194.37	2,457.70	2,721.02	2,984.35	3,019.46	3,054.57	3,089.68	3,124.79	3,159.90	3,195.01	3,230.12	3,265.23	3,300.34	3,335.45	3,370.56	3,405.67	3,440.78	3,475.89	3,511.00
Biomass waste [CAD/t]	85	42.08	42.08	42.08	42.08	42.08	42.08	42.08	42.08	42.08	42.08	42.08	42.08	42.08	42.08	42.08	42.08	42.08	42.08	42.08	42.08
	185,632.56	**21,404.58**	**19,321.16**	**17,438.46**	**15,737.40**	**14,200.67**	**12,696.96**	**11,352.45**	**10,150.30**	**9,075.43**	**8,114.36**	**7,255.06**	**6,486.74**	**5,799.78**	**5,185.56**	**4,636.38**	**4,145.35**	**3,706.32**	**3,313.78**	**2,962.81**	**2,649.01**
NPV Total	**6,455.78**	845.75	851.96	835.33	811.91	783.37	635.53	509.93	403.54	313.73	238.20	174.95	122.24	78.56	42.61	13.25	-10.50	-29.48	-44.43	-55.99	-64.69
Cumulative		845.75	1,697.71	2,533.04	3,344.95	4,128.32	4,763.85	5,273.78	5,677.33	5,991.06	6,229.26	6,404.21	6,526.45	6,605.01	6,647.62	6,660.88	6,650.38	6,620.90	6,576.47	6,520.48	6,455.78

Discount rate 12 [%]

BIOMASS BOILER

304 [m2] 6000 [l]

Lifespan	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Years	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**	**2036**	**2037**	**2038**	**2039**	**2040**	**2041**	**2042**	**2043**	**2044**	**2045**
Wood chip price [CAD/t]	95.0	97	99	101	103	105	107	109	111	114	116	118	120	123	125	128	130	133	136	138	141
Electricity rates [CAD/kWh]	0.104	0.160	0.167	0.175	0.182	0.189	0.197	0.204	0.212	0.219	0.226	0.234	0.241	0.248	0.256	0.263	0.271	0.278	0.285	0.293	0.300
Carbon offset price [CAD/t]	95	110	125	140	155	170	172	174	176	178	180	182	184	186	188	190	192	194	196	198	200
CAPEX_Heating																					
Hydronic radiant heating	12,792.51	-639.63	-639.63	-639.63	-639.63	-639.63	-639.63	-639.63	-639.63	-639.63	-639.63	-639.63	-639.63	-639.63	-639.63	-639.63	-639.63	-639.63	-639.63	-639.63	-639.63
Biomass boiler	18,900.00	-945.00	-945.00	-945.00	-945.00	-945.00	-945.00	-945.00	-945.00	-945.00	-945.00	-945.00	-945.00	-945.00	-945.00	-945.00	-945.00	-945.00	-945.00	-945.00	-945.00
Buffer tank	5,685.00	-284.25	-284.25	-284.25	-284.25	-284.25	-284.25	-284.25	-284.25	-284.25	-284.25	-284.25	-284.25	-284.25	-284.25	-284.25	-284.25	-284.25	-284.25	-284.25	-284.25
Total:	**37,377.51**	1,868.88	1,868.88	1,868.88	1,868.88	1,868.88	1,868.88	1,868.88	1,868.88	1,868.88	1,868.88	1,868.88	1,868.88	1,868.88	1,868.88	1,868.88	1,868.88	1,868.88	1,868.88	1,868.88	1,868.88
	13,959.46	**-1,668.64**	**-1,489.86**	**-1,330.23**	**-1,187.70**	**-1,060.45**	**-946.83**	**-845.38**	**-754.81**	**-673.94**	**-601.73**	**-537.26**	**-479.69**	**-428.30**	**-382.41**	**-341.44**	**-304.85**	**-272.19**	**-243.03**	**-216.99**	**-193.74**
OPEX_Heating																					
Fuel (biomass) [t]	26.54	-2,571.99	-2,623.43	-2,675.90	-2,729.42	-2,784.01	-2,839.69	-2,896.48	-2,954.41	-3,013.50	-3,073.77	-3,135.24	-3,197.95	-3,261.91	-3,327.15	-3,393.69	-3,461.56	-3,530.79	-3,601.41	-3,673.44	-3,746.91
Maintenance		-732.70	-732.70	-732.70	-732.70	-732.70	-732.70	-732.70	-732.70	-732.70	-732.70	-732.70	-732.70	-732.70	-732.70	-732.70	-732.70	-732.70	-732.70	-732.70	-732.70
Cooling	0.30	-434.95	-432.79	-451.84	-470.90	-489.95	-509.01	-528.06	-547.11	-566.17	-585.22	-604.27	-623.33	-642.38	-661.43	-680.49	-699.54	-718.60	-737.65	-756.70	-775.76
Transport		-1,356.84	-1,356.84	-1,356.84	-1,356.84	-1,356.84	-1,356.84	-1,356.84	-1,356.84	-1,356.84	-1,356.84	-1,356.84	-1,356.84	-1,356.84	-1,356.84	-1,356.84	-1,356.84	-1,356.84	-1,356.84	-1,356.84	-1,356.84
Labour		-443.24	-443.24	-443.24	-443.24	-443.24	-443.24	-443.24	-443.24	-443.24	-443.24	-443.24	-443.24	-443.24	-443.24	-443.24	-443.24	-443.24	-443.24	-443.24	-443.24
Total:		5,539.72	5,589.00	5,660.52	5,733.09	5,806.73	5,881.47	5,957.32	6,034.30	6,112.44	6,191.76	6,272.29	6,354.05	6,437.06	6,521.36	6,606.95	6,693.88	6,782.17	6,871.83	6,962.92	7,055.44
Net emissions impact	[t CO2e]	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66
	44,642.49	**-4,946.18**	**-4,455.51**	**-4,029.05**	**-3,643.48**	**-3,294.90**	**-2,979.73**	**-2,694.79**	**-2,437.15**	**-2,204.21**	**-1,993.58**	**-1,803.13**	**-1,630.93**	**-1,475.21**	**-1,334.40**	**-1,207.07**	**-1,091.92**	**-987.78**	**-893.61**	**-808.44**	**-731.41**
NPC Heating	**-58,601.95**	-6,614.82	-5,945.37	-5,359.28	-4,831.19	-4,355.35	-3,926.57	-3,540.17	-3,191.96	-2,878.14	-2,595.31	-2,340.39	-2,110.62	-1,903.51	-1,716.81	-1,548.50	-1,396.77	-1,259.98	-1,136.64	-1,025.43	-925.15
CAPEX_Non-Heating																					
Building																					
Material	48,687.79	-2,434.39	-2,434.39	-2,434.39	-2,434.39	-2,434.39	-2,434.39	-2,434.39	-2,434.39	-2,434.39	-2,434.39	-2,434.39	-2,434.39	-2,434.39	-2,434.39	-2,434.39	-2,434.39	-2,434.39	-2,434.39	-2,434.39	-2,434.39
Labour	43,396.53	-2,169.83	-2,169.83	-2,169.83	-2,169.83	-2,169.83	-2,169.83	-2,169.83	-2,169.83	-2,169.83	-2,169.83	-2,169.83	-2,169.83	-2,169.83	-2,169.83	-2,169.83	-2,169.83	-2,169.83	-2,169.83	-2,169.83	-2,169.83
Total:	**92,084.32**	4,604.22	4,604.22	4,604.22	4,604.22	4,604.22	4,604.22	4,604.22	4,604.22	4,604.22	4,604.22	4,604.22	4,604.22	4,604.22	4,604.22	4,604.22	4,604.22	4,604.22	4,604.22	4,604.22	4,604.22
Aquaponics																					
Aquaculture system	10,590.00	-529.50	-529.50	-529.50	-529.50	-529.50	-529.50	-529.50	-529.50	-529.50	-529.50	-529.50	-529.50	-529.50	-529.50	-529.50	-529.50	-529.50	-529.50	-529.50	-529.50
NFT system 1: Horizontal	13,772.50	-688.63	-688.63	-688.63	-688.63	-688.63	-688.63	-688.63	-688.63	-688.63	-688.63	-688.63	-688.63	-688.63	-688.63	-688.63	-688.63	-688.63	-688.63	-688.63	-688.63
NFT system 2: Vertical	27,385.00	-1,369.25	-1,369.25	-1,369.25	-1,369.25	-1,369.25	-1,369.25	-1,369.25	-1,369.25	-1,369.25	-1,369.25	-1,369.25	-1,369.25	-1,369.25	-1,369.25	-1,369.25	-1,369.25	-1,369.25	-1,369.25	-1,369.25	-1,369.25
Growing lights	24,756.19	-1,237.81	-1,237.81	-1,237.81	-1,237.81	-1,237.81	-1,237.81	-1,237.81	-1,237.81	-1,237.81	-1,237.81	-1,237.81	-1,237.81	-1,237.81	-1,237.81	-1,237.81	-1,237.81	-1,237.81	-1,237.81	-1,237.81	-1,237.81
Water	165.83	-8.29	-8.29	-8.29	-8.29	-8.29	-8.29	-8.29	-8.29	-8.29	-8.29	-8.29	-8.29	-8.29	-8.29	-8.29	-8.29	-8.29	-8.29	-8.29	-8.29
Total:	**76,669.52**	3,833.48	3,833.48	3,833.48	3,833.48	3,833.48	3,833.48	3,833.48	3,833.48	3,833.48	3,833.48	3,833.48	3,833.48	3,833.48	3,833.48	3,833.48	3,833.48	3,833.48	3,833.48	3,833.48	3,833.48
Soil-based cultivation																					
Growing beds	1,237.50	-61.88	-61.88	-61.88	-61.88	-61.88	-61.88	-61.88	-61.88	-61.88	-61.88	-61.88	-61.88	-61.88	-61.88	-61.88	-61.88	-61.88	-61.88	-61.88	-61.88
Soil	2,475.00	-123.75	-123.75	-123.75	-123.75	-123.75	-123.75	-123.75	-123.75	-123.75	-123.75	-123.75	-123.75	-123.75	-123.75	-123.75	-123.75	-123.75	-123.75	-123.75	-123.75
Total:	**3,712.50**	185.63	185.63	185.63	185.63	185.63	185.63	185.63	185.63	185.63	185.63	185.63	185.63	185.63	185.63	185.63	185.63	185.63	185.63	185.63	185.63
	64,411.38	**-7,699.39**	**-6,874.46**	**-6,137.91**	**-5,480.27**	**-4,893.10**	**-4,368.84**	**-3,900.75**	**-3,482.81**	**-3,109.65**	**-2,776.48**	**-2,479.00**	**-2,213.39**	**-1,976.24**	**-1,764.50**	**-1,575.45**	**-1,406.65**	**-1,255.94**	**-1,121.37**	**-1,001.23**	**-893.95**
OPEX_Non-Heating																					
Electricity: Grow lights		-2,231.80	-2,334.58	-2,437.36	-2,540.14	-2,642.92	-2,745.70	-2,848.48	-2,951.26	-3,054.04	-3,156.82	-3,259.60	-3,362.38	-3,465.16	-3,567.94	-3,670.72	-3,773.50	-3,876.28	-3,979.06	-4,081.84	-4,184.62
Pumps		-318.19	-332.85	-347.50	-362.15	-376.81	-391.46	-406.11	-420.77	-435.42	-450.07	-464.73	-479.38	-494.03	-508.69	-523.34	-538.00	-552.65	-567.30	-581.96	-596.61
Labor		-2,748.00	-2,748.00	-2,748.00	-2,748.00	-2,748.00	-2,748.00	-2,748.00	-2,748.00	-2,748.00	-2,748.00	-2,748.00	-2,748.00	-2,748.00	-2,748.00	-2,748.00	-2,748.00	-2,748.00	-2,748.00	-2,748.00	-2,748.00
Fish feed		-3,623.40	-3,623.40	-3,623.40	-3,623.40	-3,623.40	-3,623.40	-3,623.40	-3,623.40	-3,623.40	-3,623.40	-3,623.40	-3,623.40	-3,623.40	-3,623.40	-3,623.40	-3,623.40	-3,623.40	-3,623.40	-3,623.40	-3,623.40
Maintenance: Building		-1,050.03	-1,050.03	-1,050.03	-1,050.03	-1,050.03	-1,050.03	-1,050.03	-1,050.03	-1,050.03	-1,050.03	-1,050.03	-1,050.03	-1,050.03	-1,050.03	-1,050.03	-1,050.03	-1,050.03	-1,050.03	-1,050.03	-1,050.03
Aquaponics		-1,560.00	-1,560.00	-1,560.00	-1,560.00	-1,560.00	-1,560.00	-1,560.00	-1,560.00	-1,560.00	-1,560.00	-1,560.00	-1,560.00	-1,560.00	-1,560.00	-1,560.00	-1,560.00	-1,560.00	-1,560.00	-1,560.00	-1,560.00
	91,414.01	**-10,295.91**	**-9,286.40**	**-8,375.01**	**-7,552.32**	**-6,809.78**	**-6,139.65**	**-5,534.96**	**-4,989.35**	**-4,497.13**	**-4,053.10**	**-3,652.60**	**-3,291.39**	**-2,965.66**	**-2,671.94**	**-2,407.11**	**-2,168.36**	**-1,953.14**	**-1,759.15**	**-1,584.30**	**-1,426.73**
NPC Total	**-214,427.33**	-24,610.12	-22,106.22	-19,872.19	-17,863.78	-16,058.23	-14,435.06	-12,975.88	-11,664.13	-10,484.93	-9,424.89	-8,471.99	-7,615.41	-6,845.41	-6,153.25	-5,531.06	-4,971.78	-4,469.06	-4,017.16	-3,610.96	-3,245.84
AG yield																					
Fish [CAD/kg]	8.8	2,640.00	2,640.00	2,640.00	2,640.00	2,640.00	2,640.00	2,640.00	2,640.00	2,640.00	2,640.00	2,640.00	2,640.00	2,640.00	2,640.00	2,640.00	2,640.00	2,640.00	2,640.00	2,640.00	2,640.00
Basil: NFT [CAD/kg]	7.5	17,820.00	17,820.00	17,820.00	17,820.00	17,820.00	17,820.00	17,820.00	17,820.00	17,820.00	17,820.00	17,820.00	17,820.00	17,820.00	17,820.00	17,820.00	17,820.00	17,820.00	17,820.00	17,820.00	17,820.00
Lettuce: Soil [CAD/kg]	5	5,940.00	5,940.00	5,940.00	5,940.00	5,940.00	5,940.00	5,940.00	5,940.00	5,940.00	5,940.00	5,940.00	5,940.00	5,940.00	5,940.00	5,940.00	5,940.00	5,940.00	5,940.00	5,940.00	5,940.00
Additional income																					
Carbon offsets		2,197.67	2,497.36	2,797.04	3,096.72	3,396.41	3,436.36	3,476.32	3,516.28	3,556.24	3,596.20	3,636.15	3,676.11	3,716.07	3,756.03	3,795.98	3,835.94	3,875.90	3,915.86	3,955.81	3,995.77
Biomass waste [CAD/t]	85	50.50	50.50	50.50	50.50	50.50	50.50	50.50	50.50	50.50	50.50	50.50	50.50	50.50	50.50	50.50	50.50	50.50	50.50	50.50	50.50
	221,459.20	**25,578.73**	**23,077.06**	**20,817.82**	**18,777.79**	**16,935.94**	**15,141.62**	**13,537.37**	**12,103.08**	**10,820.73**	**9,674.23**	**8,649.19**	**7,732.75**	**6,913.40**	**6,180.85**	**5,525.92**	**4,940.37**	**4,416.87**	**3,948.83**	**3,530.38**	**3,156.27**
NPV Total	**7,031.87**	968.61	970.83	945.63	914.01	877.71	706.56	561.50	438.95	335.81	249.34	177.20	117.35	67.99	27.61	-5.14	-31.41	-52.19	-68.33	-80.58	-89.57
Cumulative		968.61	1,939.44	2,885.07	3,799.08	4,676.79	5,383.35	5,944.84	6,383.80	6,719.60	6,968.94	7,146.15	7,263.49	7,331.48	7,359.09	7,353.95	7,322.54	7,270.35	7,202.02	7,121.44	7,031.87

Discount rate 12 [%]

BIOMASS BOILER

348 [m2] 7000 [l]

Lifespan	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Years	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**	**2036**	**2037**	**2038**	**2039**	**2040**	**2041**	**2042**	**2043**	**2044**	**2045**
Wood chip price [CAD/t]	95.0	97	99	101	103	105	107	109	111	114	116	118	120	123	125	128	130	133	136	138	141
Electricity rates [CAD/kWh]	0.104	0.160	0.167	0.175	0.182	0.189	0.197	0.204	0.212	0.219	0.226	0.234	0.241	0.248	0.256	0.263	0.271	0.278	0.285	0.293	0.300
Carbon offset price [CAD/t]	95	110	125	140	155	170	172	174	176	178	180	182	184	186	188	190	192	194	196	198	200
CAPEX_Heating																					
Hydronic radiant heating	14,654.50	-732.73	-732.73	-732.73	-732.73	-732.73	-732.73	-732.73	-732.73	-732.73	-732.73	-732.73	-732.73	-732.73	-732.73	-732.73	-732.73	-732.73	-732.73	-732.73	-732.73
Biomass boiler	18,900.00	-945.00	-945.00	-945.00	-945.00	-945.00	-945.00	-945.00	-945.00	-945.00	-945.00	-945.00	-945.00	-945.00	-945.00	-945.00	-945.00	-945.00	-945.00	-945.00	-945.00
Buffer tank	5,685.00	-284.25	-284.25	-284.25	-284.25	-284.25	-284.25	-284.25	-284.25	-284.25	-284.25	-284.25	-284.25	-284.25	-284.25	-284.25	-284.25	-284.25	-284.25	-284.25	-284.25
Total:	**39,239.50**	1,961.98	1,961.98	1,961.98	1,961.98	1,961.98	1,961.98	1,961.98	1,961.98	1,961.98	1,961.98	1,961.98	1,961.98	1,961.98	1,961.98	1,961.98	1,961.98	1,961.98	1,961.98	1,961.98	1,961.98
	14,654.86	**-1,751.76**	**-1,564.07**	**-1,396.50**	**-1,246.87**	**-1,113.28**	**-994.00**	**-887.50**	**-792.41**	**-707.51**	**-631.70**	**-564.02**	**-503.59**	**-449.63**	**-401.46**	**-358.45**	**-320.04**	**-285.75**	**-255.13**	**-227.80**	**-203.39**
OPEX_Heating																					
Fuel (biomass) [t]	29.74	-2,881.42	-2,939.05	-2,997.83	-3,057.79	-3,118.94	-3,181.32	-3,244.95	-3,309.85	-3,376.04	-3,443.57	-3,512.44	-3,582.69	-3,654.34	-3,727.43	-3,801.97	-3,878.01	-3,955.57	-4,034.69	-4,115.38	-4,197.69
Maintenance		-821.59	-821.59	-821.59	-821.59	-821.59	-821.59	-821.59	-821.59	-821.59	-821.59	-821.59	-821.59	-821.59	-821.59	-821.59	-821.59	-821.59	-821.59	-821.59	-821.59
Cooling	0.30	-541.16	-538.07	-561.76	-585.45	-609.14	-632.82	-656.51	-680.20	-703.89	-727.58	-751.27	-774.96	-798.64	-822.33	-846.02	-869.71	-893.40	-917.09	-940.78	-964.46
Transport		-1,521.46	-1,521.46	-1,521.46	-1,521.46	-1,521.46	-1,521.46	-1,521.46	-1,521.46	-1,521.46	-1,521.46	-1,521.46	-1,521.46	-1,521.46	-1,521.46	-1,521.46	-1,521.46	-1,521.46	-1,521.46	-1,521.46	-1,521.46
Labour		-497.01	-497.01	-497.01	-497.01	-497.01	-497.01	-497.01	-497.01	-497.01	-497.01	-497.01	-497.01	-497.01	-497.01	-497.01	-497.01	-497.01	-497.01	-497.01	-497.01
Total:		6,262.63	6,317.18	6,399.65	6,483.29	6,568.13	6,654.20	6,741.52	6,830.10	6,919.99	7,011.20	7,103.76	7,197.70	7,293.04	7,389.81	7,488.05	7,587.78	7,689.03	7,791.83	7,896.21	8,002.21
Net emissions impact	[t CO2e]	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74
	50,520.48	**-5,591.64**	**-5,036.01**	**-4,555.14**	**-4,120.25**	**-3,726.94**	**-3,371.23**	**-3,049.52**	**-2,758.56**	**-2,495.42**	**-2,257.42**	**-2,042.16**	**-1,847.47**	**-1,671.38**	**-1,512.10**	**-1,368.04**	**-1,237.73**	**-1,119.86**	**-1,013.25**	**-916.80**	**-829.56**
NPC Heating	**-65,175.34**	-7,343.40	-6,600.09	-5,951.64	-5,367.12	-4,840.21	-4,365.22	-3,937.02	-3,550.97	-3,202.93	-2,889.12	-2,606.18	-2,351.06	-2,121.01	-1,913.56	-1,726.48	-1,557.77	-1,405.61	-1,268.38	-1,144.60	-1,032.95
CAPEX_Non-Heating																					
Building																					
Material	52,233.67	-2,611.68	-2,611.68	-2,611.68	-2,611.68	-2,611.68	-2,611.68	-2,611.68	-2,611.68	-2,611.68	-2,611.68	-2,611.68	-2,611.68	-2,611.68	-2,611.68	-2,611.68	-2,611.68	-2,611.68	-2,611.68	-2,611.68	-2,611.68
Labour	49,430.08	-2,471.50	-2,471.50	-2,471.50	-2,471.50	-2,471.50	-2,471.50	-2,471.50	-2,471.50	-2,471.50	-2,471.50	-2,471.50	-2,471.50	-2,471.50	-2,471.50	-2,471.50	-2,471.50	-2,471.50	-2,471.50	-2,471.50	-2,471.50
Total:	**101,663.75**	5,083.19	5,083.19	5,083.19	5,083.19	5,083.19	5,083.19	5,083.19	5,083.19	5,083.19	5,083.19	5,083.19	5,083.19	5,083.19	5,083.19	5,083.19	5,083.19	5,083.19	5,083.19	5,083.19	5,083.19
Aquaponics																					
Aquaculture system	12,355.00	-617.75	-617.75	-617.75	-617.75	-617.75	-617.75	-617.75	-617.75	-617.75	-617.75	-617.75	-617.75	-617.75	-617.75	-617.75	-617.75	-617.75	-617.75	-617.75	-617.75
NFT system 1: Horizontal	16,067.92	-803.40	-803.40	-803.40	-803.40	-803.40	-803.40	-803.40	-803.40	-803.40	-803.40	-803.40	-803.40	-803.40	-803.40	-803.40	-803.40	-803.40	-803.40	-803.40	-803.40
NFT system 2: Vertical	31,949.17	-1,597.46	-1,597.46	-1,597.46	-1,597.46	-1,597.46	-1,597.46	-1,597.46	-1,597.46	-1,597.46	-1,597.46	-1,597.46	-1,597.46	-1,597.46	-1,597.46	-1,597.46	-1,597.46	-1,597.46	-1,597.46	-1,597.46	-1,597.46
Growing lights	28,882.22	-1,444.11	-1,444.11	-1,444.11	-1,444.11	-1,444.11	-1,444.11	-1,444.11	-1,444.11	-1,444.11	-1,444.11	-1,444.11	-1,444.11	-1,444.11	-1,444.11	-1,444.11	-1,444.11	-1,444.11	-1,444.11	-1,444.11	-1,444.11
Water	193.47	-9.67	-9.67	-9.67	-9.67	-9.67	-9.67	-9.67	-9.67	-9.67	-9.67	-9.67	-9.67	-9.67	-9.67	-9.67	-9.67	-9.67	-9.67	-9.67	-9.67
Total:	**89,447.77**	4,472.39	4,472.39	4,472.39	4,472.39	4,472.39	4,472.39	4,472.39	4,472.39	4,472.39	4,472.39	4,472.39	4,472.39	4,472.39	4,472.39	4,472.39	4,472.39	4,472.39	4,472.39	4,472.39	4,472.39
Soil-based cultivation																					
Growing beds	1,443.75	-72.19	-72.19	-72.19	-72.19	-72.19	-72.19	-72.19	-72.19	-72.19	-72.19	-72.19	-72.19	-72.19	-72.19	-72.19	-72.19	-72.19	-72.19	-72.19	-72.19
Soil	2,887.50	-144.38	-144.38	-144.38	-144.38	-144.38	-144.38	-144.38	-144.38	-144.38	-144.38	-144.38	-144.38	-144.38	-144.38	-144.38	-144.38	-144.38	-144.38	-144.38	-144.38
Total:	**4,331.25**	216.56	216.56	216.56	216.56	216.56	216.56	216.56	216.56	216.56	216.56	216.56	216.56	216.56	216.56	216.56	216.56	216.56	216.56	216.56	216.56
	72,992.44	**-8,725.12**	**-7,790.29**	**-6,955.62**	**-6,210.37**	**-5,544.97**	**-4,950.87**	**-4,420.42**	**-3,946.80**	**-3,523.93**	**-3,146.37**	**-2,809.26**	**-2,508.26**	**-2,239.52**	**-1,999.57**	**-1,785.33**	**-1,594.05**	**-1,423.26**	**-1,270.76**	**-1,134.61**	**-1,013.05**
OPEX_Non-Heating																					
Electricity: Grow lights		-2,603.76	-2,723.67	-2,843.58	-2,963.49	-3,083.40	-3,203.31	-3,323.22	-3,443.13	-3,563.04	-3,682.95	-3,802.86	-3,922.77	-4,042.68	-4,162.59	-4,282.50	-4,402.41	-4,522.32	-4,642.23	-4,762.14	-4,882.06
Pumps		-371.22	-388.32	-405.42	-422.51	-439.61	-456.70	-473.80	-490.89	-507.99	-525.09	-542.18	-559.28	-576.37	-593.47	-610.57	-627.66	-644.76	-661.85	-678.95	-696.04
Labor		-3,206.00	-3,206.00	-3,206.00	-3,206.00	-3,206.00	-3,206.00	-3,206.00	-3,206.00	-3,206.00	-3,206.00	-3,206.00	-3,206.00	-3,206.00	-3,206.00	-3,206.00	-3,206.00	-3,206.00	-3,206.00	-3,206.00	-3,206.00
Fish feed		-4,227.30	-4,227.30	-4,227.30	-4,227.30	-4,227.30	-4,227.30	-4,227.30	-4,227.30	-4,227.30	-4,227.30	-4,227.30	-4,227.30	-4,227.30	-4,227.30	-4,227.30	-4,227.30	-4,227.30	-4,227.30	-4,227.30	-4,227.30
Maintenance: Building		-1,202.87	-1,202.87	-1,202.87	-1,202.87	-1,202.87	-1,202.87	-1,202.87	-1,202.87	-1,202.87	-1,202.87	-1,202.87	-1,202.87	-1,202.87	-1,202.87	-1,202.87	-1,202.87	-1,202.87	-1,202.87	-1,202.87	-1,202.87
Aquaponics		-1,820.00	-1,820.00	-1,820.00	-1,820.00	-1,820.00	-1,820.00	-1,820.00	-1,820.00	-1,820.00	-1,820.00	-1,820.00	-1,820.00	-1,820.00	-1,820.00	-1,820.00	-1,820.00	-1,820.00	-1,820.00	-1,820.00	-1,820.00
	106,484.08	**-11,992.10**	**-10,816.46**	**-9,755.07**	**-8,796.95**	**-7,932.16**	**-7,151.70**	**-6,447.42**	**-5,811.96**	**-5,238.65**	**-4,721.48**	**-4,255.00**	**-3,834.27**	**-3,454.85**	**-3,112.72**	**-2,804.25**	**-2,526.14**	**-2,275.44**	**-2,049.46**	**-1,845.78**	**-1,662.22**
NPC Total	**-244,651.86**	-28,060.63	-25,206.83	-22,662.32	-20,374.44	-18,317.35	-16,467.79	-14,804.86	-13,309.74	-11,965.51	-10,756.97	-9,670.43	-8,693.59	-7,815.39	-7,025.86	-6,316.07	-5,677.96	-5,104.31	-4,588.60	-4,124.99	-3,708.22
AG yield																					
Fish [CAD/kg]	8.8	3,080.00	3,080.00	3,080.00	3,080.00	3,080.00	3,080.00	3,080.00	3,080.00	3,080.00	3,080.00	3,080.00	3,080.00	3,080.00	3,080.00	3,080.00	3,080.00	3,080.00	3,080.00	3,080.00	3,080.00
Basil: NFT [CAD/kg]	7.5	20,790.00	20,790.00	20,790.00	20,790.00	20,790.00	20,790.00	20,790.00	20,790.00	20,790.00	20,790.00	20,790.00	20,790.00	20,790.00	20,790.00	20,790.00	20,790.00	20,790.00	20,790.00	20,790.00	20,790.00
Lettuce: Soil [CAD/kg]	5	6,930.00	6,930.00	6,930.00	6,930.00	6,930.00	6,930.00	6,930.00	6,930.00	6,930.00	6,930.00	6,930.00	6,930.00	6,930.00	6,930.00	6,930.00	6,930.00	6,930.00	6,930.00	6,930.00	6,930.00
Additional income																					
Carbon offsets		2,464.30	2,800.34	3,136.38	3,472.42	3,808.47	3,853.27	3,898.08	3,942.88	3,987.69	4,032.49	4,077.30	4,122.10	4,166.91	4,211.71	4,256.52	4,301.33	4,346.13	4,390.94	4,435.74	4,480.55
Biomass waste [CAD/t]	85	58.92	58.92	58.92	58.92	58.92	58.92	58.92	58.92	58.92	58.92	58.92	58.92	58.92	58.92	58.92	58.92	58.92	58.92	58.92	58.92
	257,285.84	**29,752.87**	**26,832.96**	**24,197.18**	**21,818.19**	**19,671.20**	**17,586.27**	**15,722.30**	**14,055.86**	**12,566.03**	**11,234.10**	**10,043.33**	**8,978.76**	**8,027.02**	**7,176.15**	**6,415.46**	**5,735.40**	**5,127.42**	**4,583.88**	**4,097.95**	**3,663.53**
NPV Total	**12,633.98**	1,692.25	1,626.12	1,534.86	1,443.75	1,353.85	1,118.48	917.44	746.13	600.52	477.13	372.89	285.16	211.63	150.29	99.39	57.44	23.11	-4.73	-27.04	-44.69
Cumulative		1,692.25	3,318.37	4,853.23	6,296.98	7,650.83	8,769.32	9,686.76	10,432.89	11,033.41	11,510.54	11,883.43	12,168.59	12,380.22	12,530.51	12,629.90	12,687.34	12,710.45	12,705.72	12,678.68	12,633.98

Discount rate 12 [%]

BIOMASS BOILER

392 [m2] 8000 [l]

Lifespan	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Years	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**	**2036**	**2037**	**2038**	**2039**	**2040**	**2041**	**2042**	**2043**	**2044**	**2045**
Wood chip price [CAD/t]	95.0	97	99	101	103	105	107	109	111	114	116	118	120	123	125	128	130	133	136	138	141
Electricity rates [CAD/kWh]	0.104	0.160	0.167	0.175	0.182	0.189	0.197	0.204	0.212	0.219	0.226	0.234	0.241	0.248	0.256	0.263	0.271	0.278	0.285	0.293	0.300
Carbon offset price [CAD/t]	95	110	125	140	155	170	172	174	176	178	180	182	184	186	188	190	192	194	196	198	200
CAPEX_Heating																					
Hydronic radiant heating	16,516.50	-825.82	-825.82	-825.82	-825.82	-825.82	-825.82	-825.82	-825.82	-825.82	-825.82	-825.82	-825.82	-825.82	-825.82	-825.82	-825.82	-825.82	-825.82	-825.82	-825.82
Biomass boiler	18,900.00	-945.00	-945.00	-945.00	-945.00	-945.00	-945.00	-945.00	-945.00	-945.00	-945.00	-945.00	-945.00	-945.00	-945.00	-945.00	-945.00	-945.00	-945.00	-945.00	-945.00
Buffer tank	5,685.00	-284.25	-284.25	-284.25	-284.25	-284.25	-284.25	-284.25	-284.25	-284.25	-284.25	-284.25	-284.25	-284.25	-284.25	-284.25	-284.25	-284.25	-284.25	-284.25	-284.25
Total:	**41,101.50**	2,055.07	2,055.07	2,055.07	2,055.07	2,055.07	2,055.07	2,055.07	2,055.07	2,055.07	2,055.07	2,055.07	2,055.07	2,055.07	2,055.07	2,055.07	2,055.07	2,055.07	2,055.07	2,055.07	2,055.07
	15,350.27	**-1,834.89**	**-1,638.29**	**-1,462.76**	**-1,306.04**	**-1,166.10**	**-1,041.16**	**-929.61**	**-830.01**	**-741.08**	**-661.68**	**-590.78**	**-527.49**	**-470.97**	**-420.51**	**-375.45**	**-335.23**	**-299.31**	**-267.24**	**-238.61**	**-213.04**
OPEX_Heating																					
Fuel (biomass) [t]	32.96	-3,193.91	-3,257.79	-3,322.94	-3,389.40	-3,457.19	-3,526.34	-3,596.86	-3,668.80	-3,742.18	-3,817.02	-3,893.36	-3,971.23	-4,050.65	-4,131.66	-4,214.30	-4,298.58	-4,384.56	-4,472.25	-4,561.69	-4,652.93
Maintenance		-911.33	-911.33	-911.33	-911.33	-911.33	-911.33	-911.33	-911.33	-911.33	-911.33	-911.33	-911.33	-911.33	-911.33	-911.33	-911.33	-911.33	-911.33	-911.33	-911.33
Cooling	0.30	-648.89	-646.56	-675.03	-703.49	-731.95	-760.42	-788.88	-817.35	-845.81	-874.28	-902.74	-931.21	-959.67	-988.14	-1,016.60	-1,045.07	-1,073.53	-1,102.00	-1,130.46	-1,158.93
Transport		-1,687.65	-1,687.65	-1,687.65	-1,687.65	-1,687.65	-1,687.65	-1,687.65	-1,687.65	-1,687.65	-1,687.65	-1,687.65	-1,687.65	-1,687.65	-1,687.65	-1,687.65	-1,687.65	-1,687.65	-1,687.65	-1,687.65	-1,687.65
Labour		-551.30	-551.30	-551.30	-551.30	-551.30	-551.30	-551.30	-551.30	-551.30	-551.30	-551.30	-551.30	-551.30	-551.30	-551.30	-551.30	-551.30	-551.30	-551.30	-551.30
Total:		6,993.09	7,054.63	7,148.26	7,243.18	7,339.43	7,437.04	7,536.03	7,636.43	7,738.28	7,841.58	7,946.39	8,052.72	8,160.61	8,270.09	8,381.19	8,493.94	8,608.37	8,724.53	8,842.44	8,962.14
Net emissions impact	[t CO2e]	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82
	56,474.30	**-6,243.83**	**-5,623.91**	**-5,087.99**	**-4,603.17**	**-4,164.59**	**-3,767.84**	**-3,408.92**	**-3,084.23**	**-2,790.50**	**-2,524.78**	**-2,284.40**	**-2,066.93**	**-1,870.20**	**-1,692.22**	**-1,531.21**	**-1,385.55**	**-1,253.76**	**-1,134.53**	**-1,026.67**	**-929.08**
NPC Heating	**-71,824.57**	-8,078.72	-7,262.20	-6,550.75	-5,909.21	-5,330.70	-4,809.00	-4,338.53	-3,914.24	-3,531.58	-3,186.46	-2,875.18	-2,594.42	-2,341.17	-2,112.73	-1,906.67	-1,720.77	-1,553.07	-1,401.78	-1,265.28	-1,142.12
CAPEX_Non-Heating																					
Building																					
Material	58,484.42	-2,924.22	-2,924.22	-2,924.22	-2,924.22	-2,924.22	-2,924.22	-2,924.22	-2,924.22	-2,924.22	-2,924.22	-2,924.22	-2,924.22	-2,924.22	-2,924.22	-2,924.22	-2,924.22	-2,924.22	-2,924.22	-2,924.22	-2,924.22
Labour	55,463.63	-2,773.18	-2,773.18	-2,773.18	-2,773.18	-2,773.18	-2,773.18	-2,773.18	-2,773.18	-2,773.18	-2,773.18	-2,773.18	-2,773.18	-2,773.18	-2,773.18	-2,773.18	-2,773.18	-2,773.18	-2,773.18	-2,773.18	-2,773.18
Total:	**113,948.05**	5,697.40	5,697.40	5,697.40	5,697.40	5,697.40	5,697.40	5,697.40	5,697.40	5,697.40	5,697.40	5,697.40	5,697.40	5,697.40	5,697.40	5,697.40	5,697.40	5,697.40	5,697.40	5,697.40	5,697.40
Aquaponics																					
Aquaculture system	14,120.00	-706.00	-706.00	-706.00	-706.00	-706.00	-706.00	-706.00	-706.00	-706.00	-706.00	-706.00	-706.00	-706.00	-706.00	-706.00	-706.00	-706.00	-706.00	-706.00	-706.00
NFT system 1: Horizontal	18,363.33	-918.17	-918.17	-918.17	-918.17	-918.17	-918.17	-918.17	-918.17	-918.17	-918.17	-918.17	-918.17	-918.17	-918.17	-918.17	-918.17	-918.17	-918.17	-918.17	-918.17
NFT system 2: Vertical	36,513.33	-1,825.67	-1,825.67	-1,825.67	-1,825.67	-1,825.67	-1,825.67	-1,825.67	-1,825.67	-1,825.67	-1,825.67	-1,825.67	-1,825.67	-1,825.67	-1,825.67	-1,825.67	-1,825.67	-1,825.67	-1,825.67	-1,825.67	-1,825.67
Growing lights	33,008.25	-1,650.41	-1,650.41	-1,650.41	-1,650.41	-1,650.41	-1,650.41	-1,650.41	-1,650.41	-1,650.41	-1,650.41	-1,650.41	-1,650.41	-1,650.41	-1,650.41	-1,650.41	-1,650.41	-1,650.41	-1,650.41	-1,650.41	-1,650.41
Water	221.11	-11.06	-11.06	-11.06	-11.06	-11.06	-11.06	-11.06	-11.06	-11.06	-11.06	-11.06	-11.06	-11.06	-11.06	-11.06	-11.06	-11.06	-11.06	-11.06	-11.06
Total:	**102,226.03**	5,111.30	5,111.30	5,111.30	5,111.30	5,111.30	5,111.30	5,111.30	5,111.30	5,111.30	5,111.30	5,111.30	5,111.30	5,111.30	5,111.30	5,111.30	5,111.30	5,111.30	5,111.30	5,111.30	5,111.30
Soil-based cultivation																					
Growing beds	1,650.00	-82.50	-82.50	-82.50	-82.50	-82.50	-82.50	-82.50	-82.50	-82.50	-82.50	-82.50	-82.50	-82.50	-82.50	-82.50	-82.50	-82.50	-82.50	-82.50	-82.50
Soil	3,300.00	-165.00	-165.00	-165.00	-165.00	-165.00	-165.00	-165.00	-165.00	-165.00	-165.00	-165.00	-165.00	-165.00	-165.00	-165.00	-165.00	-165.00	-165.00	-165.00	-165.00
Total:	**4,950.00**	247.50	247.50	247.50	247.50	247.50	247.50	247.50	247.50	247.50	247.50	247.50	247.50	247.50	247.50	247.50	247.50	247.50	247.50	247.50	247.50
	82,583.69	**-9,871.61**	**-8,813.94**	**-7,869.59**	**-7,026.42**	**-6,273.59**	**-5,601.42**	**-5,001.27**	**-4,465.42**	**-3,986.98**	**-3,559.80**	**-3,178.39**	**-2,837.85**	**-2,533.80**	**-2,262.32**	**-2,019.93**	**-1,803.51**	**-1,610.27**	**-1,437.74**	**-1,283.70**	**-1,146.16**
OPEX_Non-Heating																					
Electricity — Grow lights		-2,975.73	-3,112.77	-3,249.81	-3,386.85	-3,523.89	-3,660.93	-3,797.97	-3,935.01	-4,072.05	-4,209.09	-4,346.13	-4,483.17	-4,620.21	-4,757.25	-4,894.29	-5,031.33	-5,168.37	-5,305.41	-5,442.45	-5,579.49
Pumps		-424.26	-443.79	-463.33	-482.87	-502.41	-521.95	-541.48	-561.02	-580.56	-600.10	-619.64	-639.17	-658.71	-678.25	-697.79	-717.33	-736.86	-756.40	-775.94	-795.48
Labor		-3,664.00	-3,664.00	-3,664.00	-3,664.00	-3,664.00	-3,664.00	-3,664.00	-3,664.00	-3,664.00	-3,664.00	-3,664.00	-3,664.00	-3,664.00	-3,664.00	-3,664.00	-3,664.00	-3,664.00	-3,664.00	-3,664.00	-3,664.00
Fish feed		-4,831.20	-4,831.20	-4,831.20	-4,831.20	-4,831.20	-4,831.20	-4,831.20	-4,831.20	-4,831.20	-4,831.20	-4,831.20	-4,831.20	-4,831.20	-4,831.20	-4,831.20	-4,831.20	-4,831.20	-4,831.20	-4,831.20	-4,831.20
Maintenance — Building		-1,355.71	-1,355.71	-1,355.71	-1,355.71	-1,355.71	-1,355.71	-1,355.71	-1,355.71	-1,355.71	-1,355.71	-1,355.71	-1,355.71	-1,355.71	-1,355.71	-1,355.71	-1,355.71	-1,355.71	-1,355.71	-1,355.71	-1,355.71
Aquaponics		-2,080.00	-2,080.00	-2,080.00	-2,080.00	-2,080.00	-2,080.00	-2,080.00	-2,080.00	-2,080.00	-2,080.00	-2,080.00	-2,080.00	-2,080.00	-2,080.00	-2,080.00	-2,080.00	-2,080.00	-2,080.00	-2,080.00	-2,080.00
	121,554.16	**-13,688.29**	**-12,346.51**	**-11,135.12**	**-10,041.58**	**-9,054.55**	**-8,163.74**	**-7,359.88**	**-6,634.56**	**-5,980.18**	**-5,389.86**	**-4,857.39**	**-4,377.14**	**-3,944.05**	**-3,553.51**	**-3,201.38**	**-2,883.92**	**-2,597.73**	**-2,339.77**	**-2,107.26**	**-1,897.71**
NPC Total	**-275,962.42**	-31,638.62	-28,422.66	-25,555.46	-22,977.21	-20,658.83	-18,574.16	-16,699.68	-15,014.22	-13,498.74	-12,136.12	-10,910.97	-9,809.42	-8,819.02	-7,928.56	-7,127.98	-6,408.20	-5,761.08	-5,179.29	-4,656.23	-4,185.99
AG yield																					
Fish [CAD/kg]	8.8	3,520.00	3,520.00	3,520.00	3,520.00	3,520.00	3,520.00	3,520.00	3,520.00	3,520.00	3,520.00	3,520.00	3,520.00	3,520.00	3,520.00	3,520.00	3,520.00	3,520.00	3,520.00	3,520.00	3,520.00
Basil: NFT [CAD/kg]	7.5	23,760.00	23,760.00	23,760.00	23,760.00	23,760.00	23,760.00	23,760.00	23,760.00	23,760.00	23,760.00	23,760.00	23,760.00	23,760.00	23,760.00	23,760.00	23,760.00	23,760.00	23,760.00	23,760.00	23,760.00
Lettuce: Soil [CAD/kg]	5	7,920.00	7,920.00	7,920.00	7,920.00	7,920.00	7,920.00	7,920.00	7,920.00	7,920.00	7,920.00	7,920.00	7,920.00	7,920.00	7,920.00	7,920.00	7,920.00	7,920.00	7,920.00	7,920.00	7,920.00
Additional income																					
Carbon offsets		2,733.49	3,106.23	3,478.98	3,851.73	4,224.48	4,274.18	4,323.88	4,373.58	4,423.28	4,472.98	4,522.68	4,572.38	4,622.08	4,671.77	4,721.47	4,771.17	4,820.87	4,870.57	4,920.27	4,969.97
Biomass waste [CAD/t]	85	67.33	67.33	67.33	67.33	67.33	67.33	67.33	67.33	67.33	67.33	67.33	67.33	67.33	67.33	67.33	67.33	67.33	67.33	67.33	67.33
	293,140.29	**33,929.30**	**30,591.17**	**27,578.86**	**24,860.87**	**22,408.71**	**20,032.96**	**17,909.05**	**16,010.30**	**14,312.83**	**12,795.32**	**11,438.68**	**10,225.86**	**9,141.62**	**8,172.33**	**7,305.81**	**6,531.15**	**5,838.62**	**5,219.52**	**4,666.05**	**4,171.27**
NPV Total	**17,177.87**	2,290.68	2,168.52	2,023.40	1,883.66	1,749.89	1,458.80	1,209.37	996.08	814.09	659.19	527.71	416.44	322.61	243.77	177.83	122.95	77.54	40.23	9.82	-14.72
Cumulative		2,290.68	4,459.19	6,482.60	8,366.26	10,116.15	11,574.95	12,784.32	13,780.40	14,594.49	15,253.69	15,781.40	16,197.84	16,520.45	16,764.22	16,942.05	17,065.00	17,142.54	17,182.77	17,192.59	17,177.87

Discount rate 12 [%]

BIOMASS BOILER

436 [m2] 9000 [l]

Lifespan	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Years	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**	**2036**	**2037**	**2038**	**2039**	**2040**	**2041**	**2042**	**2043**	**2044**	**2045**
Wood chip price [CAD/t]	95.0	97	99	101	103	105	107	109	111	114	116	118	120	123	125	128	130	133	136	138	141
Electricity rates [CAD/kWh]	0.104	0.160	0.167	0.175	0.182	0.189	0.197	0.204	0.212	0.219	0.226	0.234	0.241	0.248	0.256	0.263	0.271	0.278	0.285	0.293	0.300
Carbon offset price [CAD/t]	95	110	125	140	155	170	172	174	176	178	180	182	184	186	188	190	192	194	196	198	200
CAPEX_Heating																					
Hydronic radiant heating	18,378.49	-918.92	-918.92	-918.92	-918.92	-918.92	-918.92	-918.92	-918.92	-918.92	-918.92	-918.92	-918.92	-918.92	-918.92	-918.92	-918.92	-918.92	-918.92	-918.92	-918.92
Biomass boiler	18,900.00	-945.00	-945.00	-945.00	-945.00	-945.00	-945.00	-945.00	-945.00	-945.00	-945.00	-945.00	-945.00	-945.00	-945.00	-945.00	-945.00	-945.00	-945.00	-945.00	-945.00
Buffer tank	5,685.00	-284.25	-284.25	-284.25	-284.25	-284.25	-284.25	-284.25	-284.25	-284.25	-284.25	-284.25	-284.25	-284.25	-284.25	-284.25	-284.25	-284.25	-284.25	-284.25	-284.25
Total:	**42,963.49**	2,148.17	2,148.17	2,148.17	2,148.17	2,148.17	2,148.17	2,148.17	2,148.17	2,148.17	2,148.17	2,148.17	2,148.17	2,148.17	2,148.17	2,148.17	2,148.17	2,148.17	2,148.17	2,148.17	2,148.17
	16,045.67	**-1,918.01**	**-1,712.51**	**-1,529.03**	**-1,365.20**	**-1,218.93**	**-1,088.33**	**-971.73**	**-867.61**	**-774.65**	**-691.65**	**-617.55**	**-551.38**	**-492.31**	**-439.56**	**-392.46**	**-350.41**	**-312.87**	**-279.35**	**-249.42**	**-222.69**
OPEX_Heating																					
Fuel (biomass) [t]	36.20	-3,508.08	-3,578.24	-3,649.80	-3,722.80	-3,797.25	-3,873.20	-3,950.66	-4,029.68	-4,110.27	-4,192.48	-4,276.32	-4,361.85	-4,449.09	-4,538.07	-4,628.83	-4,721.41	-4,815.84	-4,912.15	-5,010.40	-5,110.60
Maintenance		-1,001.54	-1,001.54	-1,001.54	-1,001.54	-1,001.54	-1,001.54	-1,001.54	-1,001.54	-1,001.54	-1,001.54	-1,001.54	-1,001.54	-1,001.54	-1,001.54	-1,001.54	-1,001.54	-1,001.54	-1,001.54	-1,001.54	-1,001.54
Cooling	0.30	-757.47	-756.81	-790.13	-823.45	-856.76	-890.08	-923.40	-956.72	-990.04	-1,023.36	-1,056.68	-1,090.00	-1,123.31	-1,156.63	-1,189.95	-1,223.27	-1,256.59	-1,289.91	-1,323.23	-1,356.54
Transport		-1,854.71	-1,854.71	-1,854.71	-1,854.71	-1,854.71	-1,854.71	-1,854.71	-1,854.71	-1,854.71	-1,854.71	-1,854.71	-1,854.71	-1,854.71	-1,854.71	-1,854.71	-1,854.71	-1,854.71	-1,854.71	-1,854.71	-1,854.71
Labour		-605.87	-605.87	-605.87	-605.87	-605.87	-605.87	-605.87	-605.87	-605.87	-605.87	-605.87	-605.87	-605.87	-605.87	-605.87	-605.87	-605.87	-605.87	-605.87	-605.87
Total:		7,727.68	7,797.17	7,902.06	8,008.37	8,116.15	8,225.41	8,336.19	8,448.53	8,562.44	8,677.96	8,795.13	8,913.97	9,034.53	9,156.83	9,280.91	9,406.81	9,534.55	9,664.19	9,795.75	9,929.28
Net emissions impact	[t CO2e]	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
	62,469.64	**-6,899.71**	**-6,215.86**	**-5,624.53**	**-5,089.47**	**-4,605.32**	**-4,167.25**	**-3,770.87**	**-3,412.22**	**-3,087.70**	**-2,794.07**	**-2,528.39**	**-2,288.00**	**-2,070.48**	**-1,873.67**	**-1,695.59**	**-1,534.45**	**-1,388.65**	**-1,256.73**	**-1,137.35**	**-1,029.34**
NPC Heating	**-78,515.31**	-8,817.72	-7,928.37	-7,153.56	-6,454.67	-5,824.25	-5,255.58	-4,742.60	-4,279.83	-3,862.35	-3,485.73	-3,145.94	-2,839.38	-2,562.79	-2,313.23	-2,088.05	-1,884.87	-1,701.52	-1,536.07	-1,386.77	-1,252.03
CAPEX_Non-Heating																					
Building																					
Material	60,927.23	-3,046.36	-3,046.36	-3,046.36	-3,046.36	-3,046.36	-3,046.36	-3,046.36	-3,046.36	-3,046.36	-3,046.36	-3,046.36	-3,046.36	-3,046.36	-3,046.36	-3,046.36	-3,046.36	-3,046.36	-3,046.36	-3,046.36	-3,046.36
Labour	61,497.18	-3,074.86	-3,074.86	-3,074.86	-3,074.86	-3,074.86	-3,074.86	-3,074.86	-3,074.86	-3,074.86	-3,074.86	-3,074.86	-3,074.86	-3,074.86	-3,074.86	-3,074.86	-3,074.86	-3,074.86	-3,074.86	-3,074.86	-3,074.86
Total:	**122,424.40**	6,121.22	6,121.22	6,121.22	6,121.22	6,121.22	6,121.22	6,121.22	6,121.22	6,121.22	6,121.22	6,121.22	6,121.22	6,121.22	6,121.22	6,121.22	6,121.22	6,121.22	6,121.22	6,121.22	6,121.22
Aquaponics																					
Aquaculture system	15,885.00	-794.25	-794.25	-794.25	-794.25	-794.25	-794.25	-794.25	-794.25	-794.25	-794.25	-794.25	-794.25	-794.25	-794.25	-794.25	-794.25	-794.25	-794.25	-794.25	-794.25
NFT system 1: Horizontal	20,658.75	-1,032.94	-1,032.94	-1,032.94	-1,032.94	-1,032.94	-1,032.94	-1,032.94	-1,032.94	-1,032.94	-1,032.94	-1,032.94	-1,032.94	-1,032.94	-1,032.94	-1,032.94	-1,032.94	-1,032.94	-1,032.94	-1,032.94	-1,032.94
NFT system 2: Vertical	41,077.50	-2,053.88	-2,053.88	-2,053.88	-2,053.88	-2,053.88	-2,053.88	-2,053.88	-2,053.88	-2,053.88	-2,053.88	-2,053.88	-2,053.88	-2,053.88	-2,053.88	-2,053.88	-2,053.88	-2,053.88	-2,053.88	-2,053.88	-2,053.88
Growing lights	37,134.28	-1,856.71	-1,856.71	-1,856.71	-1,856.71	-1,856.71	-1,856.71	-1,856.71	-1,856.71	-1,856.71	-1,856.71	-1,856.71	-1,856.71	-1,856.71	-1,856.71	-1,856.71	-1,856.71	-1,856.71	-1,856.71	-1,856.71	-1,856.71
Water	248.74	-12.44	-12.44	-12.44	-12.44	-12.44	-12.44	-12.44	-12.44	-12.44	-12.44	-12.44	-12.44	-12.44	-12.44	-12.44	-12.44	-12.44	-12.44	-12.44	-12.44
Total:	**115,004.28**	5,750.21	5,750.21	5,750.21	5,750.21	5,750.21	5,750.21	5,750.21	5,750.21	5,750.21	5,750.21	5,750.21	5,750.21	5,750.21	5,750.21	5,750.21	5,750.21	5,750.21	5,750.21	5,750.21	5,750.21
Soil-based cultivation																					
Growing beds	1,856.25	-92.81	-92.81	-92.81	-92.81	-92.81	-92.81	-92.81	-92.81	-92.81	-92.81	-92.81	-92.81	-92.81	-92.81	-92.81	-92.81	-92.81	-92.81	-92.81	-92.81
Soil	3,712.50	-185.63	-185.63	-185.63	-185.63	-185.63	-185.63	-185.63	-185.63	-185.63	-185.63	-185.63	-185.63	-185.63	-185.63	-185.63	-185.63	-185.63	-185.63	-185.63	-185.63
Total:	**5,568.75**	278.44	278.44	278.44	278.44	278.44	278.44	278.44	278.44	278.44	278.44	278.44	278.44	278.44	278.44	278.44	278.44	278.44	278.44	278.44	278.44
	90,752.78	**-10,848.10**	**-9,685.80**	**-8,648.04**	**-7,721.46**	**-6,894.16**	**-6,155.50**	**-5,495.98**	**-4,907.13**	**-4,381.37**	**-3,911.93**	**-3,492.80**	**-3,118.57**	**-2,784.44**	**-2,486.10**	**-2,219.74**	**-1,981.91**	**-1,769.56**	**-1,579.96**	**-1,410.68**	**-1,259.54**
OPEX_Non-Heating																					
Electricity	Grow lights	-3,347.69	-3,501.87	-3,656.04	-3,810.21	-3,964.38	-4,118.55	-4,272.72	-4,426.89	-4,581.06	-4,735.23	-4,889.40	-5,043.57	-5,197.74	-5,351.91	-5,506.08	-5,660.25	-5,814.42	-5,968.59	-6,122.76	-6,276.93
	Pumps	-477.29	-499.27	-521.25	-543.23	-565.21	-587.19	-609.17	-631.15	-653.13	-675.11	-697.09	-719.07	-741.05	-763.03	-785.01	-806.99	-828.97	-850.95	-872.93	-894.91
Labor		-4,122.00	-4,122.00	-4,122.00	-4,122.00	-4,122.00	-4,122.00	-4,122.00	-4,122.00	-4,122.00	-4,122.00	-4,122.00	-4,122.00	-4,122.00	-4,122.00	-4,122.00	-4,122.00	-4,122.00	-4,122.00	-4,122.00	-4,122.00
Fish feed		-5,435.10	-5,435.10	-5,435.10	-5,435.10	-5,435.10	-5,435.10	-5,435.10	-5,435.10	-5,435.10	-5,435.10	-5,435.10	-5,435.10	-5,435.10	-5,435.10	-5,435.10	-5,435.10	-5,435.10	-5,435.10	-5,435.10	-5,435.10
Maintenance	Building	-1,508.54	-1,508.54	-1,508.54	-1,508.54	-1,508.54	-1,508.54	-1,508.54	-1,508.54	-1,508.54	-1,508.54	-1,508.54	-1,508.54	-1,508.54	-1,508.54	-1,508.54	-1,508.54	-1,508.54	-1,508.54	-1,508.54	-1,508.54
	Aquaponics	-2,340.00	-2,340.00	-2,340.00	-2,340.00	-2,340.00	-2,340.00	-2,340.00	-2,340.00	-2,340.00	-2,340.00	-2,340.00	-2,340.00	-2,340.00	-2,340.00	-2,340.00	-2,340.00	-2,340.00	-2,340.00	-2,340.00	-2,340.00
	136,624.23	**-15,384.49**	**-13,876.57**	**-12,515.18**	**-11,286.21**	**-10,176.93**	**-9,175.79**	**-8,272.35**	**-7,457.17**	**-6,721.71**	**-6,058.24**	**-5,459.78**	**-4,920.02**	**-4,433.24**	**-3,994.30**	**-3,598.52**	**-3,241.70**	**-2,920.03**	**-2,630.07**	**-2,368.73**	**-2,133.20**
NPC Total	**-305,892.32**	-35,050.31	-31,490.75	-28,316.77	-25,462.35	-22,895.34	-20,586.87	-18,510.93	-16,644.13	-14,965.43	-13,455.90	-12,098.52	-10,877.97	-9,780.47	-8,793.63	-7,906.31	-7,108.47	-6,391.11	-5,746.11	-5,166.19	-4,644.77
AG yield																					
Fish [CAD/kg]	8.8	3,960.00	3,960.00	3,960.00	3,960.00	3,960.00	3,960.00	3,960.00	3,960.00	3,960.00	3,960.00	3,960.00	3,960.00	3,960.00	3,960.00	3,960.00	3,960.00	3,960.00	3,960.00	3,960.00	3,960.00
Basil: NFT [CAD/kg]	7.5	26,730.00	26,730.00	26,730.00	26,730.00	26,730.00	26,730.00	26,730.00	26,730.00	26,730.00	26,730.00	26,730.00	26,730.00	26,730.00	26,730.00	26,730.00	26,730.00	26,730.00	26,730.00	26,730.00	26,730.00
Lettuce: Soil [CAD/kg]	5	8,910.00	8,910.00	8,910.00	8,910.00	8,910.00	8,910.00	8,910.00	8,910.00	8,910.00	8,910.00	8,910.00	8,910.00	8,910.00	8,910.00	8,910.00	8,910.00	8,910.00	8,910.00	8,910.00	8,910.00
Additional income																					
Carbon offsets		3,004.07	3,413.72	3,823.36	4,233.01	4,642.65	4,697.27	4,751.89	4,806.51	4,861.13	4,915.75	4,970.37	5,024.99	5,079.61	5,134.23	5,188.85	5,243.47	5,298.09	5,352.71	5,407.33	5,461.94
Biomass waste [CAD/t]	85	75.75	75.75	75.75	75.75	75.75	75.75	75.75	75.75	75.75	75.75	75.75	75.75	75.75	75.75	75.75	75.75	75.75	75.75	75.75	75.75
	329,009.96	**38,106.98**	**34,350.66**	**30,961.81**	**27,904.81**	**25,147.45**	**22,480.75**	**20,096.81**	**17,965.64**	**16,060.45**	**14,357.27**	**12,834.69**	**11,473.57**	**10,256.77**	**9,169.01**	**8,196.59**	**7,327.30**	**6,550.18**	**5,855.48**	**5,234.45**	**4,679.28**
NPV Total	**23,117.64**	3,056.67	2,859.91	2,645.03	2,442.46	2,252.11	1,893.88	1,585.88	1,321.51	1,095.02	901.37	736.17	595.60	476.30	375.38	290.29	218.83	159.07	109.37	68.26	34.51
Cumulative		3,056.67	5,916.58	8,561.62	11,004.08	13,256.19	15,150.07	16,735.95	18,057.47	19,152.48	20,053.85	20,790.03	21,385.62	21,861.93	22,237.31	22,527.60	22,746.42	22,905.50	23,014.86	23,083.13	23,117.64

Discount rate 12 [%]

BIOMASS BOILER

481 [m2] 10000 [l]

Lifespan	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Years	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**	**2036**	**2037**	**2038**	**2039**	**2040**	**2041**	**2042**	**2043**	**2044**	**2045**
Wood chip price [CAD/t]	95.0	97	99	101	103	105	107	109	111	114	116	118	120	123	125	128	130	133	136	138	141
Electricity rates [CAD/kWh]	0.104	0.160	0.167	0.175	0.182	0.189	0.197	0.204	0.212	0.219	0.226	0.234	0.241	0.248	0.256	0.263	0.271	0.278	0.285	0.293	0.300
Carbon offset price [CAD/t]	95	110	125	140	155	170	172	174	176	178	180	182	184	186	188	190	192	194	196	198	200
CAPEX_Heating																					
Hydronic radiant heating	20,240.49	- 1,012.02	- 1,012.02	- 1,012.02	- 1,012.02	- 1,012.02	- 1,012.02	- 1,012.02	- 1,012.02	- 1,012.02	- 1,012.02	- 1,012.02	- 1,012.02	- 1,012.02	- 1,012.02	- 1,012.02	- 1,012.02	- 1,012.02	- 1,012.02	- 1,012.02	- 1,012.02
Biomass boiler	20,600.00	- 1,030.00	- 1,030.00	- 1,030.00	- 1,030.00	- 1,030.00	- 1,030.00	- 1,030.00	- 1,030.00	- 1,030.00	- 1,030.00	- 1,030.00	- 1,030.00	- 1,030.00	- 1,030.00	- 1,030.00	- 1,030.00	- 1,030.00	- 1,030.00	- 1,030.00	- 1,030.00
Buffer tank	4,000.00	- 200.00	- 200.00	- 200.00	- 200.00	- 200.00	- 200.00	- 200.00	- 200.00	- 200.00	- 200.00	- 200.00	- 200.00	- 200.00	- 200.00	- 200.00	- 200.00	- 200.00	- 200.00	- 200.00	- 200.00
Total:	**44,840.49**	2,242.02	2,242.02	2,242.02	2,242.02	2,242.02	2,242.02	2,242.02	2,242.02	2,242.02	2,242.02	2,242.02	2,242.02	2,242.02	2,242.02	2,242.02	2,242.02	2,242.02	2,242.02	2,242.02	2,242.02
	16,746.68	**- 2,001.81**	**- 1,787.33**	**- 1,595.83**	**- 1,424.85**	**- 1,272.18**	**- 1,135.88**	**- 1,014.18**	**- 905.52**	**- 808.50**	**- 721.87**	**- 644.53**	**- 575.47**	**- 513.81**	**- 458.76**	**- 409.61**	**- 365.72**	**- 326.54**	**- 291.55**	**- 260.31**	**- 232.42**
OPEX_Heating																					
Fuel (biomass) [t]	39.61	- 3,838.39	- 3,915.16	- 3,993.46	- 4,073.33	- 4,154.80	- 4,237.89	- 4,322.65	- 4,409.10	- 4,497.29	- 4,587.23	- 4,678.98	- 4,772.56	- 4,868.01	- 4,965.37	- 5,064.67	- 5,165.97	- 5,269.29	- 5,374.67	- 5,482.17	- 5,591.81
Maintenance		- 1,096.26	- 1,096.26	- 1,096.26	- 1,096.26	- 1,096.26	- 1,096.26	- 1,096.26	- 1,096.26	- 1,096.26	- 1,096.26	- 1,096.26	- 1,096.26	- 1,096.26	- 1,096.26	- 1,096.26	- 1,096.26	- 1,096.26	- 1,096.26	- 1,096.26	- 1,096.26
Cooling	0.30	- 1,018.39	- 1,024.67	- 1,069.78	- 1,114.89	- 1,160.00	- 1,205.11	- 1,250.23	- 1,295.34	- 1,340.45	- 1,385.56	- 1,430.67	- 1,475.78	- 1,520.89	- 1,566.00	- 1,611.12	- 1,656.23	- 1,701.34	- 1,746.45	- 1,791.56	- 1,836.67
Transport		- 2,030.10	- 2,030.10	- 2,030.10	- 2,030.10	- 2,030.10	- 2,030.10	- 2,030.10	- 2,030.10	- 2,030.10	- 2,030.10	- 2,030.10	- 2,030.10	- 2,030.10	- 2,030.10	- 2,030.10	- 2,030.10	- 2,030.10	- 2,030.10	- 2,030.10	- 2,030.10
Labour		- 663.17	- 663.17	- 663.17	- 663.17	- 663.17	- 663.17	- 663.17	- 663.17	- 663.17	- 663.17	- 663.17	- 663.17	- 663.17	- 663.17	- 663.17	- 663.17	- 663.17	- 663.17	- 663.17	- 663.17
Total:		8,646.31	8,729.35	8,852.77	8,977.75	9,104.33	9,232.53	9,362.40	9,493.97	9,627.26	9,762.32	9,899.17	10,037.86	10,178.43	10,320.90	10,465.32	10,611.72	10,760.15	10,910.65	11,063.25	11,218.01
Net emissions impact	[t CO2e]	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98
	70,156.74	**- 7,719.92**	**- 6,958.99**	**- 6,301.23**	**- 5,705.52**	**- 5,166.04**	**- 4,677.49**	**- 4,235.08**	**- 3,834.45**	**- 3,471.69**	**- 3,143.21**	**- 2,845.78**	**- 2,576.47**	**- 2,332.63**	**- 2,111.86**	**- 1,911.97**	**- 1,731.00**	**- 1,567.16**	**- 1,418.82**	**- 1,284.52**	**- 1,162.93**
NPC Heating	**- 86,903.42**	- 9,721.73	- 8,746.32	- 7,897.05	- 7,130.37	- 6,438.22	- 5,813.37	- 5,249.25	- 4,739.97	- 4,280.18	- 3,865.08	- 3,490.30	- 3,151.94	- 2,846.45	- 2,570.62	- 2,321.58	- 2,096.72	- 1,893.69	- 1,710.37	- 1,544.83	- 1,395.36
CAPEX_Non-Heating																					
Building																					
Material	69,137.60	- 3,456.88	- 3,456.88	- 3,456.88	- 3,456.88	- 3,456.88	- 3,456.88	- 3,456.88	- 3,456.88	- 3,456.88	- 3,456.88	- 3,456.88	- 3,456.88	- 3,456.88	- 3,456.88	- 3,456.88	- 3,456.88	- 3,456.88	- 3,456.88	- 3,456.88	- 3,456.88
Labour	69,801.60	- 3,490.08	- 3,490.08	- 3,490.08	- 3,490.08	- 3,490.08	- 3,490.08	- 3,490.08	- 3,490.08	- 3,490.08	- 3,490.08	- 3,490.08	- 3,490.08	- 3,490.08	- 3,490.08	- 3,490.08	- 3,490.08	- 3,490.08	- 3,490.08	- 3,490.08	- 3,490.08
Total:	**138,939.19**	6,946.96	6,946.96	6,946.96	6,946.96	6,946.96	6,946.96	6,946.96	6,946.96	6,946.96	6,946.96	6,946.96	6,946.96	6,946.96	6,946.96	6,946.96	6,946.96	6,946.96	6,946.96	6,946.96	6,946.96
Aquaponics																					
Aquaculture system	17,650.00	- 882.50	- 882.50	- 882.50	- 882.50	- 882.50	- 882.50	- 882.50	- 882.50	- 882.50	- 882.50	- 882.50	- 882.50	- 882.50	- 882.50	- 882.50	- 882.50	- 882.50	- 882.50	- 882.50	- 882.50
NFT system 1: Horizontal	22,954.17	- 1,147.71	- 1,147.71	- 1,147.71	- 1,147.71	- 1,147.71	- 1,147.71	- 1,147.71	- 1,147.71	- 1,147.71	- 1,147.71	- 1,147.71	- 1,147.71	- 1,147.71	- 1,147.71	- 1,147.71	- 1,147.71	- 1,147.71	- 1,147.71	- 1,147.71	- 1,147.71
NFT system 2: Vertical	45,641.67	- 2,282.08	- 2,282.08	- 2,282.08	- 2,282.08	- 2,282.08	- 2,282.08	- 2,282.08	- 2,282.08	- 2,282.08	- 2,282.08	- 2,282.08	- 2,282.08	- 2,282.08	- 2,282.08	- 2,282.08	- 2,282.08	- 2,282.08	- 2,282.08	- 2,282.08	- 2,282.08
Growing lights	41,260.32	- 2,063.02	- 2,063.02	- 2,063.02	- 2,063.02	- 2,063.02	- 2,063.02	- 2,063.02	- 2,063.02	- 2,063.02	- 2,063.02	- 2,063.02	- 2,063.02	- 2,063.02	- 2,063.02	- 2,063.02	- 2,063.02	- 2,063.02	- 2,063.02	- 2,063.02	- 2,063.02
Water	276.38	- 13.82	- 13.82	- 13.82	- 13.82	- 13.82	- 13.82	- 13.82	- 13.82	- 13.82	- 13.82	- 13.82	- 13.82	- 13.82	- 13.82	- 13.82	- 13.82	- 13.82	- 13.82	- 13.82	- 13.82
Total:	**127,782.53**	6,389.13	6,389.13	6,389.13	6,389.13	6,389.13	6,389.13	6,389.13	6,389.13	6,389.13	6,389.13	6,389.13	6,389.13	6,389.13	6,389.13	6,389.13	6,389.13	6,389.13	6,389.13	6,389.13	6,389.13
Soil-based cultivation																					
Growing beds	2,062.50	- 103.13	- 103.13	- 103.13	- 103.13	- 103.13	- 103.13	- 103.13	- 103.13	- 103.13	- 103.13	- 103.13	- 103.13	- 103.13	- 103.13	- 103.13	- 103.13	- 103.13	- 103.13	- 103.13	- 103.13
Soil	4,125.00	- 206.25	- 206.25	- 206.25	- 206.25	- 206.25	- 206.25	- 206.25	- 206.25	- 206.25	- 206.25	- 206.25	- 206.25	- 206.25	- 206.25	- 206.25	- 206.25	- 206.25	- 206.25	- 206.25	- 206.25
Total:	**6,187.50**	309.38	309.38	309.38	309.38	309.38	309.38	309.38	309.38	309.38	309.38	309.38	309.38	309.38	309.38	309.38	309.38	309.38	309.38	309.38	309.38
	101,924.00	**- 12,183.45**	**- 10,878.08**	**- 9,712.57**	**- 8,671.94**	**- 7,742.80**	**- 6,913.22**	**- 6,172.51**	**- 5,511.17**	**- 4,920.69**	**- 4,393.47**	**- 3,922.74**	**- 3,502.45**	**- 3,127.19**	**- 2,792.13**	**- 2,492.97**	**- 2,225.87**	**- 1,987.38**	**- 1,774.45**	**- 1,584.33**	**- 1,414.58**
OPEX_Non-Heating																					
Electricity: Grow lights		- 3,719.66	- 3,890.96	- 4,062.26	- 4,233.56	- 4,404.86	- 4,576.16	- 4,747.46	- 4,918.76	- 5,090.06	- 5,261.36	- 5,432.66	- 5,603.96	- 5,775.26	- 5,946.56	- 6,117.86	- 6,289.16	- 6,460.46	- 6,631.76	- 6,803.06	- 6,974.36
Pumps		- 530.32	- 554.74	- 579.16	- 603.59	- 628.01	- 652.43	- 676.85	- 701.28	- 725.70	- 750.12	- 774.55	- 798.97	- 823.39	- 847.81	- 872.24	- 896.66	- 921.08	- 945.50	- 969.93	- 994.35
Labor		- 4,580.00	- 4,580.00	- 4,580.00	- 4,580.00	- 4,580.00	- 4,580.00	- 4,580.00	- 4,580.00	- 4,580.00	- 4,580.00	- 4,580.00	- 4,580.00	- 4,580.00	- 4,580.00	- 4,580.00	- 4,580.00	- 4,580.00	- 4,580.00	- 4,580.00	- 4,580.00
Fish feed		- 6,039.00	- 6,039.00	- 6,039.00	- 6,039.00	- 6,039.00	- 6,039.00	- 6,039.00	- 6,039.00	- 6,039.00	- 6,039.00	- 6,039.00	- 6,039.00	- 6,039.00	- 6,039.00	- 6,039.00	- 6,039.00	- 6,039.00	- 6,039.00	- 6,039.00	- 6,039.00
Maintenance: Building		- 1,661.38	- 1,661.38	- 1,661.38	- 1,661.38	- 1,661.38	- 1,661.38	- 1,661.38	- 1,661.38	- 1,661.38	- 1,661.38	- 1,661.38	- 1,661.38	- 1,661.38	- 1,661.38	- 1,661.38	- 1,661.38	- 1,661.38	- 1,661.38	- 1,661.38	- 1,661.38
Aquaponics		- 2,600.00	- 2,600.00	- 2,600.00	- 2,600.00	- 2,600.00	- 2,600.00	- 2,600.00	- 2,600.00	- 2,600.00	- 2,600.00	- 2,600.00	- 2,600.00	- 2,600.00	- 2,600.00	- 2,600.00	- 2,600.00	- 2,600.00	- 2,600.00	- 2,600.00	- 2,600.00
	151,694.31	**- 17,080.68**	**- 15,406.63**	**- 13,895.23**	**- 12,530.84**	**- 11,299.31**	**- 10,187.83**	**- 9,184.81**	**- 8,279.77**	**- 7,463.24**	**- 6,726.62**	**- 6,062.18**	**- 5,462.90**	**- 4,922.44**	**- 4,435.08**	**- 3,995.65**	**- 3,599.48**	**- 3,242.32**	**- 2,920.38**	**- 2,630.21**	**- 2,368.69**
NPC Total	**-340,521.73**	- 38,985.85	- 35,031.03	- 31,504.86	- 28,333.15	- 25,480.34	- 22,914.41	- 20,606.58	- 18,530.92	- 16,664.11	- 14,985.17	- 13,475.23	- 12,117.29	- 10,896.07	- 9,797.84	- 8,810.21	- 7,922.07	- 7,123.40	- 6,405.20	- 5,759.37	- 5,178.63
AG yield																					
Fish [CAD/kg]	8.8	4,400.00	4,400.00	4,400.00	4,400.00	4,400.00	4,400.00	4,400.00	4,400.00	4,400.00	4,400.00	4,400.00	4,400.00	4,400.00	4,400.00	4,400.00	4,400.00	4,400.00	4,400.00	4,400.00	4,400.00
Basil: NFT [CAD/kg]	7.5	29,700.00	29,700.00	29,700.00	29,700.00	29,700.00	29,700.00	29,700.00	29,700.00	29,700.00	29,700.00	29,700.00	29,700.00	29,700.00	29,700.00	29,700.00	29,700.00	29,700.00	29,700.00	29,700.00	29,700.00
Lettuce: Soil [CAD/kg]	5	9,900.00	9,900.00	9,900.00	9,900.00	9,900.00	9,900.00	9,900.00	9,900.00	9,900.00	9,900.00	9,900.00	9,900.00	9,900.00	9,900.00	9,900.00	9,900.00	9,900.00	9,900.00	9,900.00	9,900.00
Additional income																					
Carbon offsets		3,288.15	3,736.54	4,184.92	4,633.30	5,081.69	5,141.47	5,201.26	5,261.04	5,320.83	5,380.61	5,440.40	5,500.18	5,559.97	5,619.75	5,679.53	5,739.32	5,799.10	5,858.89	5,918.67	5,978.46
Biomass waste [CAD/t]	85	84.17	84.17	84.17	84.17	84.17	84.17	84.17	84.17	84.17	84.17	84.17	84.17	84.17	84.17	84.17	84.17	84.17	84.17	84.17	84.17
	365,026.34	**42,296.71**	**38,122.37**	**34,356.98**	**30,960.83**	**27,898.03**	**24,939.24**	**22,294.22**	**19,929.70**	**17,815.94**	**15,926.33**	**14,237.13**	**12,727.07**	**11,377.15**	**10,170.41**	**9,091.64**	**8,127.29**	**7,265.22**	**6,494.57**	**5,805.67**	**5,189.83**
NPV Total	**24,504.61**	3,310.86	3,091.34	2,852.12	2,627.68	2,417.69	2,024.83	1,687.64	1,398.78	1,151.83	941.16	761.90	609.78	481.08	372.57	281.43	205.22	141.82	89.37	46.30	11.20
Cumulative		3,310.86	6,402.21	9,254.33	11,882.01	14,299.70	16,324.53	18,012.17	19,410.96	20,562.78	21,503.95	22,265.85	22,875.63	23,356.71	23,729.28	24,010.71	24,215.93	24,357.74	24,447.12	24,493.41	24,504.61

Discount rate 12 [%]

BIOMASS BOILER

525 [m2] 11000 [l]

Lifespan	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Years	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**	**2036**	**2037**	**2038**	**2039**	**2040**	**2041**	**2042**	**2043**	**2044**	**2045**
Wood chip price [CAD/t]	95.0	97	99	101	103	105	107	109	111	114	116	118	120	123	125	128	130	133	136	138	141
Electricity rates [CAD/kWh]	0.104	0.160	0.167	0.175	0.182	0.189	0.197	0.204	0.212	0.219	0.226	0.234	0.241	0.248	0.256	0.263	0.271	0.278	0.285	0.293	0.300
Carbon offset price [CAD/t]	95	110	125	140	155	170	172	174	176	178	180	182	184	186	188	190	192	194	196	198	200
CAPEX_Heating																					
Hydronic radiant heating	22,102.48	- 1,105.12	- 1,105.12	- 1,105.12	- 1,105.12	- 1,105.12	- 1,105.12	- 1,105.12	- 1,105.12	- 1,105.12	- 1,105.12	- 1,105.12	- 1,105.12	- 1,105.12	- 1,105.12	- 1,105.12	- 1,105.12	- 1,105.12	- 1,105.12	- 1,105.12	- 1,105.12
Biomass boiler	20,600.00	- 1,030.00	- 1,030.00	- 1,030.00	- 1,030.00	- 1,030.00	- 1,030.00	- 1,030.00	- 1,030.00	- 1,030.00	- 1,030.00	- 1,030.00	- 1,030.00	- 1,030.00	- 1,030.00	- 1,030.00	- 1,030.00	- 1,030.00	- 1,030.00	- 1,030.00	- 1,030.00
Buffer tank	4,000.00	- 200.00	- 200.00	- 200.00	- 200.00	- 200.00	- 200.00	- 200.00	- 200.00	- 200.00	- 200.00	- 200.00	- 200.00	- 200.00	- 200.00	- 200.00	- 200.00	- 200.00	- 200.00	- 200.00	- 200.00
Total:	**46,702.48**	2,335.12	2,335.12	2,335.12	2,335.12	2,335.12	2,335.12	2,335.12	2,335.12	2,335.12	2,335.12	2,335.12	2,335.12	2,335.12	2,335.12	2,335.12	2,335.12	2,335.12	2,335.12	2,335.12	2,335.12
	17,442.08	**- 2,084.93**	**- 1,861.55**	**- 1,662.10**	**- 1,484.01**	**- 1,325.01**	**- 1,183.05**	**- 1,056.29**	**- 943.12**	**- 842.07**	**- 751.85**	**- 671.29**	**- 599.37**	**- 535.15**	**- 477.81**	**- 426.62**	**- 380.91**	**- 340.10**	**- 303.66**	**- 271.12**	**- 242.07**
OPEX_Heating																					
Fuel (biomass) [t]	42.97	- 4,163.93	- 4,247.20	- 4,332.15	- 4,418.79	- 4,507.17	- 4,597.31	- 4,689.26	- 4,783.04	- 4,878.70	- 4,976.28	- 5,075.80	- 5,177.32	- 5,280.86	- 5,386.48	- 5,494.21	- 5,604.10	- 5,716.18	- 5,830.50	- 5,947.11	- 6,066.05
Maintenance		- 1,189.64	- 1,189.64	- 1,189.64	- 1,189.64	- 1,189.64	- 1,189.64	- 1,189.64	- 1,189.64	- 1,189.64	- 1,189.64	- 1,189.64	- 1,189.64	- 1,189.64	- 1,189.64	- 1,189.64	- 1,189.64	- 1,189.64	- 1,189.64	- 1,189.64	- 1,189.64
Cooling	0.30	- 1,147.96	- 1,156.88	- 1,207.81	- 1,258.74	- 1,309.68	- 1,360.61	- 1,411.54	- 1,462.47	- 1,513.40	- 1,564.34	- 1,615.27	- 1,666.20	- 1,717.13	- 1,768.06	- 1,819.00	- 1,869.93	- 1,920.86	- 1,971.79	- 2,022.72	- 2,073.65
Transport		- 2,203.03	- 2,203.03	- 2,203.03	- 2,203.03	- 2,203.03	- 2,203.03	- 2,203.03	- 2,203.03	- 2,203.03	- 2,203.03	- 2,203.03	- 2,203.03	- 2,203.03	- 2,203.03	- 2,203.03	- 2,203.03	- 2,203.03	- 2,203.03	- 2,203.03	- 2,203.03
Labour		- 719.66	- 719.66	- 719.66	- 719.66	- 719.66	- 719.66	- 719.66	- 719.66	- 719.66	- 719.66	- 719.66	- 719.66	- 719.66	- 719.66	- 719.66	- 719.66	- 719.66	- 719.66	- 719.66	- 719.66
Total:		9,424.21	9,516.41	9,652.28	9,789.86	9,929.16	10,070.24	10,213.12	10,357.83	10,504.43	10,652.93	10,803.39	10,955.84	11,110.32	11,266.87	11,425.53	11,586.34	11,749.36	11,914.61	12,082.15	12,252.03
Net emissions impact	[t CO2e]	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06
	76,530.37	**- 8,414.47**	**- 7,586.42**	**- 6,870.30**	**- 6,221.63**	**- 5,634.07**	**- 5,101.90**	**- 4,619.90**	**- 4,183.36**	**- 3,788.00**	**- 3,429.96**	**- 3,105.72**	**- 2,812.09**	**- 2,546.20**	**- 2,305.42**	**- 2,087.40**	**- 1,889.98**	**- 1,711.23**	**- 1,549.37**	**- 1,402.82**	**- 1,270.13**
NPC Heating	**- 93,972.45**	- 10,499.40	- 9,447.97	- 8,532.40	- 7,705.64	- 6,959.09	- 6,284.94	- 5,676.19	- 5,126.47	- 4,630.07	- 4,181.81	- 3,777.01	- 3,411.46	- 3,081.35	- 2,783.24	- 2,514.02	- 2,270.89	- 2,051.33	- 1,853.03	- 1,673.94	- 1,512.20
CAPEX_Non-Heating																					
Building																					
Material	70,527.84	- 3,526.39	- 3,526.39	- 3,526.39	- 3,526.39	- 3,526.39	- 3,526.39	- 3,526.39	- 3,526.39	- 3,526.39	- 3,526.39	- 3,526.39	- 3,526.39	- 3,526.39	- 3,526.39	- 3,526.39	- 3,526.39	- 3,526.39	- 3,526.39	- 3,526.39	- 3,526.39
Labour	76,036.14	- 3,801.81	- 3,801.81	- 3,801.81	- 3,801.81	- 3,801.81	- 3,801.81	- 3,801.81	- 3,801.81	- 3,801.81	- 3,801.81	- 3,801.81	- 3,801.81	- 3,801.81	- 3,801.81	- 3,801.81	- 3,801.81	- 3,801.81	- 3,801.81	- 3,801.81	- 3,801.81
Total:	**146,563.98**	7,328.20	7,328.20	7,328.20	7,328.20	7,328.20	7,328.20	7,328.20	7,328.20	7,328.20	7,328.20	7,328.20	7,328.20	7,328.20	7,328.20	7,328.20	7,328.20	7,328.20	7,328.20	7,328.20	7,328.20
Aquaponics																					
Aquaculture system	19,415.00	- 970.75	- 970.75	- 970.75	- 970.75	- 970.75	- 970.75	- 970.75	- 970.75	- 970.75	- 970.75	- 970.75	- 970.75	- 970.75	- 970.75	- 970.75	- 970.75	- 970.75	- 970.75	- 970.75	- 970.75
NFT system 1: Horizontal	25,249.58	- 1,262.48	- 1,262.48	- 1,262.48	- 1,262.48	- 1,262.48	- 1,262.48	- 1,262.48	- 1,262.48	- 1,262.48	- 1,262.48	- 1,262.48	- 1,262.48	- 1,262.48	- 1,262.48	- 1,262.48	- 1,262.48	- 1,262.48	- 1,262.48	- 1,262.48	- 1,262.48
NFT system 2: Vertical	50,205.83	- 2,510.29	- 2,510.29	- 2,510.29	- 2,510.29	- 2,510.29	- 2,510.29	- 2,510.29	- 2,510.29	- 2,510.29	- 2,510.29	- 2,510.29	- 2,510.29	- 2,510.29	- 2,510.29	- 2,510.29	- 2,510.29	- 2,510.29	- 2,510.29	- 2,510.29	- 2,510.29
Growing lights	45,386.35	- 2,269.32	- 2,269.32	- 2,269.32	- 2,269.32	- 2,269.32	- 2,269.32	- 2,269.32	- 2,269.32	- 2,269.32	- 2,269.32	- 2,269.32	- 2,269.32	- 2,269.32	- 2,269.32	- 2,269.32	- 2,269.32	- 2,269.32	- 2,269.32	- 2,269.32	- 2,269.32
Water	304.02	- 15.20	- 15.20	- 15.20	- 15.20	- 15.20	- 15.20	- 15.20	- 15.20	- 15.20	- 15.20	- 15.20	- 15.20	- 15.20	- 15.20	- 15.20	- 15.20	- 15.20	- 15.20	- 15.20	- 15.20
Total:	**140,560.78**	7,028.04	7,028.04	7,028.04	7,028.04	7,028.04	7,028.04	7,028.04	7,028.04	7,028.04	7,028.04	7,028.04	7,028.04	7,028.04	7,028.04	7,028.04	7,028.04	7,028.04	7,028.04	7,028.04	7,028.04
Soil-based cultivation																					
Growing beds	2,268.75	- 113.44	- 113.44	- 113.44	- 113.44	- 113.44	- 113.44	- 113.44	- 113.44	- 113.44	- 113.44	- 113.44	- 113.44	- 113.44	- 113.44	- 113.44	- 113.44	- 113.44	- 113.44	- 113.44	- 113.44
Soil	4,537.50	- 226.88	- 226.88	- 226.88	- 226.88	- 226.88	- 226.88	- 226.88	- 226.88	- 226.88	- 226.88	- 226.88	- 226.88	- 226.88	- 226.88	- 226.88	- 226.88	- 226.88	- 226.88	- 226.88	- 226.88
Total:	**6,806.25**	340.31	340.31	340.31	340.31	340.31	340.31	340.31	340.31	340.31	340.31	340.31	340.31	340.31	340.31	340.31	340.31	340.31	340.31	340.31	340.31
	109,775.06	**- 13,121.92**	**- 11,716.00**	**- 10,460.71**	**- 9,339.92**	**- 8,339.22**	**- 7,445.73**	**- 6,647.97**	**- 5,935.69**	**- 5,299.72**	**- 4,731.90**	**- 4,224.91**	**- 3,772.24**	**- 3,368.07**	**- 3,007.21**	**- 2,685.00**	**- 2,397.33**	**- 2,140.47**	**- 1,911.13**	**- 1,706.37**	**- 1,523.54**
OPEX_Non-Heating																					
Electricity Grow lights		- 4,091.63	- 4,280.06	- 4,468.49	- 4,656.92	- 4,845.35	- 5,033.78	- 5,222.21	- 5,410.64	- 5,599.07	- 5,787.50	- 5,975.93	- 6,164.36	- 6,352.79	- 6,541.22	- 6,729.65	- 6,918.08	- 7,106.51	- 7,294.94	- 7,483.37	- 7,671.80
Pumps		- 583.35	- 610.22	- 637.08	- 663.95	- 690.81	- 717.68	- 744.54	- 771.41	- 798.27	- 825.14	- 852.00	- 878.86	- 905.73	- 932.59	- 959.46	- 986.32	- 1,013.19	- 1,040.05	- 1,066.92	- 1,093.78
Labor		- 5,038.00	- 5,038.00	- 5,038.00	- 5,038.00	- 5,038.00	- 5,038.00	- 5,038.00	- 5,038.00	- 5,038.00	- 5,038.00	- 5,038.00	- 5,038.00	- 5,038.00	- 5,038.00	- 5,038.00	- 5,038.00	- 5,038.00	- 5,038.00	- 5,038.00	- 5,038.00
Fish feed		- 6,642.90	- 6,642.90	- 6,642.90	- 6,642.90	- 6,642.90	- 6,642.90	- 6,642.90	- 6,642.90	- 6,642.90	- 6,642.90	- 6,642.90	- 6,642.90	- 6,642.90	- 6,642.90	- 6,642.90	- 6,642.90	- 6,642.90	- 6,642.90	- 6,642.90	- 6,642.90
Maintenance Building		- 1,814.21	- 1,814.21	- 1,814.21	- 1,814.21	- 1,814.21	- 1,814.21	- 1,814.21	- 1,814.21	- 1,814.21	- 1,814.21	- 1,814.21	- 1,814.21	- 1,814.21	- 1,814.21	- 1,814.21	- 1,814.21	- 1,814.21	- 1,814.21	- 1,814.21	- 1,814.21
Aquaponics		- 2,860.00	- 2,860.00	- 2,860.00	- 2,860.00	- 2,860.00	- 2,860.00	- 2,860.00	- 2,860.00	- 2,860.00	- 2,860.00	- 2,860.00	- 2,860.00	- 2,860.00	- 2,860.00	- 2,860.00	- 2,860.00	- 2,860.00	- 2,860.00	- 2,860.00	- 2,860.00
	166,764.38	**- 18,776.87**	**- 16,936.69**	**- 15,275.29**	**- 13,775.48**	**- 12,421.70**	**- 11,199.87**	**- 10,097.28**	**- 9,102.38**	**- 8,204.76**	**- 7,395.00**	**- 6,664.57**	**- 6,005.77**	**- 5,411.64**	**- 4,875.87**	**- 4,392.79**	**- 3,957.25**	**- 3,564.62**	**- 3,210.69**	**- 2,891.69**	**- 2,604.18**
NPC Total	**-370,511.89**	- 42,398.19	- 38,100.66	- 34,268.40	- 30,821.04	- 27,720.00	- 24,930.55	- 22,421.44	- 20,164.54	- 18,134.56	- 16,308.70	- 14,666.49	- 13,189.47	- 11,861.05	- 10,666.31	- 9,591.81	- 8,625.47	- 7,756.41	- 6,974.85	- 6,272.00	- 5,639.93
AG yield																					
Fish [CAD/kg]	8.8	4,840.00	4,840.00	4,840.00	4,840.00	4,840.00	4,840.00	4,840.00	4,840.00	4,840.00	4,840.00	4,840.00	4,840.00	4,840.00	4,840.00	4,840.00	4,840.00	4,840.00	4,840.00	4,840.00	4,840.00
Basil: NFT [CAD/kg]	7.5	32,670.00	32,670.00	32,670.00	32,670.00	32,670.00	32,670.00	32,670.00	32,670.00	32,670.00	32,670.00	32,670.00	32,670.00	32,670.00	32,670.00	32,670.00	32,670.00	32,670.00	32,670.00	32,670.00	32,670.00
Lettuce: Soil [CAD/kg]	5	10,890.00	10,890.00	10,890.00	10,890.00	10,890.00	10,890.00	10,890.00	10,890.00	10,890.00	10,890.00	10,890.00	10,890.00	10,890.00	10,890.00	10,890.00	10,890.00	10,890.00	10,890.00	10,890.00	10,890.00
Additional income																					
Carbon offsets		3,568.24	4,054.82	4,541.39	5,027.97	5,514.55	5,579.43	5,644.30	5,709.18	5,774.06	5,838.94	5,903.81	5,968.69	6,033.57	6,098.44	6,163.32	6,228.20	6,293.08	6,357.95	6,422.83	6,487.71
Biomass waste [CAD/t]	85	92.58	92.58	92.58	92.58	92.58	92.58	92.58	92.58	92.58	92.58	92.58	92.58	92.58	92.58	92.58	92.58	92.58	92.58	92.58	92.58
	400,999.30	**46,482.88**	**41,890.47**	**37,748.54**	**34,013.28**	**30,645.10**	**27,394.56**	**24,488.78**	**21,891.18**	**19,569.10**	**17,493.30**	**15,637.66**	**13,978.85**	**12,495.99**	**11,170.41**	**9,985.43**	**8,926.14**	**7,979.22**	**7,132.74**	**6,376.05**	**5,699.63**
NPV Total	**30,487.42**	4,084.69	3,789.81	3,480.14	3,192.24	2,925.10	2,464.02	2,067.34	1,726.64	1,434.54	1,184.59	971.18	789.38	634.93	504.09	393.62	300.67	222.81	157.89	104.05	59.70
Cumulative		4,084.69	7,874.49	11,354.63	14,546.86	17,471.96	19,935.98	22,003.32	23,729.96	25,164.50	26,349.09	27,320.27	28,109.65	28,744.59	29,248.68	29,642.30	29,942.97	30,165.78	30,323.66	30,427.72	30,487.42

C.1.3. Biodigester (Biogas boiler)

Increasing greenhouse size per page.

Discount rate 12 [%]

BIODIGESTER (BIOGAS)

260 [m2] 5000 [l]

Lifespan	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Years	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**	**2036**	**2037**	**2038**	**2039**	**2040**	**2041**	**2042**	**2043**	**2044**	**2045**
Electricity rates [CAD/kWh]	0.104	0.160	0.167	0.175	0.182	0.189	0.197	0.204	0.212	0.219	0.226	0.234	0.241	0.248	0.256	0.263	0.271	0.278	0.285	0.293	0.300
Carbon offset price [CAD/t]	95	110	125	140	155	170	172	174	176	178	180	182	184	186	188	190	192	194	196	198	200
CAPEX_Heating																					
Hydronic radiant heating	10,930.51	-546.53	-546.53	-546.53	-546.53	-546.53	-546.53	-546.53	-546.53	-546.53	-546.53	-546.53	-546.53	-546.53	-546.53	-546.53	-546.53	-546.53	-546.53	-546.53	-546.53
Biogas boiler (incl. burner)	19,690.00	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50
Buffer tank	1,420.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00
Biodigester	14,000.00	-700.00	-700.00	-700.00	-700.00	-700.00	-700.00	-700.00	-700.00	-700.00	-700.00	-700.00	-700.00	-700.00	-700.00	-700.00	-700.00	-700.00	-700.00	-700.00	-700.00
Total:	**46,040.51**	2,302.03	2,302.03	2,302.03	2,302.03	2,302.03	2,302.03	2,302.03	2,302.03	2,302.03	2,302.03	2,302.03	2,302.03	2,302.03	2,302.03	2,302.03	2,302.03	2,302.03	2,302.03	2,302.03	2,302.03
	17,194.85	**-2,055.38**	**-1,835.16**	**-1,638.54**	**-1,462.98**	**-1,306.23**	**-1,166.28**	**-1,041.32**	**-929.75**	**-830.13**	**-741.19**	**-661.78**	**-590.87**	**-527.56**	**-471.04**	**-420.57**	**-375.51**	**-335.28**	**-299.35**	**-267.28**	**-238.64**
OPEX_Heating																					
Water [CAD/m3]	10.93	-1,380.19	-1,380.19	-1,380.19	-1,380.19	-1,380.19	-1,380.19	-1,380.19	-1,380.19	-1,380.19	-1,380.19	-1,380.19	-1,380.19	-1,380.19	-1,380.19	-1,380.19	-1,380.19	-1,380.19	-1,380.19	-1,380.19	-1,380.19
Maintenance		-1,061.21	-1,061.21	-1,061.21	-1,061.21	-1,061.21	-1,061.21	-1,061.21	-1,061.21	-1,061.21	-1,061.21	-1,061.21	-1,061.21	-1,061.21	-1,061.21	-1,061.21	-1,061.21	-1,061.21	-1,061.21	-1,061.21	-1,061.21
Cooling	0.30	-328.75	-327.51	-341.93	-356.35	-370.77	-385.19	-399.60	-414.02	-428.44	-442.86	-457.28	-471.70	-486.12	-500.54	-514.95	-529.37	-543.79	-558.21	-572.63	-587.05
Transport		-3,156.87	-3,156.87	-3,156.87	-3,156.87	-3,156.87	-3,156.87	-3,156.87	-3,156.87	-3,156.87	-3,156.87	-3,156.87	-3,156.87	-3,156.87	-3,156.87	-3,156.87	-3,156.87	-3,156.87	-3,156.87	-3,156.87	-3,156.87
Labour		-2,104.58	-2,104.58	-2,104.58	-2,104.58	-2,104.58	-2,104.58	-2,104.58	-2,104.58	-2,104.58	-2,104.58	-2,104.58	-2,104.58	-2,104.58	-2,104.58	-2,104.58	-2,104.58	-2,104.58	-2,104.58	-2,104.58	-2,104.58
Total:		8,031.61	8,030.37	8,044.79	8,059.20	8,073.62	8,088.04	8,102.46	8,116.88	8,131.30	8,145.72	8,160.14	8,174.55	8,188.97	8,203.39	8,217.81	8,232.23	8,246.65	8,261.07	8,275.48	8,289.90
Net emissions impact	[t CO2e]	1.53	1.53	1.53	1.53	1.53	1.53	1.53	1.53	1.53	1.53	1.53	1.53	1.53	1.53	1.53	1.53	1.53	1.53	1.53	1.53
	60,537.03	**-7,171.08**	**-6,401.76**	**-5,726.12**	**-5,121.77**	**-4,581.19**	**-4,097.65**	**-3,665.14**	**-3,278.27**	**-2,932.23**	**-2,622.70**	**-2,345.84**	**-2,098.20**	**-1,876.70**	**-1,678.58**	**-1,501.36**	**-1,342.85**	**-1,201.08**	**-1,074.27**	**-960.84**	**-859.39**
NPC Heating	**-77,731.88**	-9,226.46	-8,236.92	-7,364.66	-6,584.75	-5,887.42	-5,263.93	-4,706.46	-4,208.02	-3,762.36	-3,363.89	-3,007.62	-2,689.08	-2,404.27	-2,149.62	-1,921.93	-1,718.37	-1,536.35	-1,373.62	-1,228.12	-1,098.03
CAPEX_Non-Heating																					
Building																					
Material	42,069.34	-2,103.47	-2,103.47	-2,103.47	-2,103.47	-2,103.47	-2,103.47	-2,103.47	-2,103.47	-2,103.47	-2,103.47	-2,103.47	-2,103.47	-2,103.47	-2,103.47	-2,103.47	-2,103.47	-2,103.47	-2,103.47	-2,103.47	-2,103.47
Labour	37,362.98	-1,868.15	-1,868.15	-1,868.15	-1,868.15	-1,868.15	-1,868.15	-1,868.15	-1,868.15	-1,868.15	-1,868.15	-1,868.15	-1,868.15	-1,868.15	-1,868.15	-1,868.15	-1,868.15	-1,868.15	-1,868.15	-1,868.15	-1,868.15
Total:	**79,432.33**	3,971.62	3,971.62	3,971.62	3,971.62	3,971.62	3,971.62	3,971.62	3,971.62	3,971.62	3,971.62	3,971.62	3,971.62	3,971.62	3,971.62	3,971.62	3,971.62	3,971.62	3,971.62	3,971.62	3,971.62
Aquaponics																					
Aquaculture system	8,825.00	-441.25	-441.25	-441.25	-441.25	-441.25	-441.25	-441.25	-441.25	-441.25	-441.25	-441.25	-441.25	-441.25	-441.25	-441.25	-441.25	-441.25	-441.25	-441.25	-441.25
NFT system 1: Horizontal	11,477.08	-573.85	-573.85	-573.85	-573.85	-573.85	-573.85	-573.85	-573.85	-573.85	-573.85	-573.85	-573.85	-573.85	-573.85	-573.85	-573.85	-573.85	-573.85	-573.85	-573.85
NFT system 2: Vertical	22,820.83	-1,141.04	-1,141.04	-1,141.04	-1,141.04	-1,141.04	-1,141.04	-1,141.04	-1,141.04	-1,141.04	-1,141.04	-1,141.04	-1,141.04	-1,141.04	-1,141.04	-1,141.04	-1,141.04	-1,141.04	-1,141.04	-1,141.04	-1,141.04
Growing lights	20,630.16	-1,031.51	-1,031.51	-1,031.51	-1,031.51	-1,031.51	-1,031.51	-1,031.51	-1,031.51	-1,031.51	-1,031.51	-1,031.51	-1,031.51	-1,031.51	-1,031.51	-1,031.51	-1,031.51	-1,031.51	-1,031.51	-1,031.51	-1,031.51
Water	138.19	-6.91	-6.91	-6.91	-6.91	-6.91	-6.91	-6.91	-6.91	-6.91	-6.91	-6.91	-6.91	-6.91	-6.91	-6.91	-6.91	-6.91	-6.91	-6.91	-6.91
Total:	**63,891.27**	3,194.56	3,194.56	3,194.56	3,194.56	3,194.56	3,194.56	3,194.56	3,194.56	3,194.56	3,194.56	3,194.56	3,194.56	3,194.56	3,194.56	3,194.56	3,194.56	3,194.56	3,194.56	3,194.56	3,194.56
Soil-based cultivation																					
Growing beds	1,031.25	-51.56	-51.56	-51.56	-51.56	-51.56	-51.56	-51.56	-51.56	-51.56	-51.56	-51.56	-51.56	-51.56	-51.56	-51.56	-51.56	-51.56	-51.56	-51.56	-51.56
Soil	2,062.50	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13
Total:	**3,093.75**	154.69	154.69	154.69	154.69	154.69	154.69	154.69	154.69	154.69	154.69	154.69	154.69	154.69	154.69	154.69	154.69	154.69	154.69	154.69	154.69
	54,682.80	**-6,536.49**	**-5,836.15**	**-5,210.85**	**-4,652.54**	**-4,154.06**	**-3,708.98**	**-3,311.59**	**-2,956.78**	**-2,639.98**	**-2,357.12**	**-2,104.57**	**-1,879.08**	**-1,677.75**	**-1,497.99**	**-1,337.50**	**-1,194.19**	**-1,066.24**	**-952.00**	**-850.00**	**-758.93**
OPEX_Non-Heating																					
Electricity — Grow lights		-1,859.83	-1,945.48	-2,031.13	-2,116.78	-2,202.43	-2,288.08	-2,373.73	-2,459.38	-2,545.03	-2,630.68	-2,716.33	-2,801.98	-2,887.63	-2,973.28	-3,058.93	-3,144.58	-3,230.23	-3,315.88	-3,401.53	-3,487.18
Pumps		-265.16	-277.37	-289.58	-301.79	-314.00	-326.22	-338.43	-350.64	-362.85	-375.06	-387.27	-399.48	-411.70	-423.91	-436.12	-448.33	-460.54	-472.75	-484.96	-497.17
Labor		-2,290.00	-2,290.00	-2,290.00	-2,290.00	-2,290.00	-2,290.00	-2,290.00	-2,290.00	-2,290.00	-2,290.00	-2,290.00	-2,290.00	-2,290.00	-2,290.00	-2,290.00	-2,290.00	-2,290.00	-2,290.00	-2,290.00	-2,290.00
Fish feed		-3,019.50	-3,019.50	-3,019.50	-3,019.50	-3,019.50	-3,019.50	-3,019.50	-3,019.50	-3,019.50	-3,019.50	-3,019.50	-3,019.50	-3,019.50	-3,019.50	-3,019.50	-3,019.50	-3,019.50	-3,019.50	-3,019.50	-3,019.50
Maintenance — Building		-897.20	-897.20	-897.20	-897.20	-897.20	-897.20	-897.20	-897.20	-897.20	-897.20	-897.20	-897.20	-897.20	-897.20	-897.20	-897.20	-897.20	-897.20	-897.20	-897.20
Aquaponics		-1,300.00	-1,300.00	-1,300.00	-1,300.00	-1,300.00	-1,300.00	-1,300.00	-1,300.00	-1,300.00	-1,300.00	-1,300.00	-1,300.00	-1,300.00	-1,300.00	-1,300.00	-1,300.00	-1,300.00	-1,300.00	-1,300.00	-1,300.00
	76,343.93	**-8,599.72**	**-7,756.34**	**-6,994.96**	**-6,307.69**	**-5,687.39**	**-5,127.61**	**-4,622.49**	**-4,166.75**	**-3,755.60**	**-3,384.72**	**-3,050.21**	**-2,748.52**	**-2,476.46**	**-2,231.15**	**-2,009.98**	**-1,810.59**	**-1,630.85**	**-1,468.84**	**-1,322.83**	**-1,191.24**
NPC Total	**-208,758.61**	-24,362.67	-21,829.41	-19,570.46	-17,544.98	-15,728.87	-14,100.52	-12,640.54	-11,331.55	-10,157.94	-9,105.74	-8,162.40	-7,316.68	-6,558.48	-5,878.76	-5,269.41	-4,723.14	-4,233.45	-3,794.46	-3,400.95	-3,048.20
AG yield																					
Fish [CAD/kg]	8.8	2,200.00	2,200.00	2,200.00	2,200.00	2,200.00	2,200.00	2,200.00	2,200.00	2,200.00	2,200.00	2,200.00	2,200.00	2,200.00	2,200.00	2,200.00	2,200.00	2,200.00	2,200.00	2,200.00	2,200.00
Basil: NFT [CAD/kg]	7.5	14,850.00	14,850.00	14,850.00	14,850.00	14,850.00	14,850.00	14,850.00	14,850.00	14,850.00	14,850.00	14,850.00	14,850.00	14,850.00	14,850.00	14,850.00	14,850.00	14,850.00	14,850.00	14,850.00	14,850.00
Lettuce: Soil [CAD/kg]	5	4,950.00	4,950.00	4,950.00	4,950.00	4,950.00	4,950.00	4,950.00	4,950.00	4,950.00	4,950.00	4,950.00	4,950.00	4,950.00	4,950.00	4,950.00	4,950.00	4,950.00	4,950.00	4,950.00	4,950.00
Additional income																					
Carbon offsets		1,826.60	2,075.68	2,324.76	2,573.84	2,822.92	2,856.13	2,889.34	2,922.55	2,955.76	2,988.97	3,022.18	3,055.40	3,088.61	3,121.82	3,155.03	3,188.24	3,221.45	3,254.66	3,287.87	3,321.08
Farm waste [CAD/t]	50	3,156.87	3,156.87	3,156.87	3,156.87	3,156.87	3,156.87	3,156.87	3,156.87	3,156.87	3,156.87	3,156.87	3,156.87	3,156.87	3,156.87	3,156.87	3,156.87	3,156.87	3,156.87	3,156.87	3,156.87
AG waste [CAD/t]	50	22.65	22.65	22.65	22.65	22.65	22.65	22.65	22.65	22.65	22.65	22.65	22.65	22.65	22.65	22.65	22.65	22.65	22.65	22.65	22.65
	207,932.05	**24,112.60**	**21,727.68**	**19,577.00**	**17,637.76**	**15,889.34**	**14,203.73**	**12,696.93**	**11,349.96**	**10,145.86**	**9,069.50**	**8,107.32**	**7,247.20**	**6,478.32**	**5,791.01**	**5,176.62**	**4,627.40**	**4,136.44**	**3,697.57**	**3,305.26**	**2,954.57**
NPV Total	**-826.56**	-250.06	-101.73	6.54	92.78	160.46	103.21	56.39	18.41	-12.08	-36.24	-55.09	-69.48	-80.16	-87.75	-92.79	-95.75	-97.01	-96.89	-95.69	-93.64
Cumulative		-250.06	-351.80	-345.25	-252.48	-92.01	11.20	67.59	86.00	73.92	37.68	-17.41	-86.89	-167.04	-254.79	-347.58	-443.33	-540.33	-637.23	-732.92	-826.56

Discount rate 12 [%]

BIODIGESTER (BIOGAS)

304 [m2] 6000 [l]

Lifespan	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Years	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**	**2036**	**2037**	**2038**	**2039**	**2040**	**2041**	**2042**	**2043**	**2044**	**2045**
Electricity rates [CAD/kWh]	0.104	0.160	0.167	0.175	0.182	0.189	0.197	0.204	0.212	0.219	0.226	0.234	0.241	0.248	0.256	0.263	0.271	0.278	0.285	0.293	0.300
Carbon offset price [CAD/t]	95	110	125	140	155	170	172	174	176	178	180	182	184	186	188	190	192	194	196	198	200
CAPEX_Heating																					
Hydronic radiant heating	12,792.51	-639.63	-639.63	-639.63	-639.63	-639.63	-639.63	-639.63	-639.63	-639.63	-639.63	-639.63	-639.63	-639.63	-639.63	-639.63	-639.63	-639.63	-639.63	-639.63	-639.63
Biogas boiler (incl. burner)	19,690.00	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50
Buffer tank	1,420.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00
Biodigester	21,000.00	-1,050.00	-1,050.00	-1,050.00	-1,050.00	-1,050.00	-1,050.00	-1,050.00	-1,050.00	-1,050.00	-1,050.00	-1,050.00	-1,050.00	-1,050.00	-1,050.00	-1,050.00	-1,050.00	-1,050.00	-1,050.00	-1,050.00	-1,050.00
Total:	**54,902.51**	2,745.13	2,745.13	2,745.13	2,745.13	2,745.13	2,745.13	2,745.13	2,745.13	2,745.13	2,745.13	2,745.13	2,745.13	2,745.13	2,745.13	2,745.13	2,745.13	2,745.13	2,745.13	2,745.13	2,745.13
	20,504.56	**-2,451.00**	**-2,188.40**	**-1,953.93**	**-1,744.58**	**-1,557.66**	**-1,390.77**	**-1,241.76**	**-1,108.71**	**-989.92**	**-883.86**	**-789.16**	**-704.61**	**-629.11**	**-561.71**	**-501.52**	**-447.79**	**-399.81**	**-356.97**	**-318.73**	**-284.58**
OPEX_Heating																					
Water [CAD/m3]	10.93	-1,570.75	-1,570.75	-1,570.75	-1,570.75	-1,570.75	-1,570.75	-1,570.75	-1,570.75	-1,570.75	-1,570.75	-1,570.75	-1,570.75	-1,570.75	-1,570.75	-1,570.75	-1,570.75	-1,570.75	-1,570.75	-1,570.75	-1,570.75
Maintenance		-1,207.74	-1,207.74	-1,207.74	-1,207.74	-1,207.74	-1,207.74	-1,207.74	-1,207.74	-1,207.74	-1,207.74	-1,207.74	-1,207.74	-1,207.74	-1,207.74	-1,207.74	-1,207.74	-1,207.74	-1,207.74	-1,207.74	-1,207.74
Cooling	0.30	-434.95	-432.79	-451.84	-470.90	-489.95	-509.01	-528.06	-547.11	-566.17	-585.22	-604.27	-623.33	-642.38	-661.43	-680.49	-699.54	-718.60	-737.65	-756.70	-775.76
Transport		-3,592.75	-3,592.75	-3,592.75	-3,592.75	-3,592.75	-3,592.75	-3,592.75	-3,592.75	-3,592.75	-3,592.75	-3,592.75	-3,592.75	-3,592.75	-3,592.75	-3,592.75	-3,592.75	-3,592.75	-3,592.75	-3,592.75	-3,592.75
Labour		-2,395.17	-2,395.17	-2,395.17	-2,395.17	-2,395.17	-2,395.17	-2,395.17	-2,395.17	-2,395.17	-2,395.17	-2,395.17	-2,395.17	-2,395.17	-2,395.17	-2,395.17	-2,395.17	-2,395.17	-2,395.17	-2,395.17	-2,395.17
Total:		9,201.37	9,199.20	9,218.26	9,237.31	9,256.37	9,275.42	9,294.47	9,313.53	9,332.58	9,351.63	9,370.69	9,389.74	9,408.79	9,427.85	9,446.90	9,465.96	9,485.01	9,504.06	9,523.12	9,542.17
Net emissions impact	[t CO2e]	1.74	1.74	1.74	1.74	1.74	1.74	1.74	1.74	1.74	1.74	1.74	1.74	1.74	1.74	1.74	1.74	1.74	1.74	1.74	1.74
	69,446.36	**-8,215.51**	**-7,333.55**	**-6,561.37**	**-5,870.48**	**-5,252.31**	**-4,699.22**	**-4,204.35**	**-3,761.58**	**-3,365.42**	**-3,010.98**	**-2,693.85**	**-2,410.11**	**-2,156.25**	**-1,929.12**	**-1,725.91**	**-1,544.10**	**-1,381.44**	**-1,235.90**	**-1,105.70**	**-989.21**
NPC Heating	**-89,950.92**	-10,666.51	-9,521.95	-8,515.30	-7,615.06	-6,809.97	-6,089.98	-5,446.10	-4,870.29	-4,355.34	-3,894.83	-3,483.01	-3,114.72	-2,785.36	-2,490.83	-2,227.44	-1,991.89	-1,781.25	-1,592.88	-1,424.43	-1,273.78
CAPEX_Non-Heating																					
Building																					
Material	48,687.79	-2,434.39	-2,434.39	-2,434.39	-2,434.39	-2,434.39	-2,434.39	-2,434.39	-2,434.39	-2,434.39	-2,434.39	-2,434.39	-2,434.39	-2,434.39	-2,434.39	-2,434.39	-2,434.39	-2,434.39	-2,434.39	-2,434.39	-2,434.39
Labour	43,396.53	-2,169.83	-2,169.83	-2,169.83	-2,169.83	-2,169.83	-2,169.83	-2,169.83	-2,169.83	-2,169.83	-2,169.83	-2,169.83	-2,169.83	-2,169.83	-2,169.83	-2,169.83	-2,169.83	-2,169.83	-2,169.83	-2,169.83	-2,169.83
Total:	**92,084.32**	4,604.22	4,604.22	4,604.22	4,604.22	4,604.22	4,604.22	4,604.22	4,604.22	4,604.22	4,604.22	4,604.22	4,604.22	4,604.22	4,604.22	4,604.22	4,604.22	4,604.22	4,604.22	4,604.22	4,604.22
Aquaponics																					
Aquaculture system	10,590.00	-529.50	-529.50	-529.50	-529.50	-529.50	-529.50	-529.50	-529.50	-529.50	-529.50	-529.50	-529.50	-529.50	-529.50	-529.50	-529.50	-529.50	-529.50	-529.50	-529.50
NFT system 1: Horizontal	13,772.50	-688.63	-688.63	-688.63	-688.63	-688.63	-688.63	-688.63	-688.63	-688.63	-688.63	-688.63	-688.63	-688.63	-688.63	-688.63	-688.63	-688.63	-688.63	-688.63	-688.63
NFT system 2: Vertical	27,385.00	-1,369.25	-1,369.25	-1,369.25	-1,369.25	-1,369.25	-1,369.25	-1,369.25	-1,369.25	-1,369.25	-1,369.25	-1,369.25	-1,369.25	-1,369.25	-1,369.25	-1,369.25	-1,369.25	-1,369.25	-1,369.25	-1,369.25	-1,369.25
Growing lights	24,756.19	-1,237.81	-1,237.81	-1,237.81	-1,237.81	-1,237.81	-1,237.81	-1,237.81	-1,237.81	-1,237.81	-1,237.81	-1,237.81	-1,237.81	-1,237.81	-1,237.81	-1,237.81	-1,237.81	-1,237.81	-1,237.81	-1,237.81	-1,237.81
Water	165.83	-8.29	-8.29	-8.29	-8.29	-8.29	-8.29	-8.29	-8.29	-8.29	-8.29	-8.29	-8.29	-8.29	-8.29	-8.29	-8.29	-8.29	-8.29	-8.29	-8.29
Total:	**76,669.52**	3,833.48	3,833.48	3,833.48	3,833.48	3,833.48	3,833.48	3,833.48	3,833.48	3,833.48	3,833.48	3,833.48	3,833.48	3,833.48	3,833.48	3,833.48	3,833.48	3,833.48	3,833.48	3,833.48	3,833.48
Soil-based cultivation																					
Growing beds	1,237.50	-61.88	-61.88	-61.88	-61.88	-61.88	-61.88	-61.88	-61.88	-61.88	-61.88	-61.88	-61.88	-61.88	-61.88	-61.88	-61.88	-61.88	-61.88	-61.88	-61.88
Soil	2,475.00	-123.75	-123.75	-123.75	-123.75	-123.75	-123.75	-123.75	-123.75	-123.75	-123.75	-123.75	-123.75	-123.75	-123.75	-123.75	-123.75	-123.75	-123.75	-123.75	-123.75
Total:	**3,712.50**	185.63	185.63	185.63	185.63	185.63	185.63	185.63	185.63	185.63	185.63	185.63	185.63	185.63	185.63	185.63	185.63	185.63	185.63	185.63	185.63
	64,411.38	**-7,699.39**	**-6,874.46**	**-6,137.91**	**-5,480.27**	**-4,893.10**	**-4,368.84**	**-3,900.75**	**-3,482.81**	**-3,109.65**	**-2,776.48**	**-2,479.00**	**-2,213.39**	**-1,976.24**	**-1,764.50**	**-1,575.45**	**-1,406.65**	**-1,255.94**	**-1,121.37**	**-1,001.23**	**-893.95**
OPEX_Non-Heating																					
Electricity – Grow lights		-2,231.80	-2,334.58	-2,437.36	-2,540.14	-2,642.92	-2,745.70	-2,848.48	-2,951.26	-3,054.04	-3,156.82	-3,259.60	-3,362.38	-3,465.16	-3,567.94	-3,670.72	-3,773.50	-3,876.28	-3,979.06	-4,081.84	-4,184.62
Pumps		-318.19	-332.85	-347.50	-362.15	-376.81	-391.46	-406.11	-420.77	-435.42	-450.07	-464.73	-479.38	-494.03	-508.69	-523.34	-538.00	-552.65	-567.30	-581.96	-596.61
Labor		-2,748.00	-2,748.00	-2,748.00	-2,748.00	-2,748.00	-2,748.00	-2,748.00	-2,748.00	-2,748.00	-2,748.00	-2,748.00	-2,748.00	-2,748.00	-2,748.00	-2,748.00	-2,748.00	-2,748.00	-2,748.00	-2,748.00	-2,748.00
Fish feed		-3,623.40	-3,623.40	-3,623.40	-3,623.40	-3,623.40	-3,623.40	-3,623.40	-3,623.40	-3,623.40	-3,623.40	-3,623.40	-3,623.40	-3,623.40	-3,623.40	-3,623.40	-3,623.40	-3,623.40	-3,623.40	-3,623.40	-3,623.40
Maintenance – Building		-1,050.03	-1,050.03	-1,050.03	-1,050.03	-1,050.03	-1,050.03	-1,050.03	-1,050.03	-1,050.03	-1,050.03	-1,050.03	-1,050.03	-1,050.03	-1,050.03	-1,050.03	-1,050.03	-1,050.03	-1,050.03	-1,050.03	-1,050.03
Aquaponics		-1,560.00	-1,560.00	-1,560.00	-1,560.00	-1,560.00	-1,560.00	-1,560.00	-1,560.00	-1,560.00	-1,560.00	-1,560.00	-1,560.00	-1,560.00	-1,560.00	-1,560.00	-1,560.00	-1,560.00	-1,560.00	-1,560.00	-1,560.00
	91,414.01	**-10,295.91**	**-9,286.40**	**-8,375.01**	**-7,552.32**	**-6,809.78**	**-6,139.65**	**-5,534.96**	**-4,989.35**	**-4,497.13**	**-4,053.10**	**-3,652.60**	**-3,291.39**	**-2,965.66**	**-2,671.94**	**-2,407.11**	**-2,168.36**	**-1,953.14**	**-1,759.15**	**-1,584.30**	**-1,426.73**
NPC Total	**-245,776.30**	-28,661.81	-25,682.80	-23,028.22	-20,647.65	-18,512.85	-16,598.48	-14,881.81	-13,342.45	-11,962.12	-10,724.41	-9,614.61	-8,619.50	-7,727.26	-6,927.27	-6,210.00	-5,566.91	-4,990.33	-4,473.40	-4,009.95	-3,594.47
AG yield																					
Fish [CAD/kg]	8.8	2,640.00	2,640.00	2,640.00	2,640.00	2,640.00	2,640.00	2,640.00	2,640.00	2,640.00	2,640.00	2,640.00	2,640.00	2,640.00	2,640.00	2,640.00	2,640.00	2,640.00	2,640.00	2,640.00	2,640.00
Basil: NFT [CAD/kg]	7.5	17,820.00	17,820.00	17,820.00	17,820.00	17,820.00	17,820.00	17,820.00	17,820.00	17,820.00	17,820.00	17,820.00	17,820.00	17,820.00	17,820.00	17,820.00	17,820.00	17,820.00	17,820.00	17,820.00	17,820.00
Lettuce: Soil [CAD/kg]	5	5,940.00	5,940.00	5,940.00	5,940.00	5,940.00	5,940.00	5,940.00	5,940.00	5,940.00	5,940.00	5,940.00	5,940.00	5,940.00	5,940.00	5,940.00	5,940.00	5,940.00	5,940.00	5,940.00	5,940.00
Additional income																					
Carbon offsets		2,078.80	2,362.27	2,645.74	2,929.22	3,212.69	3,250.49	3,288.28	3,326.08	3,363.87	3,401.67	3,439.47	3,477.26	3,515.06	3,552.86	3,590.65	3,628.45	3,666.25	3,704.04	3,741.84	3,779.63
Farm waste [CAD/t]	50	3,592.75	3,592.75	3,592.75	3,592.75	3,592.75	3,592.75	3,592.75	3,592.75	3,592.75	3,592.75	3,592.75	3,592.75	3,592.75	3,592.75	3,592.75	3,592.75	3,592.75	3,592.75	3,592.75	3,592.75
AG waste [CAD/t]	50	27.18	27.18	27.18	27.18	27.18	27.18	27.18	27.18	27.18	27.18	27.18	27.18	27.18	27.18	27.18	27.18	27.18	27.18	27.18	27.18
	246,828.67	**28,659.58**	**25,814.89**	**23,250.78**	**20,939.78**	**18,857.08**	**16,855.83**	**15,066.94**	**13,467.89**	**12,038.53**	**10,760.86**	**9,618.78**	**8,597.90**	**7,685.35**	**6,869.66**	**6,140.53**	**5,488.78**	**4,906.20**	**4,385.45**	**3,919.97**	**3,503.89**
NPV Total	**1,052.37**	-2.24	132.09	222.56	292.13	344.23	257.35	185.13	125.44	76.41	36.45	4.17	-21.61	-41.91	-57.61	-69.47	-78.13	-84.13	-87.95	-89.98	-90.57
Cumulative		-2.24	129.86	352.42	644.55	988.78	1,246.13	1,431.27	1,556.71	1,633.12	1,669.56	1,673.73	1,652.13	1,610.22	1,552.60	1,483.13	1,405.01	1,320.88	1,232.93	1,142.94	1,052.37

Discount rate 12 [%]

BIODIGESTER (BIOGAS)

348 [m2] 7000 [l]

Lifespan		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Years		**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**	**2036**	**2037**	**2038**	**2039**	**2040**	**2041**	**2042**	**2043**	**2044**	**2045**
Electricity rates [CAD/kWh]		0.104	0.160	0.167	0.175	0.182	0.189	0.197	0.204	0.212	0.219	0.226	0.234	0.241	0.248	0.256	0.263	0.271	0.278	0.285	0.293	0.300
Carbon offset price [CAD/t]		95	110	125	140	155	170	172	174	176	178	180	182	184	186	188	190	192	194	196	198	200
CAPEX_Heating																						
Hydronic radiant heating		14,654.50	-732.73	-732.73	-732.73	-732.73	-732.73	-732.73	-732.73	-732.73	-732.73	-732.73	-732.73	-732.73	-732.73	-732.73	-732.73	-732.73	-732.73	-732.73	-732.73	-732.73
Biogas boiler (incl. burner)		19,690.00	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50
Buffer tank		1,420.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00
Biodigester		21,000.00	-1,050.00	-1,050.00	-1,050.00	-1,050.00	-1,050.00	-1,050.00	-1,050.00	-1,050.00	-1,050.00	-1,050.00	-1,050.00	-1,050.00	-1,050.00	-1,050.00	-1,050.00	-1,050.00	-1,050.00	-1,050.00	-1,050.00	-1,050.00
	Total:	**56,764.50**	2,838.23	2,838.23	2,838.23	2,838.23	2,838.23	2,838.23	2,838.23	2,838.23	2,838.23	2,838.23	2,838.23	2,838.23	2,838.23	2,838.23	2,838.23	2,838.23	2,838.23	2,838.23	2,838.23	2,838.23
		21,199.96	**-2,534.13**	**-2,262.62**	**-2,020.19**	**-1,803.74**	**-1,610.49**	**-1,437.93**	**-1,283.87**	**-1,146.31**	**-1,023.49**	**-913.83**	**-815.92**	**-728.50**	**-650.45**	**-580.76**	**-518.53**	**-462.98**	**-413.37**	**-369.08**	**-329.54**	**-294.23**
OPEX_Heating																						
Water [CAD/m3]		10.93	-1,761.32	-1,761.32	-1,761.32	-1,761.32	-1,761.32	-1,761.32	-1,761.32	-1,761.32	-1,761.32	-1,761.32	-1,761.32	-1,761.32	-1,761.32	-1,761.32	-1,761.32	-1,761.32	-1,761.32	-1,761.32	-1,761.32	-1,761.32
Maintenance			-1,354.27	-1,354.27	-1,354.27	-1,354.27	-1,354.27	-1,354.27	-1,354.27	-1,354.27	-1,354.27	-1,354.27	-1,354.27	-1,354.27	-1,354.27	-1,354.27	-1,354.27	-1,354.27	-1,354.27	-1,354.27	-1,354.27	-1,354.27
Cooling		0.30	-541.16	-538.07	-561.76	-585.45	-609.14	-632.82	-656.51	-680.20	-703.89	-727.58	-751.27	-774.96	-798.64	-822.33	-846.02	-869.71	-893.40	-917.09	-940.78	-964.46
Transport			-4,028.63	-4,028.63	-4,028.63	-4,028.63	-4,028.63	-4,028.63	-4,028.63	-4,028.63	-4,028.63	-4,028.63	-4,028.63	-4,028.63	-4,028.63	-4,028.63	-4,028.63	-4,028.63	-4,028.63	-4,028.63	-4,028.63	-4,028.63
Labour			-2,685.76	-2,685.76	-2,685.76	-2,685.76	-2,685.76	-2,685.76	-2,685.76	-2,685.76	-2,685.76	-2,685.76	-2,685.76	-2,685.76	-2,685.76	-2,685.76	-2,685.76	-2,685.76	-2,685.76	-2,685.76	-2,685.76	-2,685.76
		Total:	10,371.13	10,368.04	10,391.73	10,415.42	10,439.11	10,462.80	10,486.48	10,510.17	10,533.86	10,557.55	10,581.24	10,604.93	10,628.62	10,652.31	10,675.99	10,699.68	10,723.37	10,747.06	10,770.75	10,794.44
Net emissions impact		[t CO2e]	1.95	1.95	1.95	1.95	1.95	1.95	1.95	1.95	1.95	1.95	1.95	1.95	1.95	1.95	1.95	1.95	1.95	1.95	1.95	1.95
		78,355.69	**-9,259.94**	**-8,265.34**	**-7,396.63**	**-6,619.19**	**-5,923.43**	**-5,300.78**	**-4,743.55**	**-4,244.88**	**-3,798.62**	**-3,399.25**	**-3,041.85**	**-2,722.02**	**-2,435.80**	**-2,179.67**	**-1,950.46**	**-1,745.35**	**-1,561.80**	**-1,397.54**	**-1,250.56**	**-1,119.02**
NPC Heating		**-99,555.65**	-11,794.07	-10,527.96	-9,416.82	-8,422.93	-7,533.92	-6,738.71	-6,027.42	-5,391.19	-4,822.11	-4,313.08	-3,857.78	-3,450.52	-3,086.25	-2,760.43	-2,469.00	-2,208.33	-1,975.17	-1,766.62	-1,580.09	-1,413.25
CAPEX_Non-Heating																						
Building																						
	Material	52,233.67	-2,611.68	-2,611.68	-2,611.68	-2,611.68	-2,611.68	-2,611.68	-2,611.68	-2,611.68	-2,611.68	-2,611.68	-2,611.68	-2,611.68	-2,611.68	-2,611.68	-2,611.68	-2,611.68	-2,611.68	-2,611.68	-2,611.68	-2,611.68
	Labour	49,430.08	-2,471.50	-2,471.50	-2,471.50	-2,471.50	-2,471.50	-2,471.50	-2,471.50	-2,471.50	-2,471.50	-2,471.50	-2,471.50	-2,471.50	-2,471.50	-2,471.50	-2,471.50	-2,471.50	-2,471.50	-2,471.50	-2,471.50	-2,471.50
	Total:	**101,663.75**	5,083.19	5,083.19	5,083.19	5,083.19	5,083.19	5,083.19	5,083.19	5,083.19	5,083.19	5,083.19	5,083.19	5,083.19	5,083.19	5,083.19	5,083.19	5,083.19	5,083.19	5,083.19	5,083.19	5,083.19
Aquaponics																						
	Aquaculture system	12,355.00	-617.75	-617.75	-617.75	-617.75	-617.75	-617.75	-617.75	-617.75	-617.75	-617.75	-617.75	-617.75	-617.75	-617.75	-617.75	-617.75	-617.75	-617.75	-617.75	-617.75
	NFT system 1: Horizontal	16,067.92	-803.40	-803.40	-803.40	-803.40	-803.40	-803.40	-803.40	-803.40	-803.40	-803.40	-803.40	-803.40	-803.40	-803.40	-803.40	-803.40	-803.40	-803.40	-803.40	-803.40
	NFT system 2: Vertical	31,949.17	-1,597.46	-1,597.46	-1,597.46	-1,597.46	-1,597.46	-1,597.46	-1,597.46	-1,597.46	-1,597.46	-1,597.46	-1,597.46	-1,597.46	-1,597.46	-1,597.46	-1,597.46	-1,597.46	-1,597.46	-1,597.46	-1,597.46	-1,597.46
	Growing lights	28,882.22	-1,444.11	-1,444.11	-1,444.11	-1,444.11	-1,444.11	-1,444.11	-1,444.11	-1,444.11	-1,444.11	-1,444.11	-1,444.11	-1,444.11	-1,444.11	-1,444.11	-1,444.11	-1,444.11	-1,444.11	-1,444.11	-1,444.11	-1,444.11
	Water	193.47	-9.67	-9.67	-9.67	-9.67	-9.67	-9.67	-9.67	-9.67	-9.67	-9.67	-9.67	-9.67	-9.67	-9.67	-9.67	-9.67	-9.67	-9.67	-9.67	-9.67
	Total:	**89,447.77**	4,472.39	4,472.39	4,472.39	4,472.39	4,472.39	4,472.39	4,472.39	4,472.39	4,472.39	4,472.39	4,472.39	4,472.39	4,472.39	4,472.39	4,472.39	4,472.39	4,472.39	4,472.39	4,472.39	4,472.39
Soil-based cultivation																						
	Growing beds	1,443.75	-72.19	-72.19	-72.19	-72.19	-72.19	-72.19	-72.19	-72.19	-72.19	-72.19	-72.19	-72.19	-72.19	-72.19	-72.19	-72.19	-72.19	-72.19	-72.19	-72.19
	Soil	2,887.50	-144.38	-144.38	-144.38	-144.38	-144.38	-144.38	-144.38	-144.38	-144.38	-144.38	-144.38	-144.38	-144.38	-144.38	-144.38	-144.38	-144.38	-144.38	-144.38	-144.38
	Total:	**4,331.25**	216.56	216.56	216.56	216.56	216.56	216.56	216.56	216.56	216.56	216.56	216.56	216.56	216.56	216.56	216.56	216.56	216.56	216.56	216.56	216.56
		72,992.44	**-8,725.12**	**-7,790.29**	**-6,955.62**	**-6,210.37**	**-5,544.97**	**-4,950.87**	**-4,420.42**	**-3,946.80**	**-3,523.93**	**-3,146.37**	**-2,809.26**	**-2,508.26**	**-2,239.52**	**-1,999.57**	**-1,785.33**	**-1,594.05**	**-1,423.26**	**-1,270.76**	**-1,134.61**	**-1,013.05**
OPEX_Non-Heating																						
Electricity	Grow lights		-2,603.76	-2,723.67	-2,843.58	-2,963.49	-3,083.40	-3,203.31	-3,323.22	-3,443.13	-3,563.04	-3,682.95	-3,802.86	-3,922.77	-4,042.68	-4,162.59	-4,282.50	-4,402.41	-4,522.32	-4,642.23	-4,762.14	-4,882.06
	Pumps		-371.22	-388.32	-405.42	-422.51	-439.61	-456.70	-473.80	-490.89	-507.99	-525.09	-542.18	-559.28	-576.37	-593.47	-610.57	-627.66	-644.76	-661.85	-678.95	-696.04
Labor			-3,206.00	-3,206.00	-3,206.00	-3,206.00	-3,206.00	-3,206.00	-3,206.00	-3,206.00	-3,206.00	-3,206.00	-3,206.00	-3,206.00	-3,206.00	-3,206.00	-3,206.00	-3,206.00	-3,206.00	-3,206.00	-3,206.00	-3,206.00
Fish feed			-4,227.30	-4,227.30	-4,227.30	-4,227.30	-4,227.30	-4,227.30	-4,227.30	-4,227.30	-4,227.30	-4,227.30	-4,227.30	-4,227.30	-4,227.30	-4,227.30	-4,227.30	-4,227.30	-4,227.30	-4,227.30	-4,227.30	-4,227.30
Maintenance	Building		-1,202.87	-1,202.87	-1,202.87	-1,202.87	-1,202.87	-1,202.87	-1,202.87	-1,202.87	-1,202.87	-1,202.87	-1,202.87	-1,202.87	-1,202.87	-1,202.87	-1,202.87	-1,202.87	-1,202.87	-1,202.87	-1,202.87	-1,202.87
	Aquaponics		-1,820.00	-1,820.00	-1,820.00	-1,820.00	-1,820.00	-1,820.00	-1,820.00	-1,820.00	-1,820.00	-1,820.00	-1,820.00	-1,820.00	-1,820.00	-1,820.00	-1,820.00	-1,820.00	-1,820.00	-1,820.00	-1,820.00	-1,820.00
		106,484.08	**-11,992.10**	**-10,816.46**	**-9,755.07**	**-8,796.95**	**-7,932.16**	**-7,151.70**	**-6,447.42**	**-5,811.96**	**-5,238.65**	**-4,721.48**	**-4,255.00**	**-3,834.27**	**-3,454.85**	**-3,112.72**	**-2,804.25**	**-2,526.14**	**-2,275.44**	**-2,049.46**	**-1,845.78**	**-1,662.22**
NPC Total		**-279,032.17**	-32,511.29	-29,134.70	-26,127.50	-23,430.25	-21,011.05	-18,841.28	-16,895.26	-15,149.96	-13,584.69	-12,180.93	-10,922.03	-9,793.06	-8,780.63	-7,872.73	-7,058.58	-6,328.52	-5,673.86	-5,086.85	-4,560.49	-4,088.52
AG yield																						
Fish [CAD/kg]		8.8	3,080.00	3,080.00	3,080.00	3,080.00	3,080.00	3,080.00	3,080.00	3,080.00	3,080.00	3,080.00	3,080.00	3,080.00	3,080.00	3,080.00	3,080.00	3,080.00	3,080.00	3,080.00	3,080.00	3,080.00
Basil: NFT [CAD/kg]		7.5	20,790.00	20,790.00	20,790.00	20,790.00	20,790.00	20,790.00	20,790.00	20,790.00	20,790.00	20,790.00	20,790.00	20,790.00	20,790.00	20,790.00	20,790.00	20,790.00	20,790.00	20,790.00	20,790.00	20,790.00
Lettuce: Soil [CAD/kg]		5	6,930.00	6,930.00	6,930.00	6,930.00	6,930.00	6,930.00	6,930.00	6,930.00	6,930.00	6,930.00	6,930.00	6,930.00	6,930.00	6,930.00	6,930.00	6,930.00	6,930.00	6,930.00	6,930.00	6,930.00
Additional income																						
Carbon offsets			2,331.00	2,648.87	2,966.73	3,284.60	3,602.46	3,644.84	3,687.22	3,729.60	3,771.99	3,814.37	3,856.75	3,899.13	3,941.51	3,983.90	4,026.28	4,068.66	4,111.04	4,153.42	4,195.81	4,238.19
Farm waste [CAD/t]		50	4,028.63	4,028.63	4,028.63	4,028.63	4,028.63	4,028.63	4,028.63	4,028.63	4,028.63	4,028.63	4,028.63	4,028.63	4,028.63	4,028.63	4,028.63	4,028.63	4,028.63	4,028.63	4,028.63	4,028.63
AG waste [CAD/t]		50	31.70	31.70	31.70	31.70	31.70	31.70	31.70	31.70	31.70	31.70	31.70	31.70	31.70	31.70	31.70	31.70	31.70	31.70	31.70	31.70
		285,725.29	**33,206.55**	**29,902.11**	**26,924.56**	**24,241.79**	**21,824.82**	**19,507.92**	**17,436.96**	**15,585.83**	**13,931.20**	**12,452.22**	**11,130.24**	**9,948.59**	**8,892.38**	**7,948.30**	**7,104.44**	**6,350.16**	**5,675.96**	**5,073.33**	**4,534.68**	**4,053.22**
NPV Total		**6,693.12**	695.26	767.41	797.06	811.54	813.77	666.64	541.70	435.87	346.51	271.29	208.21	155.53	111.76	75.57	45.86	21.65	2.10	-13.51	-25.80	-35.30
	Cumulative		695.26	1,462.67	2,259.73	3,071.27	3,885.04	4,551.69	5,093.38	5,529.26	5,875.77	6,147.06	6,355.27	6,510.80	6,622.56	6,698.13	6,743.99	6,765.64	6,767.73	6,754.22	6,728.42	6,693.12

Discount rate 12 [%]

BIODIGESTER (BIOGAS)

392 [m2] 8000 [l]

Lifespan	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Years	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**	**2036**	**2037**	**2038**	**2039**	**2040**	**2041**	**2042**	**2043**	**2044**	**2045**
Electricity rates [CAD/kWh]	0.104	0.160	0.167	0.175	0.182	0.189	0.197	0.204	0.212	0.219	0.226	0.234	0.241	0.248	0.256	0.263	0.271	0.278	0.285	0.293	0.300
Carbon offset price [CAD/t]	95	110	125	140	155	170	172	174	176	178	180	182	184	186	188	190	192	194	196	198	200
CAPEX_Heating																					
Hydronic radiant heating	16,516.50	-825.82	-825.82	-825.82	-825.82	-825.82	-825.82	-825.82	-825.82	-825.82	-825.82	-825.82	-825.82	-825.82	-825.82	-825.82	-825.82	-825.82	-825.82	-825.82	-825.82
Biogas boiler (incl. burner)	19,690.00	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50
Buffer tank	1,420.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00
Biodigester	21,000.00	-1,050.00	-1,050.00	-1,050.00	-1,050.00	-1,050.00	-1,050.00	-1,050.00	-1,050.00	-1,050.00	-1,050.00	-1,050.00	-1,050.00	-1,050.00	-1,050.00	-1,050.00	-1,050.00	-1,050.00	-1,050.00	-1,050.00	-1,050.00
Total:	**58,626.50**	2,931.32	2,931.32	2,931.32	2,931.32	2,931.32	2,931.32	2,931.32	2,931.32	2,931.32	2,931.32	2,931.32	2,931.32	2,931.32	2,931.32	2,931.32	2,931.32	2,931.32	2,931.32	2,931.32	2,931.32
	21,895.37	**-2,617.25**	**-2,336.83**	**-2,086.46**	**-1,862.91**	**-1,663.31**	**-1,485.10**	**-1,325.98**	**-1,183.91**	**-1,057.07**	**-943.81**	**-842.69**	**-752.40**	**-671.78**	**-599.81**	**-535.54**	**-478.16**	**-426.93**	**-381.19**	**-340.35**	**-303.88**
OPEX_Heating																					
Water [CAD/m3]	10.93	-1,953.71	-1,953.71	-1,953.71	-1,953.71	-1,953.71	-1,953.71	-1,953.71	-1,953.71	-1,953.71	-1,953.71	-1,953.71	-1,953.71	-1,953.71	-1,953.71	-1,953.71	-1,953.71	-1,953.71	-1,953.71	-1,953.71	-1,953.71
Maintenance		-1,502.20	-1,502.20	-1,502.20	-1,502.20	-1,502.20	-1,502.20	-1,502.20	-1,502.20	-1,502.20	-1,502.20	-1,502.20	-1,502.20	-1,502.20	-1,502.20	-1,502.20	-1,502.20	-1,502.20	-1,502.20	-1,502.20	-1,502.20
Cooling	0.30	-648.89	-646.56	-675.03	-703.49	-731.95	-760.42	-788.88	-817.35	-845.81	-874.28	-902.74	-931.21	-959.67	-988.14	-1,016.60	-1,045.07	-1,073.53	-1,102.00	-1,130.46	-1,158.93
Transport		-4,468.69	-4,468.69	-4,468.69	-4,468.69	-4,468.69	-4,468.69	-4,468.69	-4,468.69	-4,468.69	-4,468.69	-4,468.69	-4,468.69	-4,468.69	-4,468.69	-4,468.69	-4,468.69	-4,468.69	-4,468.69	-4,468.69	-4,468.69
Labour		-2,979.13	-2,979.13	-2,979.13	-2,979.13	-2,979.13	-2,979.13	-2,979.13	-2,979.13	-2,979.13	-2,979.13	-2,979.13	-2,979.13	-2,979.13	-2,979.13	-2,979.13	-2,979.13	-2,979.13	-2,979.13	-2,979.13	-2,979.13
Total:		11,552.63	11,550.29	11,578.76	11,607.22	11,635.69	11,664.15	11,692.62	11,721.08	11,749.55	11,778.01	11,806.48	11,834.94	11,863.41	11,891.87	11,920.34	11,948.80	11,977.27	12,005.73	12,034.20	12,062.66
Net emissions impact	[t CO2e]	2.16	2.16	2.16	2.16	2.16	2.16	2.16	2.16	2.16	2.16	2.16	2.16	2.16	2.16	2.16	2.16	2.16	2.16	2.16	2.16
	87,369.15	**-10,314.85**	**-9,207.82**	**-8,241.53**	**-7,376.60**	**-6,602.40**	**-5,909.42**	**-5,289.15**	**-4,733.95**	**-4,237.01**	**-3,792.21**	**-3,394.08**	**-3,037.74**	**-2,718.79**	**-2,433.31**	**-2,177.80**	**-1,949.11**	**-1,744.42**	**-1,561.22**	**-1,397.25**	**-1,250.50**
NPC Heating	**-109,264.52**	-12,932.10	-11,544.66	-10,327.99	-9,239.51	-8,265.72	-7,394.52	-6,615.13	-5,917.86	-5,294.07	-4,736.01	-4,236.77	-3,790.13	-3,390.57	-3,033.12	-2,713.34	-2,427.27	-2,171.35	-1,942.41	-1,737.60	-1,554.38
CAPEX_Non-Heating																					
Building																					
Material	58,484.42	-2,924.22	-2,924.22	-2,924.22	-2,924.22	-2,924.22	-2,924.22	-2,924.22	-2,924.22	-2,924.22	-2,924.22	-2,924.22	-2,924.22	-2,924.22	-2,924.22	-2,924.22	-2,924.22	-2,924.22	-2,924.22	-2,924.22	-2,924.22
Labour	55,463.63	-2,773.18	-2,773.18	-2,773.18	-2,773.18	-2,773.18	-2,773.18	-2,773.18	-2,773.18	-2,773.18	-2,773.18	-2,773.18	-2,773.18	-2,773.18	-2,773.18	-2,773.18	-2,773.18	-2,773.18	-2,773.18	-2,773.18	-2,773.18
Total:	**113,948.05**	5,697.40	5,697.40	5,697.40	5,697.40	5,697.40	5,697.40	5,697.40	5,697.40	5,697.40	5,697.40	5,697.40	5,697.40	5,697.40	5,697.40	5,697.40	5,697.40	5,697.40	5,697.40	5,697.40	5,697.40
Aquaponics																					
Aquaculture system	14,120.00	-706.00	-706.00	-706.00	-706.00	-706.00	-706.00	-706.00	-706.00	-706.00	-706.00	-706.00	-706.00	-706.00	-706.00	-706.00	-706.00	-706.00	-706.00	-706.00	-706.00
NFT system 1: Horizontal	18,363.33	-918.17	-918.17	-918.17	-918.17	-918.17	-918.17	-918.17	-918.17	-918.17	-918.17	-918.17	-918.17	-918.17	-918.17	-918.17	-918.17	-918.17	-918.17	-918.17	-918.17
NFT system 2: Vertical	36,513.33	-1,825.67	-1,825.67	-1,825.67	-1,825.67	-1,825.67	-1,825.67	-1,825.67	-1,825.67	-1,825.67	-1,825.67	-1,825.67	-1,825.67	-1,825.67	-1,825.67	-1,825.67	-1,825.67	-1,825.67	-1,825.67	-1,825.67	-1,825.67
Growing lights	33,008.25	-1,650.41	-1,650.41	-1,650.41	-1,650.41	-1,650.41	-1,650.41	-1,650.41	-1,650.41	-1,650.41	-1,650.41	-1,650.41	-1,650.41	-1,650.41	-1,650.41	-1,650.41	-1,650.41	-1,650.41	-1,650.41	-1,650.41	-1,650.41
Water	221.11	-11.06	-11.06	-11.06	-11.06	-11.06	-11.06	-11.06	-11.06	-11.06	-11.06	-11.06	-11.06	-11.06	-11.06	-11.06	-11.06	-11.06	-11.06	-11.06	-11.06
Total:	**102,226.03**	5,111.30	5,111.30	5,111.30	5,111.30	5,111.30	5,111.30	5,111.30	5,111.30	5,111.30	5,111.30	5,111.30	5,111.30	5,111.30	5,111.30	5,111.30	5,111.30	5,111.30	5,111.30	5,111.30	5,111.30
Soil-based cultivation																					
Growing beds	1,650.00	-82.50	-82.50	-82.50	-82.50	-82.50	-82.50	-82.50	-82.50	-82.50	-82.50	-82.50	-82.50	-82.50	-82.50	-82.50	-82.50	-82.50	-82.50	-82.50	-82.50
Soil	3,300.00	-165.00	-165.00	-165.00	-165.00	-165.00	-165.00	-165.00	-165.00	-165.00	-165.00	-165.00	-165.00	-165.00	-165.00	-165.00	-165.00	-165.00	-165.00	-165.00	-165.00
Total:	**4,950.00**	247.50	247.50	247.50	247.50	247.50	247.50	247.50	247.50	247.50	247.50	247.50	247.50	247.50	247.50	247.50	247.50	247.50	247.50	247.50	247.50
	82,583.69	**-9,871.61**	**-8,813.94**	**-7,869.59**	**-7,026.42**	**-6,273.59**	**-5,601.42**	**-5,001.27**	**-4,465.42**	**-3,986.98**	**-3,559.80**	**-3,178.39**	**-2,837.85**	**-2,533.80**	**-2,262.32**	**-2,019.93**	**-1,803.51**	**-1,610.27**	**-1,437.74**	**-1,283.70**	**-1,146.16**
OPEX_Non-Heating																					
Electricity Grow lights		-2,975.73	-3,112.77	-3,249.81	-3,386.85	-3,523.89	-3,660.93	-3,797.97	-3,935.01	-4,072.05	-4,209.09	-4,346.13	-4,483.17	-4,620.21	-4,757.25	-4,894.29	-5,031.33	-5,168.37	-5,305.41	-5,442.45	-5,579.49
Pumps		-424.26	-443.79	-463.33	-482.87	-502.41	-521.95	-541.48	-561.02	-580.56	-600.10	-619.64	-639.17	-658.71	-678.25	-697.79	-717.33	-736.86	-756.40	-775.94	-795.48
Labor		-3,664.00	-3,664.00	-3,664.00	-3,664.00	-3,664.00	-3,664.00	-3,664.00	-3,664.00	-3,664.00	-3,664.00	-3,664.00	-3,664.00	-3,664.00	-3,664.00	-3,664.00	-3,664.00	-3,664.00	-3,664.00	-3,664.00	-3,664.00
Fish feed		-4,831.20	-4,831.20	-4,831.20	-4,831.20	-4,831.20	-4,831.20	-4,831.20	-4,831.20	-4,831.20	-4,831.20	-4,831.20	-4,831.20	-4,831.20	-4,831.20	-4,831.20	-4,831.20	-4,831.20	-4,831.20	-4,831.20	-4,831.20
Maintenance Building		-1,355.71	-1,355.71	-1,355.71	-1,355.71	-1,355.71	-1,355.71	-1,355.71	-1,355.71	-1,355.71	-1,355.71	-1,355.71	-1,355.71	-1,355.71	-1,355.71	-1,355.71	-1,355.71	-1,355.71	-1,355.71	-1,355.71	-1,355.71
Aquaponics		-2,080.00	-2,080.00	-2,080.00	-2,080.00	-2,080.00	-2,080.00	-2,080.00	-2,080.00	-2,080.00	-2,080.00	-2,080.00	-2,080.00	-2,080.00	-2,080.00	-2,080.00	-2,080.00	-2,080.00	-2,080.00	-2,080.00	-2,080.00
	121,554.16	**-13,688.29**	**-12,346.51**	**-11,135.12**	**-10,041.58**	**-9,054.55**	**-8,163.74**	**-7,359.88**	**-6,634.56**	**-5,980.18**	**-5,389.86**	**-4,857.39**	**-4,377.14**	**-3,944.05**	**-3,553.51**	**-3,201.38**	**-2,883.92**	**-2,597.73**	**-2,339.77**	**-2,107.26**	**-1,897.71**
NPC Total	**-313,402.37**	-36,492.01	-32,705.11	-29,332.70	-26,307.51	-23,593.85	-21,159.68	-18,976.28	-17,017.84	-15,261.23	-13,685.68	-12,272.55	-11,005.13	-9,868.42	-8,848.95	-7,934.65	-7,114.70	-6,379.36	-5,719.92	-5,128.56	-4,598.25
AG yield																					
Fish [CAD/kg]	8.8	3,520.00	3,520.00	3,520.00	3,520.00	3,520.00	3,520.00	3,520.00	3,520.00	3,520.00	3,520.00	3,520.00	3,520.00	3,520.00	3,520.00	3,520.00	3,520.00	3,520.00	3,520.00	3,520.00	3,520.00
Basil: NFT [CAD/kg]	7.5	23,760.00	23,760.00	23,760.00	23,760.00	23,760.00	23,760.00	23,760.00	23,760.00	23,760.00	23,760.00	23,760.00	23,760.00	23,760.00	23,760.00	23,760.00	23,760.00	23,760.00	23,760.00	23,760.00	23,760.00
Lettuce: Soil [CAD/kg]	5	7,920.00	7,920.00	7,920.00	7,920.00	7,920.00	7,920.00	7,920.00	7,920.00	7,920.00	7,920.00	7,920.00	7,920.00	7,920.00	7,920.00	7,920.00	7,920.00	7,920.00	7,920.00	7,920.00	7,920.00
Additional income																					
Carbon offsets		2,585.63	2,938.21	3,290.80	3,643.38	3,995.97	4,042.98	4,089.99	4,137.00	4,184.01	4,231.03	4,278.04	4,325.05	4,372.06	4,419.07	4,466.08	4,513.09	4,560.10	4,607.12	4,654.13	4,701.14
Farm waste [CAD/t]	50	4,468.69	4,468.69	4,468.69	4,468.69	4,468.69	4,468.69	4,468.69	4,468.69	4,468.69	4,468.69	4,468.69	4,468.69	4,468.69	4,468.69	4,468.69	4,468.69	4,468.69	4,468.69	4,468.69	4,468.69
AG waste [CAD/t]	50	36.23	36.23	36.23	36.23	36.23	36.23	36.23	36.23	36.23	36.23	36.23	36.23	36.23	36.23	36.23	36.23	36.23	36.23	36.23	36.23
	324,679.44	**37,759.42**	**33,994.85**	**30,603.51**	**27,548.64**	**24,797.06**	**22,164.05**	**19,810.60**	**17,707.02**	**15,826.79**	**14,146.20**	**12,644.05**	**11,301.40**	**10,101.31**	**9,028.64**	**8,069.88**	**7,212.92**	**6,446.95**	**5,762.32**	**5,150.39**	**4,603.43**
NPV Total	**11,277.07**	1,267.42	1,289.74	1,270.81	1,241.13	1,203.22	1,004.37	834.32	689.18	565.56	460.52	371.50	296.27	232.89	179.70	135.22	98.22	67.59	42.40	21.83	5.18
Cumulative		1,267.42	2,557.16	3,827.97	5,069.09	6,272.31	7,276.67	8,110.99	8,800.17	9,365.73	9,826.26	10,197.76	10,494.03	10,726.92	10,906.62	11,041.84	11,140.06	11,207.65	11,250.05	11,271.89	11,277.07

Discount rate 12 [%]

BIODIGESTER (BIOGAS)

436 [m2] 9000 [l]

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Lifespan	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Years	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**	**2036**	**2037**	**2038**	**2039**	**2040**	**2041**	**2042**	**2043**	**2044**	**2045**
Electricity rates [CAD/kWh]	0.104	0.160	0.167	0.175	0.182	0.189	0.197	0.204	0.212	0.219	0.226	0.234	0.241	0.248	0.256	0.263	0.271	0.278	0.285	0.293	0.300
Carbon offset price [CAD/t]	95	110	125	140	155	170	172	174	176	178	180	182	184	186	188	190	192	194	196	198	200
CAPEX_Heating																					
Hydronic radiant heating	18,378.49	-918.92	-918.92	-918.92	-918.92	-918.92	-918.92	-918.92	-918.92	-918.92	-918.92	-918.92	-918.92	-918.92	-918.92	-918.92	-918.92	-918.92	-918.92	-918.92	-918.92
Biogas boiler (incl. burner)	24,690.00	-1,234.50	-1,234.50	-1,234.50	-1,234.50	-1,234.50	-1,234.50	-1,234.50	-1,234.50	-1,234.50	-1,234.50	-1,234.50	-1,234.50	-1,234.50	-1,234.50	-1,234.50	-1,234.50	-1,234.50	-1,234.50	-1,234.50	-1,234.50
Buffer tank	1,775.00	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75
Biodigester	28,000.00	-1,400.00	-1,400.00	-1,400.00	-1,400.00	-1,400.00	-1,400.00	-1,400.00	-1,400.00	-1,400.00	-1,400.00	-1,400.00	-1,400.00	-1,400.00	-1,400.00	-1,400.00	-1,400.00	-1,400.00	-1,400.00	-1,400.00	-1,400.00
Total:	**72,843.49**	3,642.17	3,642.17	3,642.17	3,642.17	3,642.17	3,642.17	3,642.17	3,642.17	3,642.17	3,642.17	3,642.17	3,642.17	3,642.17	3,642.17	3,642.17	3,642.17	3,642.17	3,642.17	3,642.17	3,642.17
	27,205.02	**-3,251.94**	**-2,903.52**	**-2,592.43**	**-2,314.67**	**-2,066.67**	**-1,845.24**	**-1,647.53**	**-1,471.01**	**-1,313.40**	**-1,172.68**	**-1,047.04**	**-934.86**	**-834.69**	**-745.26**	**-665.41**	**-594.12**	**-530.46**	**-473.63**	**-422.88**	**-377.57**
OPEX_Heating																					
Water [CAD/m3]	10.93	-2,147.11	-2,147.11	-2,147.11	-2,147.11	-2,147.11	-2,147.11	-2,147.11	-2,147.11	-2,147.11	-2,147.11	-2,147.11	-2,147.11	-2,147.11	-2,147.11	-2,147.11	-2,147.11	-2,147.11	-2,147.11	-2,147.11	-2,147.11
Maintenance		-1,650.90	-1,650.90	-1,650.90	-1,650.90	-1,650.90	-1,650.90	-1,650.90	-1,650.90	-1,650.90	-1,650.90	-1,650.90	-1,650.90	-1,650.90	-1,650.90	-1,650.90	-1,650.90	-1,650.90	-1,650.90	-1,650.90	-1,650.90
Cooling	0.30	-757.47	-756.81	-790.13	-823.45	-856.76	-890.08	-923.40	-956.72	-990.04	-1,023.36	-1,056.68	-1,090.00	-1,123.31	-1,156.63	-1,189.95	-1,223.27	-1,256.59	-1,289.91	-1,323.23	-1,356.54
Transport		-4,911.05	-4,911.05	-4,911.05	-4,911.05	-4,911.05	-4,911.05	-4,911.05	-4,911.05	-4,911.05	-4,911.05	-4,911.05	-4,911.05	-4,911.05	-4,911.05	-4,911.05	-4,911.05	-4,911.05	-4,911.05	-4,911.05	-4,911.05
Labour		-3,274.03	-3,274.03	-3,274.03	-3,274.03	-3,274.03	-3,274.03	-3,274.03	-3,274.03	-3,274.03	-3,274.03	-3,274.03	-3,274.03	-3,274.03	-3,274.03	-3,274.03	-3,274.03	-3,274.03	-3,274.03	-3,274.03	-3,274.03
Total:		12,740.55	12,739.89	12,773.21	12,806.53	12,839.85	12,873.17	12,906.48	12,939.80	12,973.12	13,006.44	13,039.76	13,073.08	13,106.40	13,139.71	13,173.03	13,206.35	13,239.67	13,272.99	13,306.31	13,339.63
Net emissions impact	[t CO2e]	2.37	2.37	2.37	2.37	2.37	2.37	2.37	2.37	2.37	2.37	2.37	2.37	2.37	2.37	2.37	2.37	2.37	2.37	2.37	2.37
	96,439.62	**-11,375.49**	**-10,156.16**	**-9,091.72**	**-8,138.78**	**-7,285.67**	**-6,521.95**	**-5,838.24**	**-5,226.17**	**-4,678.24**	**-4,187.73**	**-3,748.62**	**-3,355.53**	**-3,003.65**	**-2,688.65**	**-2,406.66**	**-2,154.24**	**-1,928.28**	**-1,726.01**	**-1,544.95**	**-1,382.88**
NPC Heating	**-123,644.64**	-14,627.44	-13,059.68	-11,684.15	-10,453.45	-9,352.34	-8,367.19	-7,485.77	-6,697.18	-5,991.64	-5,360.41	-4,795.66	-4,290.39	-3,838.34	-3,433.91	-3,072.08	-2,748.36	-2,458.75	-2,199.64	-1,967.83	-1,760.45
CAPEX_Non-Heating																					
Building																					
Material	60,927.23	-3,046.36	-3,046.36	-3,046.36	-3,046.36	-3,046.36	-3,046.36	-3,046.36	-3,046.36	-3,046.36	-3,046.36	-3,046.36	-3,046.36	-3,046.36	-3,046.36	-3,046.36	-3,046.36	-3,046.36	-3,046.36	-3,046.36	-3,046.36
Labour	61,497.18	-3,074.86	-3,074.86	-3,074.86	-3,074.86	-3,074.86	-3,074.86	-3,074.86	-3,074.86	-3,074.86	-3,074.86	-3,074.86	-3,074.86	-3,074.86	-3,074.86	-3,074.86	-3,074.86	-3,074.86	-3,074.86	-3,074.86	-3,074.86
Total:	**122,424.40**	6,121.22	6,121.22	6,121.22	6,121.22	6,121.22	6,121.22	6,121.22	6,121.22	6,121.22	6,121.22	6,121.22	6,121.22	6,121.22	6,121.22	6,121.22	6,121.22	6,121.22	6,121.22	6,121.22	6,121.22
Aquaponics																					
Aquaculture system	15,885.00	-794.25	-794.25	-794.25	-794.25	-794.25	-794.25	-794.25	-794.25	-794.25	-794.25	-794.25	-794.25	-794.25	-794.25	-794.25	-794.25	-794.25	-794.25	-794.25	-794.25
NFT system 1: Horizontal	20,658.75	-1,032.94	-1,032.94	-1,032.94	-1,032.94	-1,032.94	-1,032.94	-1,032.94	-1,032.94	-1,032.94	-1,032.94	-1,032.94	-1,032.94	-1,032.94	-1,032.94	-1,032.94	-1,032.94	-1,032.94	-1,032.94	-1,032.94	-1,032.94
NFT system 2: Vertical	41,077.50	-2,053.88	-2,053.88	-2,053.88	-2,053.88	-2,053.88	-2,053.88	-2,053.88	-2,053.88	-2,053.88	-2,053.88	-2,053.88	-2,053.88	-2,053.88	-2,053.88	-2,053.88	-2,053.88	-2,053.88	-2,053.88	-2,053.88	-2,053.88
Growing lights	37,134.28	-1,856.71	-1,856.71	-1,856.71	-1,856.71	-1,856.71	-1,856.71	-1,856.71	-1,856.71	-1,856.71	-1,856.71	-1,856.71	-1,856.71	-1,856.71	-1,856.71	-1,856.71	-1,856.71	-1,856.71	-1,856.71	-1,856.71	-1,856.71
Water	248.74	-12.44	-12.44	-12.44	-12.44	-12.44	-12.44	-12.44	-12.44	-12.44	-12.44	-12.44	-12.44	-12.44	-12.44	-12.44	-12.44	-12.44	-12.44	-12.44	-12.44
Total:	**115,004.28**	5,750.21	5,750.21	5,750.21	5,750.21	5,750.21	5,750.21	5,750.21	5,750.21	5,750.21	5,750.21	5,750.21	5,750.21	5,750.21	5,750.21	5,750.21	5,750.21	5,750.21	5,750.21	5,750.21	5,750.21
Soil-based cultivation																					
Growing beds	1,856.25	-92.81	-92.81	-92.81	-92.81	-92.81	-92.81	-92.81	-92.81	-92.81	-92.81	-92.81	-92.81	-92.81	-92.81	-92.81	-92.81	-92.81	-92.81	-92.81	-92.81
Soil	3,712.50	-185.63	-185.63	-185.63	-185.63	-185.63	-185.63	-185.63	-185.63	-185.63	-185.63	-185.63	-185.63	-185.63	-185.63	-185.63	-185.63	-185.63	-185.63	-185.63	-185.63
Total:	**5,568.75**	278.44	278.44	278.44	278.44	278.44	278.44	278.44	278.44	278.44	278.44	278.44	278.44	278.44	278.44	278.44	278.44	278.44	278.44	278.44	278.44
	90,752.78	**-10,848.10**	**-9,685.80**	**-8,648.04**	**-7,721.46**	**-6,894.16**	**-6,155.50**	**-5,495.98**	**-4,907.13**	**-4,381.37**	**-3,911.93**	**-3,492.80**	**-3,118.57**	**-2,784.44**	**-2,486.10**	**-2,219.74**	**-1,981.91**	**-1,769.56**	**-1,579.96**	**-1,410.68**	**-1,259.54**
OPEX_Non-Heating																					
Electricity – Grow lights		-3,347.69	-3,501.87	-3,656.04	-3,810.21	-3,964.38	-4,118.55	-4,272.72	-4,426.89	-4,581.06	-4,735.23	-4,889.40	-5,043.57	-5,197.74	-5,351.91	-5,506.08	-5,660.25	-5,814.42	-5,968.59	-6,122.76	-6,276.93
Pumps		-477.29	-499.27	-521.25	-543.23	-565.21	-587.19	-609.17	-631.15	-653.13	-675.11	-697.09	-719.07	-741.05	-763.03	-785.01	-806.99	-828.97	-850.95	-872.93	-894.91
Labor		-4,122.00	-4,122.00	-4,122.00	-4,122.00	-4,122.00	-4,122.00	-4,122.00	-4,122.00	-4,122.00	-4,122.00	-4,122.00	-4,122.00	-4,122.00	-4,122.00	-4,122.00	-4,122.00	-4,122.00	-4,122.00	-4,122.00	-4,122.00
Fish feed		-5,435.10	-5,435.10	-5,435.10	-5,435.10	-5,435.10	-5,435.10	-5,435.10	-5,435.10	-5,435.10	-5,435.10	-5,435.10	-5,435.10	-5,435.10	-5,435.10	-5,435.10	-5,435.10	-5,435.10	-5,435.10	-5,435.10	-5,435.10
Maintenance – Building		-1,508.54	-1,508.54	-1,508.54	-1,508.54	-1,508.54	-1,508.54	-1,508.54	-1,508.54	-1,508.54	-1,508.54	-1,508.54	-1,508.54	-1,508.54	-1,508.54	-1,508.54	-1,508.54	-1,508.54	-1,508.54	-1,508.54	-1,508.54
Aquaponics		-2,340.00	-2,340.00	-2,340.00	-2,340.00	-2,340.00	-2,340.00	-2,340.00	-2,340.00	-2,340.00	-2,340.00	-2,340.00	-2,340.00	-2,340.00	-2,340.00	-2,340.00	-2,340.00	-2,340.00	-2,340.00	-2,340.00	-2,340.00
	136,624.23	**-15,384.49**	**-13,876.57**	**-12,515.18**	**-11,286.21**	**-10,176.93**	**-9,175.79**	**-8,272.35**	**-7,457.17**	**-6,721.71**	**-6,058.24**	**-5,459.78**	**-4,920.02**	**-4,433.24**	**-3,994.30**	**-3,598.52**	**-3,241.70**	**-2,920.03**	**-2,630.07**	**-2,368.73**	**-2,133.20**
NPC Total	**-351,021.65**	-40,860.02	-36,622.06	-32,847.36	-29,461.12	-26,423.43	-23,698.48	-21,254.11	-19,061.48	-17,094.72	-15,330.58	-13,748.24	-12,328.98	-11,056.02	-9,914.31	-8,890.33	-7,971.96	-7,148.33	-6,409.68	-5,747.25	-5,153.19
AG yield																					
Fish [CAD/kg]	8.8	3,960.00	3,960.00	3,960.00	3,960.00	3,960.00	3,960.00	3,960.00	3,960.00	3,960.00	3,960.00	3,960.00	3,960.00	3,960.00	3,960.00	3,960.00	3,960.00	3,960.00	3,960.00	3,960.00	3,960.00
Basil: NFT [CAD/kg]	7.5	26,730.00	26,730.00	26,730.00	26,730.00	26,730.00	26,730.00	26,730.00	26,730.00	26,730.00	26,730.00	26,730.00	26,730.00	26,730.00	26,730.00	26,730.00	26,730.00	26,730.00	26,730.00	26,730.00	26,730.00
Lettuce: Soil [CAD/kg]	5	8,910.00	8,910.00	8,910.00	8,910.00	8,910.00	8,910.00	8,910.00	8,910.00	8,910.00	8,910.00	8,910.00	8,910.00	8,910.00	8,910.00	8,910.00	8,910.00	8,910.00	8,910.00	8,910.00	8,910.00
Additional income																					
Carbon offsets		2,841.57	3,229.06	3,616.55	4,004.04	4,391.52	4,443.19	4,494.85	4,546.52	4,598.18	4,649.85	4,701.51	4,753.18	4,804.84	4,856.51	4,908.17	4,959.84	5,011.50	5,063.17	5,114.83	5,166.50
Farm waste [CAD/t]	50	4,911.05	4,911.05	4,911.05	4,911.05	4,911.05	4,911.05	4,911.05	4,911.05	4,911.05	4,911.05	4,911.05	4,911.05	4,911.05	4,911.05	4,911.05	4,911.05	4,911.05	4,911.05	4,911.05	4,911.05
AG waste [CAD/t]	50	40.76	40.76	40.76	40.76	40.76	40.76	40.76	40.76	40.76	40.76	40.76	40.76	40.76	40.76	40.76	40.76	40.76	40.76	40.76	40.76
	363,665.08	**42,315.52**	**38,090.62**	**34,285.29**	**30,858.12**	**27,771.76**	**24,822.39**	**22,186.22**	**19,829.99**	**17,723.98**	**15,841.62**	**14,159.15**	**12,655.36**	**11,311.27**	**10,109.92**	**9,036.15**	**8,076.42**	**7,218.62**	**6,451.91**	**5,766.63**	**5,154.14**
NPV Total	**12,643.43**	1,455.50	1,468.56	1,437.92	1,396.99	1,348.33	1,123.92	932.11	768.51	629.26	511.03	410.92	326.38	255.25	195.61	145.82	104.46	70.28	42.23	19.38	0.95
Cumulative		1,455.50	2,924.06	4,361.98	5,758.97	7,107.30	8,231.22	9,163.33	9,931.84	10,561.11	11,072.14	11,483.06	11,809.44	12,064.69	12,260.30	12,406.12	12,510.58	12,580.87	12,623.10	12,642.48	12,643.43

Discount rate 12 [%]

BIODIGESTER (BIOGAS)

481 [m2] 10000 [l]

Lifespan	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Years	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**	**2036**	**2037**	**2038**	**2039**	**2040**	**2041**	**2042**	**2043**	**2044**	**2045**
Electricity rates [CAD/kWh]	0.104	0.160	0.167	0.175	0.182	0.189	0.197	0.204	0.212	0.219	0.226	0.234	0.241	0.248	0.256	0.263	0.271	0.278	0.285	0.293	0.300
Carbon offset price [CAD/t]	95	110	125	140	155	170	172	174	176	178	180	182	184	186	188	190	192	194	196	198	200
CAPEX_Heating																					
Hydronic radiant heating	20,240.49	-1,012.02	-1,012.02	-1,012.02	-1,012.02	-1,012.02	-1,012.02	-1,012.02	-1,012.02	-1,012.02	-1,012.02	-1,012.02	-1,012.02	-1,012.02	-1,012.02	-1,012.02	-1,012.02	-1,012.02	-1,012.02	-1,012.02	-1,012.02
Biogas boiler (incl. burner)	24,690.00	-1,234.50	-1,234.50	-1,234.50	-1,234.50	-1,234.50	-1,234.50	-1,234.50	-1,234.50	-1,234.50	-1,234.50	-1,234.50	-1,234.50	-1,234.50	-1,234.50	-1,234.50	-1,234.50	-1,234.50	-1,234.50	-1,234.50	-1,234.50
Buffer tank	1,775.00	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75
Biodigester	28,000.00	-1,400.00	-1,400.00	-1,400.00	-1,400.00	-1,400.00	-1,400.00	-1,400.00	-1,400.00	-1,400.00	-1,400.00	-1,400.00	-1,400.00	-1,400.00	-1,400.00	-1,400.00	-1,400.00	-1,400.00	-1,400.00	-1,400.00	-1,400.00
Total:	**74,705.49**	3,735.27	3,735.27	3,735.27	3,735.27	3,735.27	3,735.27	3,735.27	3,735.27	3,735.27	3,735.27	3,735.27	3,735.27	3,735.27	3,735.27	3,735.27	3,735.27	3,735.27	3,735.27	3,735.27	3,735.27
	27,900.42	**-3,335.07**	**-2,977.74**	**-2,658.69**	**-2,373.83**	**-2,119.50**	**-1,892.41**	**-1,689.65**	**-1,508.61**	**-1,346.98**	**-1,202.66**	**-1,073.80**	**-958.75**	**-856.03**	**-764.31**	**-682.42**	**-609.30**	**-544.02**	**-485.73**	**-433.69**	**-387.22**
OPEX_Heating																					
Water [CAD/m3]	10.93	-2,350.15	-2,350.15	-2,350.15	-2,350.15	-2,350.15	-2,350.15	-2,350.15	-2,350.15	-2,350.15	-2,350.15	-2,350.15	-2,350.15	-2,350.15	-2,350.15	-2,350.15	-2,350.15	-2,350.15	-2,350.15	-2,350.15	-2,350.15
Maintenance		-1,807.02	-1,807.02	-1,807.02	-1,807.02	-1,807.02	-1,807.02	-1,807.02	-1,807.02	-1,807.02	-1,807.02	-1,807.02	-1,807.02	-1,807.02	-1,807.02	-1,807.02	-1,807.02	-1,807.02	-1,807.02	-1,807.02	-1,807.02
Cooling	0.30	-1,018.39	-1,024.67	-1,069.78	-1,114.89	-1,160.00	-1,205.11	-1,250.23	-1,295.34	-1,340.45	-1,385.56	-1,430.67	-1,475.78	-1,520.89	-1,566.00	-1,611.12	-1,656.23	-1,701.34	-1,746.45	-1,791.56	-1,836.67
Transport		-5,375.46	-5,375.46	-5,375.46	-5,375.46	-5,375.46	-5,375.46	-5,375.46	-5,375.46	-5,375.46	-5,375.46	-5,375.46	-5,375.46	-5,375.46	-5,375.46	-5,375.46	-5,375.46	-5,375.46	-5,375.46	-5,375.46	-5,375.46
Labour		-3,583.64	-3,583.64	-3,583.64	-3,583.64	-3,583.64	-3,583.64	-3,583.64	-3,583.64	-3,583.64	-3,583.64	-3,583.64	-3,583.64	-3,583.64	-3,583.64	-3,583.64	-3,583.64	-3,583.64	-3,583.64	-3,583.64	-3,583.64
Total:		14,134.66	14,140.94	14,186.05	14,231.16	14,276.27	14,321.38	14,366.50	14,411.61	14,456.72	14,501.83	14,546.94	14,592.05	14,637.16	14,682.27	14,727.39	14,772.50	14,817.61	14,862.72	14,907.83	14,952.94
Net emissions impact	[t CO2e]	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60
	107,351.21	**-12,620.23**	**-11,273.07**	**-10,097.35**	**-9,044.16**	**-8,100.74**	**-7,255.66**	**-6,498.67**	**-5,820.61**	**-5,213.24**	**-4,669.20**	**-4,181.90**	**-3,745.42**	**-3,354.46**	**-3,004.28**	**-2,690.64**	**-2,409.71**	**-2,158.10**	**-1,932.74**	**-1,730.90**	**-1,550.12**
NPC Heating	**-135,251.63**	-15,955.30	-14,250.81	-12,756.05	-11,418.00	-10,220.24	-9,148.07	-8,188.32	-7,329.22	-6,560.21	-5,871.86	-5,255.70	-4,704.17	-4,210.49	-3,768.60	-3,373.06	-3,019.02	-2,702.12	-2,418.48	-2,164.59	-1,937.35
CAPEX_Non-Heating																					
Building																					
Material	69,137.60	-3,456.88	-3,456.88	-3,456.88	-3,456.88	-3,456.88	-3,456.88	-3,456.88	-3,456.88	-3,456.88	-3,456.88	-3,456.88	-3,456.88	-3,456.88	-3,456.88	-3,456.88	-3,456.88	-3,456.88	-3,456.88	-3,456.88	-3,456.88
Labour	69,801.60	-3,490.08	-3,490.08	-3,490.08	-3,490.08	-3,490.08	-3,490.08	-3,490.08	-3,490.08	-3,490.08	-3,490.08	-3,490.08	-3,490.08	-3,490.08	-3,490.08	-3,490.08	-3,490.08	-3,490.08	-3,490.08	-3,490.08	-3,490.08
Total:	**138,939.19**	6,946.96	6,946.96	6,946.96	6,946.96	6,946.96	6,946.96	6,946.96	6,946.96	6,946.96	6,946.96	6,946.96	6,946.96	6,946.96	6,946.96	6,946.96	6,946.96	6,946.96	6,946.96	6,946.96	6,946.96
Aquaponics																					
Aquaculture system	17,650.00	-882.50	-882.50	-882.50	-882.50	-882.50	-882.50	-882.50	-882.50	-882.50	-882.50	-882.50	-882.50	-882.50	-882.50	-882.50	-882.50	-882.50	-882.50	-882.50	-882.50
NFT system 1: Horizontal	22,954.17	-1,147.71	-1,147.71	-1,147.71	-1,147.71	-1,147.71	-1,147.71	-1,147.71	-1,147.71	-1,147.71	-1,147.71	-1,147.71	-1,147.71	-1,147.71	-1,147.71	-1,147.71	-1,147.71	-1,147.71	-1,147.71	-1,147.71	-1,147.71
NFT system 2: Vertical	45,641.67	-2,282.08	-2,282.08	-2,282.08	-2,282.08	-2,282.08	-2,282.08	-2,282.08	-2,282.08	-2,282.08	-2,282.08	-2,282.08	-2,282.08	-2,282.08	-2,282.08	-2,282.08	-2,282.08	-2,282.08	-2,282.08	-2,282.08	-2,282.08
Growing lights	41,260.32	-2,063.02	-2,063.02	-2,063.02	-2,063.02	-2,063.02	-2,063.02	-2,063.02	-2,063.02	-2,063.02	-2,063.02	-2,063.02	-2,063.02	-2,063.02	-2,063.02	-2,063.02	-2,063.02	-2,063.02	-2,063.02	-2,063.02	-2,063.02
Water	276.38	-13.82	-13.82	-13.82	-13.82	-13.82	-13.82	-13.82	-13.82	-13.82	-13.82	-13.82	-13.82	-13.82	-13.82	-13.82	-13.82	-13.82	-13.82	-13.82	-13.82
Total:	**127,782.53**	6,389.13	6,389.13	6,389.13	6,389.13	6,389.13	6,389.13	6,389.13	6,389.13	6,389.13	6,389.13	6,389.13	6,389.13	6,389.13	6,389.13	6,389.13	6,389.13	6,389.13	6,389.13	6,389.13	6,389.13
Soil-based cultivation																					
Growing beds	2,062.50	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13
Soil	4,125.00	-206.25	-206.25	-206.25	-206.25	-206.25	-206.25	-206.25	-206.25	-206.25	-206.25	-206.25	-206.25	-206.25	-206.25	-206.25	-206.25	-206.25	-206.25	-206.25	-206.25
Total:	**6,187.50**	309.38	309.38	309.38	309.38	309.38	309.38	309.38	309.38	309.38	309.38	309.38	309.38	309.38	309.38	309.38	309.38	309.38	309.38	309.38	309.38
	101,924.00	**-12,183.45**	**-10,878.08**	**-9,712.57**	**-8,671.94**	**-7,742.80**	**-6,913.22**	**-6,172.51**	**-5,511.17**	**-4,920.69**	**-4,393.47**	**-3,922.74**	**-3,502.45**	**-3,127.19**	**-2,792.13**	**-2,492.97**	**-2,225.87**	**-1,987.38**	**-1,774.45**	**-1,584.33**	**-1,414.58**
OPEX_Non-Heating																					
Electricity – Grow lights		-3,719.66	-3,890.96	-4,062.26	-4,233.56	-4,404.86	-4,576.16	-4,747.46	-4,918.76	-5,090.06	-5,261.36	-5,432.66	-5,603.96	-5,775.26	-5,946.56	-6,117.86	-6,289.16	-6,460.46	-6,631.76	-6,803.06	-6,974.36
Pumps		-530.32	-554.74	-579.16	-603.59	-628.01	-652.43	-676.85	-701.28	-725.70	-750.12	-774.55	-798.97	-823.39	-847.81	-872.24	-896.66	-921.08	-945.50	-969.93	-994.35
Labor		-4,580.00	-4,580.00	-4,580.00	-4,580.00	-4,580.00	-4,580.00	-4,580.00	-4,580.00	-4,580.00	-4,580.00	-4,580.00	-4,580.00	-4,580.00	-4,580.00	-4,580.00	-4,580.00	-4,580.00	-4,580.00	-4,580.00	-4,580.00
Fish feed		-6,039.00	-6,039.00	-6,039.00	-6,039.00	-6,039.00	-6,039.00	-6,039.00	-6,039.00	-6,039.00	-6,039.00	-6,039.00	-6,039.00	-6,039.00	-6,039.00	-6,039.00	-6,039.00	-6,039.00	-6,039.00	-6,039.00	-6,039.00
Maintenance – Building		-1,661.38	-1,661.38	-1,661.38	-1,661.38	-1,661.38	-1,661.38	-1,661.38	-1,661.38	-1,661.38	-1,661.38	-1,661.38	-1,661.38	-1,661.38	-1,661.38	-1,661.38	-1,661.38	-1,661.38	-1,661.38	-1,661.38	-1,661.38
Aquaponics		-2,600.00	-2,600.00	-2,600.00	-2,600.00	-2,600.00	-2,600.00	-2,600.00	-2,600.00	-2,600.00	-2,600.00	-2,600.00	-2,600.00	-2,600.00	-2,600.00	-2,600.00	-2,600.00	-2,600.00	-2,600.00	-2,600.00	-2,600.00
	151,694.31	**-17,080.68**	**-15,406.63**	**-13,895.23**	**-12,530.84**	**-11,299.31**	**-10,187.83**	**-9,184.81**	**-8,279.77**	**-7,463.24**	**-6,726.62**	**-6,062.18**	**-5,462.90**	**-4,922.44**	**-4,435.08**	**-3,995.65**	**-3,599.48**	**-3,242.32**	**-2,920.38**	**-2,630.21**	**-2,368.69**
NPC Total	**-388,869.94**	-45,219.42	-40,535.52	-36,363.85	-32,620.78	-29,262.35	-26,249.11	-23,545.65	-21,120.17	-18,944.14	-16,991.95	-15,240.62	-13,669.51	-12,260.12	-10,995.81	-9,861.69	-8,844.36	-7,931.83	-7,113.31	-6,379.13	-5,720.62
AG yield																					
Fish [CAD/kg]	8.8	4,400.00	4,400.00	4,400.00	4,400.00	4,400.00	4,400.00	4,400.00	4,400.00	4,400.00	4,400.00	4,400.00	4,400.00	4,400.00	4,400.00	4,400.00	4,400.00	4,400.00	4,400.00	4,400.00	4,400.00
Basil: NFT [CAD/kg]	7.5	29,700.00	29,700.00	29,700.00	29,700.00	29,700.00	29,700.00	29,700.00	29,700.00	29,700.00	29,700.00	29,700.00	29,700.00	29,700.00	29,700.00	29,700.00	29,700.00	29,700.00	29,700.00	29,700.00	29,700.00
Lettuce: Soil [CAD/kg]	5	9,900.00	9,900.00	9,900.00	9,900.00	9,900.00	9,900.00	9,900.00	9,900.00	9,900.00	9,900.00	9,900.00	9,900.00	9,900.00	9,900.00	9,900.00	9,900.00	9,900.00	9,900.00	9,900.00	9,900.00
Additional income																					
Carbon offsets		3,110.29	3,534.42	3,958.55	4,382.68	4,806.81	4,863.36	4,919.91	4,976.46	5,033.01	5,089.57	5,146.12	5,202.67	5,259.22	5,315.77	5,372.32	5,428.87	5,485.42	5,541.97	5,598.52	5,655.07
Farm waste [CAD/t]	50	5,375.46	5,375.46	5,375.46	5,375.46	5,375.46	5,375.46	5,375.46	5,375.46	5,375.46	5,375.46	5,375.46	5,375.46	5,375.46	5,375.46	5,375.46	5,375.46	5,375.46	5,375.46	5,375.46	5,375.46
AG waste [CAD/t]	50	45.29	45.29	45.29	45.29	45.29	45.29	45.29	45.29	45.29	45.29	45.29	45.29	45.29	45.29	45.29	45.29	45.29	45.29	45.29	45.29
	402,954.33	**46,902.72**	**42,215.54**	**37,994.33**	**34,193.06**	**30,770.18**	**27,502.02**	**24,580.96**	**21,970.12**	**19,636.57**	**17,550.86**	**15,686.67**	**14,020.47**	**12,531.24**	**11,200.18**	**10,010.49**	**8,947.16**	**7,996.77**	**7,147.33**	**6,388.11**	**5,709.53**
NPV Total	**14,084.39**	1,683.29	1,680.02	1,630.49	1,572.28	1,507.83	1,252.91	1,035.31	849.96	692.43	558.91	446.05	350.96	271.12	204.37	148.80	102.80	64.94	34.02	8.98	-11.09
Cumulative		1,683.29	3,363.32	4,993.80	6,566.08	8,073.91	9,326.82	10,362.13	11,212.09	11,904.52	12,463.43	12,909.48	13,260.44	13,531.56	13,735.93	13,884.73	13,987.53	14,052.47	14,086.49	14,095.47	14,084.39

Discount rate 12 [%]

BIODIGESTER (BIOGAS)

525 [m2] 11000 [l]

Lifespan	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Years	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**	**2036**	**2037**	**2038**	**2039**	**2040**	**2041**	**2042**	**2043**	**2044**	**2045**
Electricity rates [CAD/kWh]	0.104	0.160	0.167	0.175	0.182	0.189	0.197	0.204	0.212	0.219	0.226	0.234	0.241	0.248	0.256	0.263	0.271	0.278	0.285	0.293	0.300
Carbon offset price [CAD/t]	95	110	125	140	155	170	172	174	176	178	180	182	184	186	188	190	192	194	196	198	200
CAPEX_Heating																					
Hydronic radiant heating	22,102.48	-1,105.12	-1,105.12	-1,105.12	-1,105.12	-1,105.12	-1,105.12	-1,105.12	-1,105.12	-1,105.12	-1,105.12	-1,105.12	-1,105.12	-1,105.12	-1,105.12	-1,105.12	-1,105.12	-1,105.12	-1,105.12	-1,105.12	-1,105.12
Biogas boiler (incl. burner)	24,690.00	-1,234.50	-1,234.50	-1,234.50	-1,234.50	-1,234.50	-1,234.50	-1,234.50	-1,234.50	-1,234.50	-1,234.50	-1,234.50	-1,234.50	-1,234.50	-1,234.50	-1,234.50	-1,234.50	-1,234.50	-1,234.50	-1,234.50	-1,234.50
Buffer tank	1,775.00	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75
Biodigester	28,000.00	-1,400.00	-1,400.00	-1,400.00	-1,400.00	-1,400.00	-1,400.00	-1,400.00	-1,400.00	-1,400.00	-1,400.00	-1,400.00	-1,400.00	-1,400.00	-1,400.00	-1,400.00	-1,400.00	-1,400.00	-1,400.00	-1,400.00	-1,400.00
Total:	**76,567.48**	3,828.37	3,828.37	3,828.37	3,828.37	3,828.37	3,828.37	3,828.37	3,828.37	3,828.37	3,828.37	3,828.37	3,828.37	3,828.37	3,828.37	3,828.37	3,828.37	3,828.37	3,828.37	3,828.37	3,828.37
	28,595.83	**-3,418.19**	**-3,051.96**	**-2,724.96**	**-2,433.00**	**-2,172.32**	**-1,939.57**	**-1,731.76**	**-1,546.22**	**-1,380.55**	**-1,232.63**	**-1,100.57**	**-982.65**	**-877.36**	**-783.36**	**-699.43**	**-624.49**	**-557.58**	**-497.84**	**-444.50**	**-396.88**
OPEX_Heating																					
Water [CAD/m3]	10.93	-2,550.34	-2,550.34	-2,550.34	-2,550.34	-2,550.34	-2,550.34	-2,550.34	-2,550.34	-2,550.34	-2,550.34	-2,550.34	-2,550.34	-2,550.34	-2,550.34	-2,550.34	-2,550.34	-2,550.34	-2,550.34	-2,550.34	-2,550.34
Maintenance		-1,960.94	-1,960.94	-1,960.94	-1,960.94	-1,960.94	-1,960.94	-1,960.94	-1,960.94	-1,960.94	-1,960.94	-1,960.94	-1,960.94	-1,960.94	-1,960.94	-1,960.94	-1,960.94	-1,960.94	-1,960.94	-1,960.94	-1,960.94
Cooling	0.30	-1,147.96	-1,156.88	-1,207.81	-1,258.74	-1,309.68	-1,360.61	-1,411.54	-1,462.47	-1,513.40	-1,564.34	-1,615.27	-1,666.20	-1,717.13	-1,768.06	-1,819.00	-1,869.93	-1,920.86	-1,971.79	-2,022.72	-2,073.65
Transport		-5,833.35	-5,833.35	-5,833.35	-5,833.35	-5,833.35	-5,833.35	-5,833.35	-5,833.35	-5,833.35	-5,833.35	-5,833.35	-5,833.35	-5,833.35	-5,833.35	-5,833.35	-5,833.35	-5,833.35	-5,833.35	-5,833.35	-5,833.35
Labour		-3,888.90	-3,888.90	-3,888.90	-3,888.90	-3,888.90	-3,888.90	-3,888.90	-3,888.90	-3,888.90	-3,888.90	-3,888.90	-3,888.90	-3,888.90	-3,888.90	-3,888.90	-3,888.90	-3,888.90	-3,888.90	-3,888.90	-3,888.90
Total:		15,381.48	15,390.40	15,441.34	15,492.27	15,543.20	15,594.13	15,645.06	15,696.00	15,746.93	15,797.86	15,848.79	15,899.72	15,950.65	16,001.59	16,052.52	16,103.45	16,154.38	16,205.31	16,256.25	16,307.18
Net emissions impact	[t CO2e]	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82
	116,905.12	**-13,733.47**	**-12,269.14**	**-10,990.84**	**-9,845.62**	**-8,819.63**	**-7,900.47**	**-7,077.03**	**-6,339.35**	**-5,678.50**	**-5,086.49**	**-4,556.15**	**-4,081.06**	**-3,655.48**	**-3,274.24**	**-2,932.74**	**-2,626.82**	**-2,352.79**	**-2,107.33**	**-1,887.46**	**-1,690.51**
NPC Heating	**-145,500.94**	-17,151.66	-15,321.09	-13,715.80	-12,278.62	-10,991.95	-9,840.05	-8,808.79	-7,885.57	-7,059.05	-6,319.12	-5,656.71	-5,063.71	-4,532.84	-4,057.60	-3,632.16	-3,251.31	-2,910.38	-2,605.17	-2,331.96	-2,087.39

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
CAPEX_Non-Heating																					
Building																					
Material	70,527.84	-3,526.39	-3,526.39	-3,526.39	-3,526.39	-3,526.39	-3,526.39	-3,526.39	-3,526.39	-3,526.39	-3,526.39	-3,526.39	-3,526.39	-3,526.39	-3,526.39	-3,526.39	-3,526.39	-3,526.39	-3,526.39	-3,526.39	-3,526.39
Labour	76,036.14	-3,801.81	-3,801.81	-3,801.81	-3,801.81	-3,801.81	-3,801.81	-3,801.81	-3,801.81	-3,801.81	-3,801.81	-3,801.81	-3,801.81	-3,801.81	-3,801.81	-3,801.81	-3,801.81	-3,801.81	-3,801.81	-3,801.81	-3,801.81
Total:	**146,563.98**	7,328.20	7,328.20	7,328.20	7,328.20	7,328.20	7,328.20	7,328.20	7,328.20	7,328.20	7,328.20	7,328.20	7,328.20	7,328.20	7,328.20	7,328.20	7,328.20	7,328.20	7,328.20	7,328.20	7,328.20
Aquaponics																					
Aquaculture system	19,415.00	-970.75	-970.75	-970.75	-970.75	-970.75	-970.75	-970.75	-970.75	-970.75	-970.75	-970.75	-970.75	-970.75	-970.75	-970.75	-970.75	-970.75	-970.75	-970.75	-970.75
NFT system 1: Horizontal	25,249.58	-1,262.48	-1,262.48	-1,262.48	-1,262.48	-1,262.48	-1,262.48	-1,262.48	-1,262.48	-1,262.48	-1,262.48	-1,262.48	-1,262.48	-1,262.48	-1,262.48	-1,262.48	-1,262.48	-1,262.48	-1,262.48	-1,262.48	-1,262.48
NFT system 2: Vertical	50,205.83	-2,510.29	-2,510.29	-2,510.29	-2,510.29	-2,510.29	-2,510.29	-2,510.29	-2,510.29	-2,510.29	-2,510.29	-2,510.29	-2,510.29	-2,510.29	-2,510.29	-2,510.29	-2,510.29	-2,510.29	-2,510.29	-2,510.29	-2,510.29
Growing lights	45,386.35	-2,269.32	-2,269.32	-2,269.32	-2,269.32	-2,269.32	-2,269.32	-2,269.32	-2,269.32	-2,269.32	-2,269.32	-2,269.32	-2,269.32	-2,269.32	-2,269.32	-2,269.32	-2,269.32	-2,269.32	-2,269.32	-2,269.32	-2,269.32
Water	304.02	-15.20	-15.20	-15.20	-15.20	-15.20	-15.20	-15.20	-15.20	-15.20	-15.20	-15.20	-15.20	-15.20	-15.20	-15.20	-15.20	-15.20	-15.20	-15.20	-15.20
Total:	**140,560.78**	7,028.04	7,028.04	7,028.04	7,028.04	7,028.04	7,028.04	7,028.04	7,028.04	7,028.04	7,028.04	7,028.04	7,028.04	7,028.04	7,028.04	7,028.04	7,028.04	7,028.04	7,028.04	7,028.04	7,028.04
Soil-based cultivation																					
Growing beds	2,268.75	-113.44	-113.44	-113.44	-113.44	-113.44	-113.44	-113.44	-113.44	-113.44	-113.44	-113.44	-113.44	-113.44	-113.44	-113.44	-113.44	-113.44	-113.44	-113.44	-113.44
Soil	4,537.50	-226.88	-226.88	-226.88	-226.88	-226.88	-226.88	-226.88	-226.88	-226.88	-226.88	-226.88	-226.88	-226.88	-226.88	-226.88	-226.88	-226.88	-226.88	-226.88	-226.88
Total:	**6,806.25**	340.31	340.31	340.31	340.31	340.31	340.31	340.31	340.31	340.31	340.31	340.31	340.31	340.31	340.31	340.31	340.31	340.31	340.31	340.31	340.31
	109,775.06	**-13,121.92**	**-11,716.00**	**-10,460.71**	**-9,339.92**	**-8,339.22**	**-7,445.73**	**-6,647.97**	**-5,935.69**	**-5,299.72**	**-4,731.90**	**-4,224.91**	**-3,772.24**	**-3,368.07**	**-3,007.21**	**-2,685.00**	**-2,397.33**	**-2,140.47**	**-1,911.13**	**-1,706.37**	**-1,523.54**
OPEX_Non-Heating																					
Electricity — Grow lights		-4,091.63	-4,280.06	-4,468.49	-4,656.92	-4,845.35	-5,033.78	-5,222.21	-5,410.64	-5,599.07	-5,787.50	-5,975.93	-6,164.36	-6,352.79	-6,541.22	-6,729.65	-6,918.08	-7,106.51	-7,294.94	-7,483.37	-7,671.80
Pumps		-583.35	-610.22	-637.08	-663.95	-690.81	-717.68	-744.54	-771.41	-798.27	-825.14	-852.00	-878.86	-905.73	-932.59	-959.46	-986.32	-1,013.19	-1,040.05	-1,066.92	-1,093.78
Labor		-5,038.00	-5,038.00	-5,038.00	-5,038.00	-5,038.00	-5,038.00	-5,038.00	-5,038.00	-5,038.00	-5,038.00	-5,038.00	-5,038.00	-5,038.00	-5,038.00	-5,038.00	-5,038.00	-5,038.00	-5,038.00	-5,038.00	-5,038.00
Fish feed		-6,642.90	-6,642.90	-6,642.90	-6,642.90	-6,642.90	-6,642.90	-6,642.90	-6,642.90	-6,642.90	-6,642.90	-6,642.90	-6,642.90	-6,642.90	-6,642.90	-6,642.90	-6,642.90	-6,642.90	-6,642.90	-6,642.90	-6,642.90
Maintenance — Building		-1,814.21	-1,814.21	-1,814.21	-1,814.21	-1,814.21	-1,814.21	-1,814.21	-1,814.21	-1,814.21	-1,814.21	-1,814.21	-1,814.21	-1,814.21	-1,814.21	-1,814.21	-1,814.21	-1,814.21	-1,814.21	-1,814.21	-1,814.21
Aquaponics		-2,860.00	-2,860.00	-2,860.00	-2,860.00	-2,860.00	-2,860.00	-2,860.00	-2,860.00	-2,860.00	-2,860.00	-2,860.00	-2,860.00	-2,860.00	-2,860.00	-2,860.00	-2,860.00	-2,860.00	-2,860.00	-2,860.00	-2,860.00
	166,764.38	**-18,776.87**	**-16,936.69**	**-15,275.29**	**-13,775.48**	**-12,421.70**	**-11,199.87**	**-10,097.28**	**-9,102.38**	**-8,204.76**	**-7,395.00**	**-6,664.57**	**-6,005.77**	**-5,411.64**	**-4,875.87**	**-4,392.79**	**-3,957.25**	**-3,564.62**	**-3,210.69**	**-2,891.69**	**-2,604.18**
NPC Total	**-422,040.38**	-49,050.45	-43,973.79	-39,451.80	-35,394.02	-31,752.86	-28,485.65	-25,554.04	-22,923.64	-20,563.54	-18,446.02	-16,546.19	-14,841.72	-13,312.55	-11,940.68	-10,709.96	-9,605.89	-8,615.46	-7,727.00	-6,930.02	-6,215.11

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
AG yield																					
Fish [CAD/kg]	8.8	4,840.00	4,840.00	4,840.00	4,840.00	4,840.00	4,840.00	4,840.00	4,840.00	4,840.00	4,840.00	4,840.00	4,840.00	4,840.00	4,840.00	4,840.00	4,840.00	4,840.00	4,840.00	4,840.00	4,840.00
Basil: NFT [CAD/kg]	7.5	32,670.00	32,670.00	32,670.00	32,670.00	32,670.00	32,670.00	32,670.00	32,670.00	32,670.00	32,670.00	32,670.00	32,670.00	32,670.00	32,670.00	32,670.00	32,670.00	32,670.00	32,670.00	32,670.00	32,670.00
Lettuce: Soil [CAD/kg]	5	10,890.00	10,890.00	10,890.00	10,890.00	10,890.00	10,890.00	10,890.00	10,890.00	10,890.00	10,890.00	10,890.00	10,890.00	10,890.00	10,890.00	10,890.00	10,890.00	10,890.00	10,890.00	10,890.00	10,890.00
Additional income																					
Carbon offsets		3,375.23	3,835.48	4,295.74	4,756.00	5,216.26	5,277.63	5,339.00	5,400.36	5,461.73	5,523.10	5,584.47	5,645.83	5,707.20	5,768.57	5,829.94	5,891.30	5,952.67	6,014.04	6,075.41	6,136.78
Farm waste [CAD/t]	50	5,833.35	5,833.35	5,833.35	5,833.35	5,833.35	5,833.35	5,833.35	5,833.35	5,833.35	5,833.35	5,833.35	5,833.35	5,833.35	5,833.35	5,833.35	5,833.35	5,833.35	5,833.35	5,833.35	5,833.35
AG waste [CAD/t]	50	49.82	49.82	49.82	49.82	49.82	49.82	49.82	49.82	49.82	49.82	49.82	49.82	49.82	49.82	49.82	49.82	49.82	49.82	49.82	49.82
	442,153.72	**51,480.71**	**46,331.84**	**41,695.31**	**37,520.46**	**33,761.57**	**30,175.35**	**26,970.04**	**24,105.18**	**21,544.61**	**19,256.02**	**17,210.51**	**15,382.28**	**13,748.24**	**12,287.78**	**10,982.44**	**9,815.76**	**8,773.01**	**7,841.02**	**7,008.04**	**6,263.54**
NPV Total	**20,113.34**	2,430.26	2,358.05	2,243.51	2,126.44	2,008.71	1,689.70	1,415.99	1,181.54	981.07	810.00	664.32	540.56	435.70	347.10	272.48	209.87	157.55	114.03	78.02	48.43
Cumulative		2,430.26	4,788.31	7,031.82	9,158.27	11,166.98	12,856.68	14,272.67	15,454.22	16,435.29	17,245.29	17,909.61	18,450.17	18,885.87	19,232.97	19,505.45	19,715.32	19,872.86	19,986.89	20,064.91	20,113.34

C.1.4. GSHP

Increasing greenhouse size per page.

Discount rate 12 [%]

GSHP - CLOSED-LOOP HORIZONTAL

260 [m2] 5000 [l]

Lifespan		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Years		**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**	**2036**	**2037**	**2038**	**2039**	**2040**	**2041**	**2042**	**2043**	**2044**	**2045**
Electricity rates [CAD/kWh]		0.104	0.160	0.167	0.175	0.182	0.189	0.197	0.204	0.212	0.219	0.226	0.234	0.241	0.248	0.256	0.263	0.271	0.278	0.285	0.293	0.300
Carbon offset price [CAD/t]		95	110	125	140	155	170	172	174	176	178	180	182	184	186	188	190	192	194	196	198	200
CAPEX_Heating																						
Hydronic radiant heating		10,930.51	- 546.53	- 546.53	- 546.53	- 546.53	- 546.53	- 546.53	- 546.53	- 546.53	- 546.53	- 546.53	- 546.53	- 546.53	- 546.53	- 546.53	- 546.53	- 546.53	- 546.53	- 546.53	- 546.53	- 546.53
Ground loop installation		24,718.67	- 1,235.93	- 1,235.93	- 1,235.93	- 1,235.93	- 1,235.93	- 1,235.93	- 1,235.93	- 1,235.93	- 1,235.93	- 1,235.93	- 1,235.93	- 1,235.93	- 1,235.93	- 1,235.93	- 1,235.93	- 1,235.93	- 1,235.93	- 1,235.93	- 1,235.93	- 1,235.93
Heat pump		39,972.00	- 1,998.60	- 1,998.60	- 1,998.60	- 1,998.60	- 1,998.60	- 1,998.60	- 1,998.60	- 1,998.60	- 1,998.60	- 1,998.60	- 1,998.60	- 1,998.60	- 1,998.60	- 1,998.60	- 1,998.60	- 1,998.60	- 1,998.60	- 1,998.60	- 1,998.60	- 1,998.60
	Total:	**75,621.18**	3,781.06	3,781.06	3,781.06	3,781.06	3,781.06	3,781.06	3,781.06	3,781.06	3,781.06	3,781.06	3,781.06	3,781.06	3,781.06	3,781.06	3,781.06	3,781.06	3,781.06	3,781.06	3,781.06	3,781.06
		28,242.41	**- 3,375.95**	**- 3,014.24**	**- 2,691.28**	**- 2,402.93**	**- 2,145.47**	**- 1,915.60**	**- 1,710.36**	**- 1,527.11**	**- 1,363.49**	**- 1,217.40**	**- 1,086.96**	**- 970.50**	**- 866.52**	**- 773.68**	**- 690.79**	**- 616.77**	**- 550.69**	**- 491.69**	**- 439.01**	**- 391.97**
OPEX_Heating																						
CoE			- 3,768.61	- 3,942.16	- 4,115.71	- 4,289.27	- 4,462.82	- 4,636.38	- 4,809.93	- 4,983.49	- 5,157.04	- 5,330.59	- 5,504.15	- 5,677.70	- 5,851.26	- 6,024.81	- 6,198.36	- 6,371.92	- 6,545.47	- 6,719.03	- 6,892.58	- 7,066.14
Maintenance			- 289.71	- 289.71	- 289.71	- 289.71	- 289.71	- 289.71	- 289.71	- 289.71	- 289.71	- 289.71	- 289.71	- 289.71	- 289.71	- 289.71	- 289.71	- 289.71	- 289.71	- 289.71	- 289.71	- 289.71
		Total:	4,058.32	4,231.87	4,405.43	4,578.98	4,752.53	4,926.09	5,099.64	5,273.20	5,446.75	5,620.31	5,793.86	5,967.41	6,140.97	6,314.52	6,488.08	6,661.63	6,835.18	7,008.74	7,182.29	7,355.85
Net emissions impact (Gas)		[t CO2e]	11.54	11.54	11.54	11.54	11.54	11.54	11.54	11.54	11.54	11.54	11.54	11.54	11.54	11.54	11.54	11.54	11.54	11.54	11.54	11.54
Net emissions impact (RE)		[t CO2e]	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
		38,117.68	**- 3,623.50**	**- 3,373.62**	**- 3,135.70**	**- 2,910.02**	**- 2,696.72**	**- 2,495.71**	**- 2,306.82**	**- 2,129.76**	**- 1,964.15**	**- 1,809.59**	**- 1,665.60**	**- 1,531.69**	**- 1,407.35**	**- 1,292.08**	**- 1,185.35**	**- 1,086.66**	**- 995.51**	**- 911.41**	**- 833.91**	**- 762.56**
NPC Heating		**- 66,360.09**	- 6,999.44	- 6,387.86	- 5,826.98	- 5,312.96	- 4,842.19	- 4,411.31	- 4,017.18	- 3,656.86	- 3,327.64	- 3,026.99	- 2,752.56	- 2,502.19	- 2,273.87	- 2,065.76	- 1,876.13	- 1,703.43	- 1,546.20	- 1,403.10	- 1,272.92	- 1,154.53
CAPEX_Non-Heating																						
Building																						
	Material	42,069.34	- 2,103.47	- 2,103.47	- 2,103.47	- 2,103.47	- 2,103.47	- 2,103.47	- 2,103.47	- 2,103.47	- 2,103.47	- 2,103.47	- 2,103.47	- 2,103.47	- 2,103.47	- 2,103.47	- 2,103.47	- 2,103.47	- 2,103.47	- 2,103.47	- 2,103.47	- 2,103.47
	Labour	37,362.98	- 1,868.15	- 1,868.15	- 1,868.15	- 1,868.15	- 1,868.15	- 1,868.15	- 1,868.15	- 1,868.15	- 1,868.15	- 1,868.15	- 1,868.15	- 1,868.15	- 1,868.15	- 1,868.15	- 1,868.15	- 1,868.15	- 1,868.15	- 1,868.15	- 1,868.15	- 1,868.15
	Total:	**79,432.33**	3,971.62	3,971.62	3,971.62	3,971.62	3,971.62	3,971.62	3,971.62	3,971.62	3,971.62	3,971.62	3,971.62	3,971.62	3,971.62	3,971.62	3,971.62	3,971.62	3,971.62	3,971.62	3,971.62	3,971.62
Aquaponics																						
	Aquaculture system	8,825.00	- 441.25	- 441.25	- 441.25	- 441.25	- 441.25	- 441.25	- 441.25	- 441.25	- 441.25	- 441.25	- 441.25	- 441.25	- 441.25	- 441.25	- 441.25	- 441.25	- 441.25	- 441.25	- 441.25	- 441.25
	NFT system 1: Horizontal	11,477.08	- 573.85	- 573.85	- 573.85	- 573.85	- 573.85	- 573.85	- 573.85	- 573.85	- 573.85	- 573.85	- 573.85	- 573.85	- 573.85	- 573.85	- 573.85	- 573.85	- 573.85	- 573.85	- 573.85	- 573.85
	NFT system 2: Vertical	22,820.83	- 1,141.04	- 1,141.04	- 1,141.04	- 1,141.04	- 1,141.04	- 1,141.04	- 1,141.04	- 1,141.04	- 1,141.04	- 1,141.04	- 1,141.04	- 1,141.04	- 1,141.04	- 1,141.04	- 1,141.04	- 1,141.04	- 1,141.04	- 1,141.04	- 1,141.04	- 1,141.04
	Growing lights	20,630.16	- 1,031.51	- 1,031.51	- 1,031.51	- 1,031.51	- 1,031.51	- 1,031.51	- 1,031.51	- 1,031.51	- 1,031.51	- 1,031.51	- 1,031.51	- 1,031.51	- 1,031.51	- 1,031.51	- 1,031.51	- 1,031.51	- 1,031.51	- 1,031.51	- 1,031.51	- 1,031.51
	Water	138.19	- 6.91	- 6.91	- 6.91	- 6.91	- 6.91	- 6.91	- 6.91	- 6.91	- 6.91	- 6.91	- 6.91	- 6.91	- 6.91	- 6.91	- 6.91	- 6.91	- 6.91	- 6.91	- 6.91	- 6.91
	Total:	**63,891.27**	3,194.56	3,194.56	3,194.56	3,194.56	3,194.56	3,194.56	3,194.56	3,194.56	3,194.56	3,194.56	3,194.56	3,194.56	3,194.56	3,194.56	3,194.56	3,194.56	3,194.56	3,194.56	3,194.56	3,194.56
Soil-based cultivation																						
	Growing beds	1,031.25	- 51.56	- 51.56	- 51.56	- 51.56	- 51.56	- 51.56	- 51.56	- 51.56	- 51.56	- 51.56	- 51.56	- 51.56	- 51.56	- 51.56	- 51.56	- 51.56	- 51.56	- 51.56	- 51.56	- 51.56
	Soil	2,062.50	- 103.13	- 103.13	- 103.13	- 103.13	- 103.13	- 103.13	- 103.13	- 103.13	- 103.13	- 103.13	- 103.13	- 103.13	- 103.13	- 103.13	- 103.13	- 103.13	- 103.13	- 103.13	- 103.13	- 103.13
	Total:	**3,093.75**	154.69	154.69	154.69	154.69	154.69	154.69	154.69	154.69	154.69	154.69	154.69	154.69	154.69	154.69	154.69	154.69	154.69	154.69	154.69	154.69
		54,682.80	**- 6,536.49**	**- 5,836.15**	**- 5,210.85**	**- 4,652.54**	**- 4,154.06**	**- 3,708.98**	**- 3,311.59**	**- 2,956.78**	**- 2,639.98**	**- 2,357.12**	**- 2,104.57**	**- 1,879.08**	**- 1,677.75**	**- 1,497.99**	**- 1,337.50**	**- 1,194.19**	**- 1,066.24**	**- 952.00**	**- 850.00**	**- 758.93**
OPEX_Non-Heating																						
Electricity	Grow lights		- 1,859.83	- 1,945.48	- 2,031.13	- 2,116.78	- 2,202.43	- 2,288.08	- 2,373.73	- 2,459.38	- 2,545.03	- 2,630.68	- 2,716.33	- 2,801.98	- 2,887.63	- 2,973.28	- 3,058.93	- 3,144.58	- 3,230.23	- 3,315.88	- 3,401.53	- 3,487.18
	Pumps		- 265.16	- 277.37	- 289.58	- 301.79	- 314.00	- 326.22	- 338.43	- 350.64	- 362.85	- 375.06	- 387.27	- 399.48	- 411.70	- 423.91	- 436.12	- 448.33	- 460.54	- 472.75	- 484.96	- 497.17
Labor			- 2,290.00	- 2,290.00	- 2,290.00	- 2,290.00	- 2,290.00	- 2,290.00	- 2,290.00	- 2,290.00	- 2,290.00	- 2,290.00	- 2,290.00	- 2,290.00	- 2,290.00	- 2,290.00	- 2,290.00	- 2,290.00	- 2,290.00	- 2,290.00	- 2,290.00	- 2,290.00
Fish feed			- 3,019.50	- 3,019.50	- 3,019.50	- 3,019.50	- 3,019.50	- 3,019.50	- 3,019.50	- 3,019.50	- 3,019.50	- 3,019.50	- 3,019.50	- 3,019.50	- 3,019.50	- 3,019.50	- 3,019.50	- 3,019.50	- 3,019.50	- 3,019.50	- 3,019.50	- 3,019.50
Maintenance	Building		- 897.20	- 897.20	- 897.20	- 897.20	- 897.20	- 897.20	- 897.20	- 897.20	- 897.20	- 897.20	- 897.20	- 897.20	- 897.20	- 897.20	- 897.20	- 897.20	- 897.20	- 897.20	- 897.20	- 897.20
	Aquaponics		- 1,300.00	- 1,300.00	- 1,300.00	- 1,300.00	- 1,300.00	- 1,300.00	- 1,300.00	- 1,300.00	- 1,300.00	- 1,300.00	- 1,300.00	- 1,300.00	- 1,300.00	- 1,300.00	- 1,300.00	- 1,300.00	- 1,300.00	- 1,300.00	- 1,300.00	- 1,300.00
		76,343.93	**- 8,599.72**	**- 7,756.34**	**- 6,994.96**	**- 6,307.69**	**- 5,687.39**	**- 5,127.61**	**- 4,622.49**	**- 4,166.75**	**- 3,755.60**	**- 3,384.72**	**- 3,050.21**	**- 2,748.52**	**- 2,476.46**	**- 2,231.15**	**- 2,009.98**	**- 1,810.59**	**- 1,630.85**	**- 1,468.84**	**- 1,322.83**	**- 1,191.24**
NPC Total		**-197,386.83**	- 22,135.65	- 19,980.35	- 18,032.78	- 16,273.19	- 14,683.64	- 13,247.90	- 11,951.26	- 10,780.39	- 9,723.22	- 8,768.84	- 7,907.34	- 7,129.79	- 6,428.09	- 5,794.90	- 5,223.61	- 4,708.21	- 4,243.29	- 3,823.94	- 3,445.75	- 3,104.70
AG yield																						
Fish [CAD/kg]		8.8	2,200.00	2,200.00	2,200.00	2,200.00	2,200.00	2,200.00	2,200.00	2,200.00	2,200.00	2,200.00	2,200.00	2,200.00	2,200.00	2,200.00	2,200.00	2,200.00	2,200.00	2,200.00	2,200.00	2,200.00
Basil: NFT [CAD/kg]		7.5	14,850.00	14,850.00	14,850.00	14,850.00	14,850.00	14,850.00	14,850.00	14,850.00	14,850.00	14,850.00	14,850.00	14,850.00	14,850.00	14,850.00	14,850.00	14,850.00	14,850.00	14,850.00	14,850.00	14,850.00
Lettuce: Soil [CAD/kg]		5	4,950.00	4,950.00	4,950.00	4,950.00	4,950.00	4,950.00	4,950.00	4,950.00	4,950.00	4,950.00	4,950.00	4,950.00	4,950.00	4,950.00	4,950.00	4,950.00	4,950.00	4,950.00	4,950.00	4,950.00
Additional income																						
Carbon offsets (Gas)			724.89	823.73	922.58	1,021.43	1,120.28	1,133.46	1,146.64	1,159.82	1,173.00	1,186.18	1,199.36	1,212.54	1,225.72	1,238.90	1,252.08	1,265.26	1,278.44	1,291.62	1,304.80	1,317.98
Carbon offsets (RE)		Assumption	1,976.38	2,245.88	2,515.39	2,784.89	3,054.40	3,090.33	3,126.27	3,162.20	3,198.14	3,234.07	3,270.01	3,305.94	3,341.87	3,377.81	3,413.74	3,449.68	3,485.61	3,521.54	3,557.48	3,593.41
Savings of cooling			328.75	327.51	341.93	356.35	370.77	385.19	399.60	414.02	428.44	442.86	457.28	471.70	486.12	500.54	514.95	529.37	543.79	558.21	572.63	587.05
		185,810.94	**21,407.48**	**19,328.67**	**17,449.57**	**15,751.25**	**14,216.54**	**12,711.54**	**11,365.85**	**10,162.59**	**9,086.70**	**8,124.70**	**7,264.52**	**6,495.40**	**5,807.70**	**5,192.80**	**4,643.00**	**4,151.39**	**3,711.83**	**3,318.81**	**2,967.40**	**2,653.19**
NPV Total		**- 11,575.89**	- 728.17	- 651.68	- 583.21	- 521.94	- 467.10	- 536.36	- 585.41	- 617.79	- 636.52	- 644.14	- 642.82	- 634.39	- 620.38	- 602.10	- 580.61	- 556.81	- 531.45	- 505.13	- 478.35	- 451.51
		Cumulative	- 728.17	- 1,379.85	- 1,963.06	- 2,485.00	- 2,952.10	- 3,488.46	- 4,073.87	- 4,691.67	- 5,328.19	- 5,972.33	- 6,615.15	- 7,249.53	- 7,869.92	- 8,472.02	- 9,052.63	- 9,609.44	- 10,140.89	- 10,646.03	- 11,124.38	- 11,575.89

Discount rate 12 [%]

GSHP - CLOSED-LOOP HORIZONTAL

304 [m2] 6000 [l]

Lifespan	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Years	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**	**2036**	**2037**	**2038**	**2039**	**2040**	**2041**	**2042**	**2043**	**2044**	**2045**
Electricity rates [CAD/kWh]	0.104	0.160	0.167	0.175	0.182	0.189	0.197	0.204	0.212	0.219	0.226	0.234	0.241	0.248	0.256	0.263	0.271	0.278	0.285	0.293	0.300
Carbon offset price [CAD/t]	95	110	125	140	155	170	172	174	176	178	180	182	184	186	188	190	192	194	196	198	200
CAPEX_Heating																					
Hydronic radiant heating	12,792.51	-639.63	-639.63	-639.63	-639.63	-639.63	-639.63	-639.63	-639.63	-639.63	-639.63	-639.63	-639.63	-639.63	-639.63	-639.63	-639.63	-639.63	-639.63	-639.63	-639.63
Ground loop installation	28,768.38	-1,438.42	-1,438.42	-1,438.42	-1,438.42	-1,438.42	-1,438.42	-1,438.42	-1,438.42	-1,438.42	-1,438.42	-1,438.42	-1,438.42	-1,438.42	-1,438.42	-1,438.42	-1,438.42	-1,438.42	-1,438.42	-1,438.42	-1,438.42
Heat pump	49,310.00	-2,465.50	-2,465.50	-2,465.50	-2,465.50	-2,465.50	-2,465.50	-2,465.50	-2,465.50	-2,465.50	-2,465.50	-2,465.50	-2,465.50	-2,465.50	-2,465.50	-2,465.50	-2,465.50	-2,465.50	-2,465.50	-2,465.50	-2,465.50
Total:	**90,870.89**	4,543.54	4,543.54	4,543.54	4,543.54	4,543.54	4,543.54	4,543.54	4,543.54	4,543.54	4,543.54	4,543.54	4,543.54	4,543.54	4,543.54	4,543.54	4,543.54	4,543.54	4,543.54	4,543.54	4,543.54
	33,937.75	**-4,056.74**	**-3,622.09**	**-3,234.01**	**-2,887.50**	**-2,578.13**	**-2,301.90**	**-2,055.27**	**-1,835.06**	**-1,638.45**	**-1,462.90**	**-1,306.16**	**-1,166.21**	**-1,041.26**	**-929.70**	**-830.09**	**-741.15**	**-661.74**	**-590.84**	**-527.54**	**-471.01**
OPEX_Heating																					
CoE		-4,288.95	-4,486.47	-4,683.98	-4,881.50	-5,079.02	-5,276.54	-5,474.05	-5,671.57	-5,869.09	-6,066.61	-6,264.12	-6,461.64	-6,659.16	-6,856.68	-7,054.19	-7,251.71	-7,449.23	-7,646.75	-7,844.26	-8,041.78
Maintenance		-329.71	-329.71	-329.71	-329.71	-329.71	-329.71	-329.71	-329.71	-329.71	-329.71	-329.71	-329.71	-329.71	-329.71	-329.71	-329.71	-329.71	-329.71	-329.71	-329.71
Total:		4,618.66	4,816.18	5,013.70	5,211.21	5,408.73	5,606.25	5,803.77	6,001.28	6,198.80	6,396.32	6,593.84	6,791.35	6,988.87	7,186.39	7,383.91	7,581.42	7,778.94	7,976.46	8,173.98	8,371.49
Net emissions impact (Gas)	[t CO2e]	13.13	13.13	13.13	13.13	13.13	13.13	13.13	13.13	13.13	13.13	13.13	13.13	13.13	13.13	13.13	13.13	13.13	13.13	13.13	13.13
Net emissions impact (RE)	[t CO2e]	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
	43,380.72	**-4,123.81**	**-3,839.43**	**-3,568.65**	**-3,311.82**	**-3,069.06**	**-2,840.30**	**-2,625.33**	**-2,423.82**	**-2,235.35**	**-2,059.44**	**-1,895.57**	**-1,743.17**	**-1,601.67**	**-1,470.48**	**-1,349.01**	**-1,236.69**	**-1,132.96**	**-1,037.26**	**-949.05**	**-867.85**
NPC Heating	**-77,318.47**	-8,180.54	-7,461.52	-6,802.66	-6,199.33	-5,647.19	-5,142.20	-4,680.60	-4,258.88	-3,873.80	-3,522.34	-3,201.73	-2,909.39	-2,642.93	-2,400.18	-2,179.10	-1,977.84	-1,794.70	-1,628.10	-1,476.59	-1,338.86
CAPEX_Non-Heating																					
Building																					
Material	48,687.79	-2,434.39	-2,434.39	-2,434.39	-2,434.39	-2,434.39	-2,434.39	-2,434.39	-2,434.39	-2,434.39	-2,434.39	-2,434.39	-2,434.39	-2,434.39	-2,434.39	-2,434.39	-2,434.39	-2,434.39	-2,434.39	-2,434.39	-2,434.39
Labour	43,396.53	-2,169.83	-2,169.83	-2,169.83	-2,169.83	-2,169.83	-2,169.83	-2,169.83	-2,169.83	-2,169.83	-2,169.83	-2,169.83	-2,169.83	-2,169.83	-2,169.83	-2,169.83	-2,169.83	-2,169.83	-2,169.83	-2,169.83	-2,169.83
Total:	**92,084.32**	4,604.22	4,604.22	4,604.22	4,604.22	4,604.22	4,604.22	4,604.22	4,604.22	4,604.22	4,604.22	4,604.22	4,604.22	4,604.22	4,604.22	4,604.22	4,604.22	4,604.22	4,604.22	4,604.22	4,604.22
Aquaponics																					
Aquaculture system	10,590.00	-529.50	-529.50	-529.50	-529.50	-529.50	-529.50	-529.50	-529.50	-529.50	-529.50	-529.50	-529.50	-529.50	-529.50	-529.50	-529.50	-529.50	-529.50	-529.50	-529.50
NFT system 1: Horizontal	13,772.50	-688.63	-688.63	-688.63	-688.63	-688.63	-688.63	-688.63	-688.63	-688.63	-688.63	-688.63	-688.63	-688.63	-688.63	-688.63	-688.63	-688.63	-688.63	-688.63	-688.63
NFT system 2: Vertical	27,385.00	-1,369.25	-1,369.25	-1,369.25	-1,369.25	-1,369.25	-1,369.25	-1,369.25	-1,369.25	-1,369.25	-1,369.25	-1,369.25	-1,369.25	-1,369.25	-1,369.25	-1,369.25	-1,369.25	-1,369.25	-1,369.25	-1,369.25	-1,369.25
Growing lights	24,756.19	-1,237.81	-1,237.81	-1,237.81	-1,237.81	-1,237.81	-1,237.81	-1,237.81	-1,237.81	-1,237.81	-1,237.81	-1,237.81	-1,237.81	-1,237.81	-1,237.81	-1,237.81	-1,237.81	-1,237.81	-1,237.81	-1,237.81	-1,237.81
Water	165.83	-8.29	-8.29	-8.29	-8.29	-8.29	-8.29	-8.29	-8.29	-8.29	-8.29	-8.29	-8.29	-8.29	-8.29	-8.29	-8.29	-8.29	-8.29	-8.29	-8.29
Total:	**76,669.52**	3,833.48	3,833.48	3,833.48	3,833.48	3,833.48	3,833.48	3,833.48	3,833.48	3,833.48	3,833.48	3,833.48	3,833.48	3,833.48	3,833.48	3,833.48	3,833.48	3,833.48	3,833.48	3,833.48	3,833.48
Soil-based cultivation																					
Growing beds	1,237.50	-61.88	-61.88	-61.88	-61.88	-61.88	-61.88	-61.88	-61.88	-61.88	-61.88	-61.88	-61.88	-61.88	-61.88	-61.88	-61.88	-61.88	-61.88	-61.88	-61.88
Soil	2,475.00	-123.75	-123.75	-123.75	-123.75	-123.75	-123.75	-123.75	-123.75	-123.75	-123.75	-123.75	-123.75	-123.75	-123.75	-123.75	-123.75	-123.75	-123.75	-123.75	-123.75
Total:	**3,712.50**	185.63	185.63	185.63	185.63	185.63	185.63	185.63	185.63	185.63	185.63	185.63	185.63	185.63	185.63	185.63	185.63	185.63	185.63	185.63	185.63
	64,411.38	**-7,699.39**	**-6,874.46**	**-6,137.91**	**-5,480.27**	**-4,893.10**	**-4,368.84**	**-3,900.75**	**-3,482.81**	**-3,109.65**	**-2,776.48**	**-2,479.00**	**-2,213.39**	**-1,976.24**	**-1,764.50**	**-1,575.45**	**-1,406.65**	**-1,255.94**	**-1,121.37**	**-1,001.23**	**-893.95**
OPEX_Non-Heating																					
Electricity — Grow lights		-2,231.80	-2,334.58	-2,437.36	-2,540.14	-2,642.92	-2,745.70	-2,848.48	-2,951.26	-3,054.04	-3,156.82	-3,259.60	-3,362.38	-3,465.16	-3,567.94	-3,670.72	-3,773.50	-3,876.28	-3,979.06	-4,081.84	-4,184.62
Pumps		-318.19	-332.85	-347.50	-362.15	-376.81	-391.46	-406.11	-420.77	-435.42	-450.07	-464.73	-479.38	-494.03	-508.69	-523.34	-538.00	-552.65	-567.30	-581.96	-596.61
Labor		-2,748.00	-2,748.00	-2,748.00	-2,748.00	-2,748.00	-2,748.00	-2,748.00	-2,748.00	-2,748.00	-2,748.00	-2,748.00	-2,748.00	-2,748.00	-2,748.00	-2,748.00	-2,748.00	-2,748.00	-2,748.00	-2,748.00	-2,748.00
Fish feed		-3,623.40	-3,623.40	-3,623.40	-3,623.40	-3,623.40	-3,623.40	-3,623.40	-3,623.40	-3,623.40	-3,623.40	-3,623.40	-3,623.40	-3,623.40	-3,623.40	-3,623.40	-3,623.40	-3,623.40	-3,623.40	-3,623.40	-3,623.40
Maintenance — Building		-1,050.03	-1,050.03	-1,050.03	-1,050.03	-1,050.03	-1,050.03	-1,050.03	-1,050.03	-1,050.03	-1,050.03	-1,050.03	-1,050.03	-1,050.03	-1,050.03	-1,050.03	-1,050.03	-1,050.03	-1,050.03	-1,050.03	-1,050.03
Aquaponics		-1,560.00	-1,560.00	-1,560.00	-1,560.00	-1,560.00	-1,560.00	-1,560.00	-1,560.00	-1,560.00	-1,560.00	-1,560.00	-1,560.00	-1,560.00	-1,560.00	-1,560.00	-1,560.00	-1,560.00	-1,560.00	-1,560.00	-1,560.00
	91,414.01	**-10,295.91**	**-9,286.40**	**-8,375.01**	**-7,552.32**	**-6,809.78**	**-6,139.65**	**-5,534.96**	**-4,989.35**	**-4,497.13**	**-4,053.10**	**-3,652.60**	**-3,291.39**	**-2,965.66**	**-2,671.94**	**-2,407.11**	**-2,168.36**	**-1,953.14**	**-1,759.15**	**-1,584.30**	**-1,426.73**
NPC Total	**-233,143.85**	-26,175.84	-23,622.37	-21,315.57	-19,231.92	-17,350.07	-15,650.70	-14,116.30	-12,731.05	-11,480.58	-10,351.92	-9,333.33	-8,414.17	-7,584.83	-6,836.62	-6,161.66	-5,552.86	-5,003.78	-4,508.62	-4,062.12	-3,659.54
AG yield																					
Fish [CAD/kg]	8.8	2,640.00	2,640.00	2,640.00	2,640.00	2,640.00	2,640.00	2,640.00	2,640.00	2,640.00	2,640.00	2,640.00	2,640.00	2,640.00	2,640.00	2,640.00	2,640.00	2,640.00	2,640.00	2,640.00	2,640.00
Basil: NFT [CAD/kg]	7.5	17,820.00	17,820.00	17,820.00	17,820.00	17,820.00	17,820.00	17,820.00	17,820.00	17,820.00	17,820.00	17,820.00	17,820.00	17,820.00	17,820.00	17,820.00	17,820.00	17,820.00	17,820.00	17,820.00	17,820.00
Lettuce: Soil [CAD/kg]	5	5,940.00	5,940.00	5,940.00	5,940.00	5,940.00	5,940.00	5,940.00	5,940.00	5,940.00	5,940.00	5,940.00	5,940.00	5,940.00	5,940.00	5,940.00	5,940.00	5,940.00	5,940.00	5,940.00	5,940.00
Additional income																					
Carbon offsets (Gas)		824.97	937.47	1,049.97	1,162.46	1,274.96	1,289.96	1,304.96	1,319.96	1,334.96	1,349.96	1,364.96	1,379.96	1,394.96	1,409.96	1,424.95	1,439.95	1,454.95	1,469.95	1,484.95	1,499.95
Carbon offsets (RE)	Assumption	2,249.26	2,555.98	2,862.70	3,169.41	3,476.13	3,517.03	3,557.92	3,598.82	3,639.71	3,680.61	3,721.51	3,762.40	3,803.30	3,844.19	3,885.09	3,925.98	3,966.88	4,007.78	4,048.67	4,089.57
Savings of cooling		434.95	432.79	451.84	470.90	489.95	509.01	528.06	547.11	566.17	585.22	604.27	623.33	642.38	661.43	680.49	699.54	718.60	737.65	756.70	775.76
	221,642.74	**25,579.70**	**23,083.53**	**20,828.61**	**18,791.90**	**16,952.52**	**15,156.90**	**13,551.44**	**12,116.02**	**10,832.62**	**9,685.15**	**8,659.21**	**7,741.94**	**6,921.82**	**6,188.56**	**5,532.97**	**4,946.82**	**4,422.76**	**3,954.21**	**3,535.30**	**3,160.75**
NPV Total	**-11,501.11**	-596.15	-538.84	-486.97	-440.02	-397.55	-493.80	-564.86	-615.03	-647.96	-666.77	-674.12	-672.23	-663.02	-648.05	-628.69	-606.03	-581.02	-554.40	-526.82	-498.79
Cumulative		-596.15	-1,134.98	-1,621.95	-2,061.97	-2,459.52	-2,953.32	-3,518.18	-4,133.21	-4,781.17	-5,447.94	-6,122.06	-6,794.29	-7,457.31	-8,105.36	-8,734.05	-9,340.08	-9,921.10	-10,475.50	-11,002.33	-11,501.11

Discount rate 12 [%]

GSHP - CLOSED-LOOP HORIZONTAL

348 [m2] 7000 [l]

Lifespan		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Years		**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**	**2036**	**2037**	**2038**	**2039**	**2040**	**2041**	**2042**	**2043**	**2044**	**2045**
Electricity rates [CAD/kWh]		0.104	0.160	0.167	0.175	0.182	0.189	0.197	0.204	0.212	0.219	0.226	0.234	0.241	0.248	0.256	0.263	0.271	0.278	0.285	0.293	0.300
Carbon offset price [CAD/t]		95	110	125	140	155	170	172	174	176	178	180	182	184	186	188	190	192	194	196	198	200
CAPEX_Heating																						
Hydronic radiant heating		14,654.50	-732.73	-732.73	-732.73	-732.73	-732.73	-732.73	-732.73	-732.73	-732.73	-732.73	-732.73	-732.73	-732.73	-732.73	-732.73	-732.73	-732.73	-732.73	-732.73	-732.73
Ground loop installation		32,818.10	-1,640.90	-1,640.90	-1,640.90	-1,640.90	-1,640.90	-1,640.90	-1,640.90	-1,640.90	-1,640.90	-1,640.90	-1,640.90	-1,640.90	-1,640.90	-1,640.90	-1,640.90	-1,640.90	-1,640.90	-1,640.90	-1,640.90	-1,640.90
Heat pump		49,310.00	-2,465.50	-2,465.50	-2,465.50	-2,465.50	-2,465.50	-2,465.50	-2,465.50	-2,465.50	-2,465.50	-2,465.50	-2,465.50	-2,465.50	-2,465.50	-2,465.50	-2,465.50	-2,465.50	-2,465.50	-2,465.50	-2,465.50	-2,465.50
	Total:	**96,782.60**	4,839.13	4,839.13	4,839.13	4,839.13	4,839.13	4,839.13	4,839.13	4,839.13	4,839.13	4,839.13	4,839.13	4,839.13	4,839.13	4,839.13	4,839.13	4,839.13	4,839.13	4,839.13	4,839.13	4,839.13
		36,145.61	**-4,320.65**	**-3,857.72**	**-3,444.40**	**-3,075.35**	**-2,745.85**	**-2,451.65**	**-2,188.98**	**-1,954.44**	**-1,745.04**	**-1,558.07**	**-1,391.13**	**-1,242.08**	**-1,109.00**	**-990.18**	**-884.09**	**-789.37**	**-704.79**	**-629.28**	**-561.86**	**-501.66**
OPEX_Heating																						
CoE			-4,809.29	-5,030.77	-5,252.25	-5,473.74	-5,695.22	-5,916.70	-6,138.18	-6,359.66	-6,581.14	-6,802.62	-7,024.10	-7,245.58	-7,467.06	-7,688.54	-7,910.02	-8,131.50	-8,352.98	-8,574.46	-8,795.94	-9,017.43
Maintenance			-369.71	-369.71	-369.71	-369.71	-369.71	-369.71	-369.71	-369.71	-369.71	-369.71	-369.71	-369.71	-369.71	-369.71	-369.71	-369.71	-369.71	-369.71	-369.71	-369.71
		Total:	5,179.01	5,400.49	5,621.97	5,843.45	6,064.93	6,286.41	6,507.89	6,729.37	6,950.85	7,172.33	7,393.81	7,615.29	7,836.78	8,058.26	8,279.74	8,501.22	8,722.70	8,944.18	9,165.66	9,387.14
Net emissions impact (Gas)		[t CO2e]	14.73	14.73	14.73	14.73	14.73	14.73	14.73	14.73	14.73	14.73	14.73	14.73	14.73	14.73	14.73	14.73	14.73	14.73	14.73	14.73
Net emissions impact (RE)		[t CO2e]	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21
		48,643.75	**-4,624.11**	**-4,305.24**	**-4,001.61**	**-3,713.62**	**-3,441.40**	**-3,184.89**	**-2,943.84**	**-2,717.88**	**-2,506.55**	**-2,309.30**	**-2,125.54**	**-1,954.66**	**-1,795.99**	**-1,648.88**	**-1,512.68**	**-1,386.73**	**-1,270.41**	**-1,163.10**	**-1,064.20**	**-973.13**
NPC Heating		**-84,789.36**	-8,944.77	-8,162.96	-7,446.00	-6,788.97	-6,187.26	-5,636.55	-5,132.82	-4,672.32	-4,251.59	-3,867.37	-3,516.68	-3,196.74	-2,904.99	-2,639.06	-2,396.77	-2,176.10	-1,975.20	-1,792.38	-1,626.05	-1,474.79
CAPEX_Non-Heating																						
Building																						
	Material	52,233.67	-2,611.68	-2,611.68	-2,611.68	-2,611.68	-2,611.68	-2,611.68	-2,611.68	-2,611.68	-2,611.68	-2,611.68	-2,611.68	-2,611.68	-2,611.68	-2,611.68	-2,611.68	-2,611.68	-2,611.68	-2,611.68	-2,611.68	-2,611.68
	Labour	49,430.08	-2,471.50	-2,471.50	-2,471.50	-2,471.50	-2,471.50	-2,471.50	-2,471.50	-2,471.50	-2,471.50	-2,471.50	-2,471.50	-2,471.50	-2,471.50	-2,471.50	-2,471.50	-2,471.50	-2,471.50	-2,471.50	-2,471.50	-2,471.50
	Total:	**101,663.75**	5,083.19	5,083.19	5,083.19	5,083.19	5,083.19	5,083.19	5,083.19	5,083.19	5,083.19	5,083.19	5,083.19	5,083.19	5,083.19	5,083.19	5,083.19	5,083.19	5,083.19	5,083.19	5,083.19	5,083.19
Aquaponics																						
	Aquaculture system	12,355.00	-617.75	-617.75	-617.75	-617.75	-617.75	-617.75	-617.75	-617.75	-617.75	-617.75	-617.75	-617.75	-617.75	-617.75	-617.75	-617.75	-617.75	-617.75	-617.75	-617.75
	NFT system 1: Horizontal	16,067.92	-803.40	-803.40	-803.40	-803.40	-803.40	-803.40	-803.40	-803.40	-803.40	-803.40	-803.40	-803.40	-803.40	-803.40	-803.40	-803.40	-803.40	-803.40	-803.40	-803.40
	NFT system 2: Vertical	31,949.17	-1,597.46	-1,597.46	-1,597.46	-1,597.46	-1,597.46	-1,597.46	-1,597.46	-1,597.46	-1,597.46	-1,597.46	-1,597.46	-1,597.46	-1,597.46	-1,597.46	-1,597.46	-1,597.46	-1,597.46	-1,597.46	-1,597.46	-1,597.46
	Growing lights	28,882.22	-1,444.11	-1,444.11	-1,444.11	-1,444.11	-1,444.11	-1,444.11	-1,444.11	-1,444.11	-1,444.11	-1,444.11	-1,444.11	-1,444.11	-1,444.11	-1,444.11	-1,444.11	-1,444.11	-1,444.11	-1,444.11	-1,444.11	-1,444.11
	Water	193.47	-9.67	-9.67	-9.67	-9.67	-9.67	-9.67	-9.67	-9.67	-9.67	-9.67	-9.67	-9.67	-9.67	-9.67	-9.67	-9.67	-9.67	-9.67	-9.67	-9.67
	Total:	**89,447.77**	4,472.39	4,472.39	4,472.39	4,472.39	4,472.39	4,472.39	4,472.39	4,472.39	4,472.39	4,472.39	4,472.39	4,472.39	4,472.39	4,472.39	4,472.39	4,472.39	4,472.39	4,472.39	4,472.39	4,472.39
Soil-based cultivation																						
	Growing beds	1,443.75	-72.19	-72.19	-72.19	-72.19	-72.19	-72.19	-72.19	-72.19	-72.19	-72.19	-72.19	-72.19	-72.19	-72.19	-72.19	-72.19	-72.19	-72.19	-72.19	-72.19
	Soil	2,887.50	-144.38	-144.38	-144.38	-144.38	-144.38	-144.38	-144.38	-144.38	-144.38	-144.38	-144.38	-144.38	-144.38	-144.38	-144.38	-144.38	-144.38	-144.38	-144.38	-144.38
	Total:	**4,331.25**	216.56	216.56	216.56	216.56	216.56	216.56	216.56	216.56	216.56	216.56	216.56	216.56	216.56	216.56	216.56	216.56	216.56	216.56	216.56	216.56
		72,992.44	**-8,725.12**	**-7,790.29**	**-6,955.62**	**-6,210.37**	**-5,544.97**	**-4,950.87**	**-4,420.42**	**-3,946.80**	**-3,523.93**	**-3,146.37**	**-2,809.26**	**-2,508.26**	**-2,239.52**	**-1,999.57**	**-1,785.33**	**-1,594.05**	**-1,423.26**	**-1,270.76**	**-1,134.61**	**-1,013.05**
OPEX_Non-Heating																						
Electricity		Grow lights	-2,603.76	-2,723.67	-2,843.58	-2,963.49	-3,083.40	-3,203.31	-3,323.22	-3,443.13	-3,563.04	-3,682.95	-3,802.86	-3,922.77	-4,042.68	-4,162.59	-4,282.50	-4,402.41	-4,522.32	-4,642.23	-4,762.14	-4,882.06
		Pumps	-371.22	-388.32	-405.42	-422.51	-439.61	-456.70	-473.80	-490.89	-507.99	-525.09	-542.18	-559.28	-576.37	-593.47	-610.57	-627.66	-644.76	-661.85	-678.95	-696.04
Labor			-3,206.00	-3,206.00	-3,206.00	-3,206.00	-3,206.00	-3,206.00	-3,206.00	-3,206.00	-3,206.00	-3,206.00	-3,206.00	-3,206.00	-3,206.00	-3,206.00	-3,206.00	-3,206.00	-3,206.00	-3,206.00	-3,206.00	-3,206.00
Fish feed			-4,227.30	-4,227.30	-4,227.30	-4,227.30	-4,227.30	-4,227.30	-4,227.30	-4,227.30	-4,227.30	-4,227.30	-4,227.30	-4,227.30	-4,227.30	-4,227.30	-4,227.30	-4,227.30	-4,227.30	-4,227.30	-4,227.30	-4,227.30
Maintenance		Building	-1,202.87	-1,202.87	-1,202.87	-1,202.87	-1,202.87	-1,202.87	-1,202.87	-1,202.87	-1,202.87	-1,202.87	-1,202.87	-1,202.87	-1,202.87	-1,202.87	-1,202.87	-1,202.87	-1,202.87	-1,202.87	-1,202.87	-1,202.87
		Aquaponics	-1,820.00	-1,820.00	-1,820.00	-1,820.00	-1,820.00	-1,820.00	-1,820.00	-1,820.00	-1,820.00	-1,820.00	-1,820.00	-1,820.00	-1,820.00	-1,820.00	-1,820.00	-1,820.00	-1,820.00	-1,820.00	-1,820.00	-1,820.00
		106,484.08	**-11,992.10**	**-10,816.46**	**-9,755.07**	**-8,796.95**	**-7,932.16**	**-7,151.70**	**-6,447.42**	**-5,811.96**	**-5,238.65**	**-4,721.48**	**-4,255.00**	**-3,834.27**	**-3,454.85**	**-3,112.72**	**-2,804.25**	**-2,526.14**	**-2,275.44**	**-2,049.46**	**-1,845.78**	**-1,662.22**
NPC Total		**-264,265.88**	-29,661.99	-26,769.71	-24,156.69	-21,796.29	-19,664.39	-17,739.11	-16,000.66	-14,431.09	-13,014.17	-11,735.22	-10,580.93	-9,539.27	-8,599.37	-7,751.36	-6,986.35	-6,296.29	-5,673.90	-5,112.60	-4,606.44	-4,150.06
AG yield																						
Fish [CAD/kg]		8.8	3,080.00	3,080.00	3,080.00	3,080.00	3,080.00	3,080.00	3,080.00	3,080.00	3,080.00	3,080.00	3,080.00	3,080.00	3,080.00	3,080.00	3,080.00	3,080.00	3,080.00	3,080.00	3,080.00	3,080.00
Basil: NFT [CAD/kg]		7.5	20,790.00	20,790.00	20,790.00	20,790.00	20,790.00	20,790.00	20,790.00	20,790.00	20,790.00	20,790.00	20,790.00	20,790.00	20,790.00	20,790.00	20,790.00	20,790.00	20,790.00	20,790.00	20,790.00	20,790.00
Lettuce: Soil [CAD/kg]		5	6,930.00	6,930.00	6,930.00	6,930.00	6,930.00	6,930.00	6,930.00	6,930.00	6,930.00	6,930.00	6,930.00	6,930.00	6,930.00	6,930.00	6,930.00	6,930.00	6,930.00	6,930.00	6,930.00	6,930.00
Additional income																						
Carbon offsets (Gas)			925.06	1,051.21	1,177.35	1,303.50	1,429.64	1,446.46	1,463.28	1,480.10	1,496.92	1,513.74	1,530.56	1,547.38	1,564.19	1,581.01	1,597.83	1,614.65	1,631.47	1,648.29	1,665.11	1,681.93
Carbon offsets (RE)		Assumption	2,522.15	2,866.08	3,210.00	3,553.93	3,897.86	3,943.72	3,989.58	4,035.43	4,081.29	4,127.15	4,173.01	4,218.86	4,264.72	4,310.58	4,356.43	4,402.29	4,448.15	4,494.01	4,539.86	4,585.72
Savings of cooling			541.16	538.07	561.76	585.45	609.14	632.82	656.51	680.20	703.89	727.58	751.27	774.96	798.64	822.33	846.02	869.71	893.40	917.09	940.78	964.46
		257,474.55	**29,751.92**	**26,838.39**	**24,207.65**	**21,832.55**	**19,688.50**	**17,602.25**	**15,737.04**	**14,069.45**	**12,578.54**	**11,245.61**	**10,053.90**	**8,988.47**	**8,035.93**	**7,184.32**	**6,422.95**	**5,742.26**	**5,133.69**	**4,589.62**	**4,103.20**	**3,668.32**
NPV Total		**-6,791.33**	89.92	68.68	50.96	36.25	24.11	-136.86	-263.62	-361.64	-435.63	-489.61	-527.03	-550.80	-563.44	-567.04	-563.40	-554.03	-540.20	-522.98	-503.24	-481.73
		Cumulative	89.92	158.61	209.57	245.82	269.93	133.07	-130.55	-492.19	-927.82	-1,417.43	-1,944.46	-2,495.26	-3,058.70	-3,625.74	-4,189.14	-4,743.17	-5,283.37	-5,806.35	-6,309.60	-6,791.33

Discount rate 12 [%]

GSHP - CLOSED-LOOP HORIZONTAL

392 [m2] 8000 [l]

Lifespan	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Years	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**	**2036**	**2037**	**2038**	**2039**	**2040**	**2041**	**2042**	**2043**	**2044**	**2045**
Electricity rates [CAD/kWh]	0.104	0.160	0.167	0.175	0.182	0.189	0.197	0.204	0.212	0.219	0.226	0.234	0.241	0.248	0.256	0.263	0.271	0.278	0.285	0.293	0.300
Carbon offset price [CAD/t]	95	110	125	140	155	170	172	174	176	178	180	182	184	186	188	190	192	194	196	198	200
CAPEX_Heating																					
Hydronic radiant heating	16,516.50	- 825.82	- 825.82	- 825.82	- 825.82	- 825.82	- 825.82	- 825.82	- 825.82	- 825.82	- 825.82	- 825.82	- 825.82	- 825.82	- 825.82	- 825.82	- 825.82	- 825.82	- 825.82	- 825.82	- 825.82
Ground loop installation	36,867.81	- 1,843.39	- 1,843.39	- 1,843.39	- 1,843.39	- 1,843.39	- 1,843.39	- 1,843.39	- 1,843.39	- 1,843.39	- 1,843.39	- 1,843.39	- 1,843.39	- 1,843.39	- 1,843.39	- 1,843.39	- 1,843.39	- 1,843.39	- 1,843.39	- 1,843.39	- 1,843.39
Heat pump	49,310.00	- 2,465.50	- 2,465.50	- 2,465.50	- 2,465.50	- 2,465.50	- 2,465.50	- 2,465.50	- 2,465.50	- 2,465.50	- 2,465.50	- 2,465.50	- 2,465.50	- 2,465.50	- 2,465.50	- 2,465.50	- 2,465.50	- 2,465.50	- 2,465.50	- 2,465.50	- 2,465.50
Total:	**102,694.31**	5,134.72	5,134.72	5,134.72	5,134.72	5,134.72	5,134.72	5,134.72	5,134.72	5,134.72	5,134.72	5,134.72	5,134.72	5,134.72	5,134.72	5,134.72	5,134.72	5,134.72	5,134.72	5,134.72	5,134.72
	38,353.47	**- 4,584.57**	**- 4,093.36**	**- 3,654.79**	**- 3,263.20**	**- 2,913.58**	**- 2,601.41**	**- 2,322.68**	**- 2,073.83**	**- 1,851.63**	**- 1,653.24**	**- 1,476.11**	**- 1,317.95**	**- 1,176.74**	**- 1,050.66**	**- 938.09**	**- 837.58**	**- 747.84**	**- 667.72**	**- 596.18**	**- 532.30**
OPEX_Heating																					
CoE		- 5,334.63	- 5,580.30	- 5,825.98	- 6,071.65	- 6,317.32	- 6,563.00	- 6,808.67	- 7,054.35	- 7,300.02	- 7,545.69	- 7,791.37	- 8,037.04	- 8,282.71	- 8,528.39	- 8,774.06	- 9,019.73	- 9,265.41	- 9,511.08	- 9,756.76	- 10,002.43
Maintenance		- 410.10	- 410.10	- 410.10	- 410.10	- 410.10	- 410.10	- 410.10	- 410.10	- 410.10	- 410.10	- 410.10	- 410.10	- 410.10	- 410.10	- 410.10	- 410.10	- 410.10	- 410.10	- 410.10	- 410.10
Total:		5,744.73	5,990.40	6,236.08	6,481.75	6,727.42	6,973.10	7,218.77	7,464.44	7,710.12	7,955.79	8,201.47	8,447.14	8,692.81	8,938.49	9,184.16	9,429.83	9,675.51	9,921.18	10,166.86	10,412.53
Net emissions impact (Gas)	[t CO2e]	16.34	16.34	16.34	16.34	16.34	16.34	16.34	16.34	16.34	16.34	16.34	16.34	16.34	16.34	16.34	16.34	16.34	16.34	16.34	16.34
Net emissions impact (RE)	[t CO2e]	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23
	53,957.28	**- 5,129.22**	**- 4,775.51**	**- 4,438.72**	**- 4,119.27**	**- 3,817.32**	**- 3,532.79**	**- 3,265.41**	**- 3,014.76**	**- 2,780.35**	**- 2,561.55**	**- 2,357.73**	**- 2,168.17**	**- 1,992.17**	**- 1,828.99**	**- 1,677.91**	**- 1,538.21**	**- 1,409.18**	**- 1,290.15**	**- 1,180.44**	**- 1,079.43**
NPC Heating	**- 92,310.75**	- 9,713.79	- 8,868.88	- 8,093.51	- 7,382.47	- 6,730.90	- 6,134.19	- 5,588.09	- 5,088.59	- 4,631.98	- 4,214.79	- 3,833.83	- 3,486.12	- 3,168.91	- 2,879.66	- 2,616.01	- 2,375.79	- 2,157.03	- 1,957.86	- 1,776.62	- 1,611.73
CAPEX_Non-Heating																					
Building																					
Material	58,484.42	- 2,924.22	- 2,924.22	- 2,924.22	- 2,924.22	- 2,924.22	- 2,924.22	- 2,924.22	- 2,924.22	- 2,924.22	- 2,924.22	- 2,924.22	- 2,924.22	- 2,924.22	- 2,924.22	- 2,924.22	- 2,924.22	- 2,924.22	- 2,924.22	- 2,924.22	- 2,924.22
Labour	55,463.63	- 2,773.18	- 2,773.18	- 2,773.18	- 2,773.18	- 2,773.18	- 2,773.18	- 2,773.18	- 2,773.18	- 2,773.18	- 2,773.18	- 2,773.18	- 2,773.18	- 2,773.18	- 2,773.18	- 2,773.18	- 2,773.18	- 2,773.18	- 2,773.18	- 2,773.18	- 2,773.18
Total:	**113,948.05**	5,697.40	5,697.40	5,697.40	5,697.40	5,697.40	5,697.40	5,697.40	5,697.40	5,697.40	5,697.40	5,697.40	5,697.40	5,697.40	5,697.40	5,697.40	5,697.40	5,697.40	5,697.40	5,697.40	5,697.40
Aquaponics																					
Aquaculture system	14,120.00	- 706.00	- 706.00	- 706.00	- 706.00	- 706.00	- 706.00	- 706.00	- 706.00	- 706.00	- 706.00	- 706.00	- 706.00	- 706.00	- 706.00	- 706.00	- 706.00	- 706.00	- 706.00	- 706.00	- 706.00
NFT system 1: Horizontal	18,363.33	- 918.17	- 918.17	- 918.17	- 918.17	- 918.17	- 918.17	- 918.17	- 918.17	- 918.17	- 918.17	- 918.17	- 918.17	- 918.17	- 918.17	- 918.17	- 918.17	- 918.17	- 918.17	- 918.17	- 918.17
NFT system 2: Vertical	36,513.33	- 1,825.67	- 1,825.67	- 1,825.67	- 1,825.67	- 1,825.67	- 1,825.67	- 1,825.67	- 1,825.67	- 1,825.67	- 1,825.67	- 1,825.67	- 1,825.67	- 1,825.67	- 1,825.67	- 1,825.67	- 1,825.67	- 1,825.67	- 1,825.67	- 1,825.67	- 1,825.67
Growing lights	33,008.25	- 1,650.41	- 1,650.41	- 1,650.41	- 1,650.41	- 1,650.41	- 1,650.41	- 1,650.41	- 1,650.41	- 1,650.41	- 1,650.41	- 1,650.41	- 1,650.41	- 1,650.41	- 1,650.41	- 1,650.41	- 1,650.41	- 1,650.41	- 1,650.41	- 1,650.41	- 1,650.41
Water	221.11	- 11.06	- 11.06	- 11.06	- 11.06	- 11.06	- 11.06	- 11.06	- 11.06	- 11.06	- 11.06	- 11.06	- 11.06	- 11.06	- 11.06	- 11.06	- 11.06	- 11.06	- 11.06	- 11.06	- 11.06
Total:	**102,226.03**	5,111.30	5,111.30	5,111.30	5,111.30	5,111.30	5,111.30	5,111.30	5,111.30	5,111.30	5,111.30	5,111.30	5,111.30	5,111.30	5,111.30	5,111.30	5,111.30	5,111.30	5,111.30	5,111.30	5,111.30
Soil-based cultivation																					
Growing beds	1,650.00	- 82.50	- 82.50	- 82.50	- 82.50	- 82.50	- 82.50	- 82.50	- 82.50	- 82.50	- 82.50	- 82.50	- 82.50	- 82.50	- 82.50	- 82.50	- 82.50	- 82.50	- 82.50	- 82.50	- 82.50
Soil	3,300.00	- 165.00	- 165.00	- 165.00	- 165.00	- 165.00	- 165.00	- 165.00	- 165.00	- 165.00	- 165.00	- 165.00	- 165.00	- 165.00	- 165.00	- 165.00	- 165.00	- 165.00	- 165.00	- 165.00	- 165.00
Total:	**4,950.00**	247.50	247.50	247.50	247.50	247.50	247.50	247.50	247.50	247.50	247.50	247.50	247.50	247.50	247.50	247.50	247.50	247.50	247.50	247.50	247.50
	82,583.69	**- 9,871.61**	**- 8,813.94**	**- 7,869.59**	**- 7,026.42**	**- 6,273.59**	**- 5,601.42**	**- 5,001.27**	**- 4,465.42**	**- 3,986.98**	**- 3,559.80**	**- 3,178.39**	**- 2,837.85**	**- 2,533.80**	**- 2,262.32**	**- 2,019.93**	**- 1,803.51**	**- 1,610.27**	**- 1,437.74**	**- 1,283.70**	**- 1,146.16**
OPEX_Non-Heating																					
Electricity: Grow lights		- 2,975.73	- 3,112.77	- 3,249.81	- 3,386.85	- 3,523.89	- 3,660.93	- 3,797.97	- 3,935.01	- 4,072.05	- 4,209.09	- 4,346.13	- 4,483.17	- 4,620.21	- 4,757.25	- 4,894.29	- 5,031.33	- 5,168.37	- 5,305.41	- 5,442.45	- 5,579.49
Pumps		- 424.26	- 443.79	- 463.33	- 482.87	- 502.41	- 521.95	- 541.48	- 561.02	- 580.56	- 600.10	- 619.64	- 639.17	- 658.71	- 678.25	- 697.79	- 717.33	- 736.86	- 756.40	- 775.94	- 795.48
Labor		- 3,664.00	- 3,664.00	- 3,664.00	- 3,664.00	- 3,664.00	- 3,664.00	- 3,664.00	- 3,664.00	- 3,664.00	- 3,664.00	- 3,664.00	- 3,664.00	- 3,664.00	- 3,664.00	- 3,664.00	- 3,664.00	- 3,664.00	- 3,664.00	- 3,664.00	- 3,664.00
Fish feed		- 4,831.20	- 4,831.20	- 4,831.20	- 4,831.20	- 4,831.20	- 4,831.20	- 4,831.20	- 4,831.20	- 4,831.20	- 4,831.20	- 4,831.20	- 4,831.20	- 4,831.20	- 4,831.20	- 4,831.20	- 4,831.20	- 4,831.20	- 4,831.20	- 4,831.20	- 4,831.20
Maintenance: Building		- 1,355.71	- 1,355.71	- 1,355.71	- 1,355.71	- 1,355.71	- 1,355.71	- 1,355.71	- 1,355.71	- 1,355.71	- 1,355.71	- 1,355.71	- 1,355.71	- 1,355.71	- 1,355.71	- 1,355.71	- 1,355.71	- 1,355.71	- 1,355.71	- 1,355.71	- 1,355.71
Aquaponics		- 2,080.00	- 2,080.00	- 2,080.00	- 2,080.00	- 2,080.00	- 2,080.00	- 2,080.00	- 2,080.00	- 2,080.00	- 2,080.00	- 2,080.00	- 2,080.00	- 2,080.00	- 2,080.00	- 2,080.00	- 2,080.00	- 2,080.00	- 2,080.00	- 2,080.00	- 2,080.00
	121,554.16	**- 13,688.29**	**- 12,346.51**	**- 11,135.12**	**- 10,041.58**	**- 9,054.55**	**- 8,163.74**	**- 7,359.88**	**- 6,634.56**	**- 5,980.18**	**- 5,389.86**	**- 4,857.39**	**- 4,377.14**	**- 3,944.05**	**- 3,553.51**	**- 3,201.38**	**- 2,883.92**	**- 2,597.73**	**- 2,339.77**	**- 2,107.26**	**- 1,897.71**
NPC Total	**-296,448.59**	- 33,273.69	- 30,029.33	- 27,098.22	- 24,450.47	- 22,059.03	- 19,899.35	- 17,949.24	- 16,188.57	- 14,599.14	- 13,164.46	- 11,869.62	- 10,701.12	- 9,646.76	- 8,695.49	- 7,837.32	- 7,063.22	- 6,365.03	- 5,735.37	- 5,167.57	- 4,655.60
AG yield																					
Fish [CAD/kg]	8.8	3,520.00	3,520.00	3,520.00	3,520.00	3,520.00	3,520.00	3,520.00	3,520.00	3,520.00	3,520.00	3,520.00	3,520.00	3,520.00	3,520.00	3,520.00	3,520.00	3,520.00	3,520.00	3,520.00	3,520.00
Basil: NFT [CAD/kg]	7.5	23,760.00	23,760.00	23,760.00	23,760.00	23,760.00	23,760.00	23,760.00	23,760.00	23,760.00	23,760.00	23,760.00	23,760.00	23,760.00	23,760.00	23,760.00	23,760.00	23,760.00	23,760.00	23,760.00	23,760.00
Lettuce: Soil [CAD/kg]	5	7,920.00	7,920.00	7,920.00	7,920.00	7,920.00	7,920.00	7,920.00	7,920.00	7,920.00	7,920.00	7,920.00	7,920.00	7,920.00	7,920.00	7,920.00	7,920.00	7,920.00	7,920.00	7,920.00	7,920.00
Additional income																					
Carbon offsets (Gas)		1,026.11	1,166.03	1,305.96	1,445.88	1,585.80	1,604.46	1,623.12	1,641.77	1,660.43	1,679.09	1,697.74	1,716.40	1,735.06	1,753.71	1,772.37	1,791.03	1,809.68	1,828.34	1,847.00	1,865.65
Carbon offsets (RE)	Assumption	2,797.65	3,179.15	3,560.64	3,942.14	4,323.64	4,374.51	4,425.37	4,476.24	4,527.11	4,577.97	4,628.84	4,679.70	4,730.57	4,781.44	4,832.30	4,883.17	4,934.04	4,984.90	5,035.77	5,086.64
Savings of cooling		648.89	646.56	675.03	703.49	731.95	760.42	788.88	817.35	845.81	874.28	902.74	931.21	959.67	988.14	1,016.60	1,045.07	1,073.53	1,102.00	1,130.46	1,158.93
	293,334.81	**33,926.47**	**30,595.62**	**27,589.06**	**24,875.54**	**22,426.77**	**20,049.68**	**17,924.51**	**16,024.57**	**14,325.99**	**12,807.44**	**11,449.84**	**10,236.13**	**9,151.06**	**8,180.99**	**7,313.75**	**6,538.43**	**5,845.30**	**5,225.63**	**4,671.65**	**4,176.39**
NPV Total	**- 3,113.79**	652.78	566.29	490.85	425.07	367.75	150.32	- 24.73	- 164.00	- 273.14	- 357.01	- 419.78	- 464.99	- 495.70	- 514.49	- 523.56	- 524.79	- 519.74	- 509.74	- 495.93	- 479.22
Cumulative		652.78	1,219.07	1,709.92	2,134.98	2,502.73	2,653.05	2,628.32	2,464.32	2,191.17	1,834.16	1,414.38	949.39	453.68	- 60.81	- 584.37	- 1,109.16	- 1,628.89	- 2,138.64	- 2,634.57	- 3,113.79

Discount rate 12 [%]

GSHP - CLOSED-LOOP HORIZONTAL

436 [m2] 9000 [l]

Lifespan	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Years	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**	**2036**	**2037**	**2038**	**2039**	**2040**	**2041**	**2042**	**2043**	**2044**	**2045**
Electricity rates [CAD/kWh]	0.104	0.160	0.167	0.175	0.182	0.189	0.197	0.204	0.212	0.219	0.226	0.234	0.241	0.248	0.256	0.263	0.271	0.278	0.285	0.293	0.300
Carbon offset price [CAD/t]	95	110	125	140	155	170	172	174	176	178	180	182	184	186	188	190	192	194	196	198	200
CAPEX_Heating																					
Hydronic radiant heating	18,378.49	- 918.92	- 918.92	- 918.92	- 918.92	- 918.92	- 918.92	- 918.92	- 918.92	- 918.92	- 918.92	- 918.92	- 918.92	- 918.92	- 918.92	- 918.92	- 918.92	- 918.92	- 918.92	- 918.92	- 918.92
Ground loop installation	40,917.53	- 2,045.88	- 2,045.88	- 2,045.88	- 2,045.88	- 2,045.88	- 2,045.88	- 2,045.88	- 2,045.88	- 2,045.88	- 2,045.88	- 2,045.88	- 2,045.88	- 2,045.88	- 2,045.88	- 2,045.88	- 2,045.88	- 2,045.88	- 2,045.88	- 2,045.88	- 2,045.88
Heat pump	49,310.00	- 2,465.50	- 2,465.50	- 2,465.50	- 2,465.50	- 2,465.50	- 2,465.50	- 2,465.50	- 2,465.50	- 2,465.50	- 2,465.50	- 2,465.50	- 2,465.50	- 2,465.50	- 2,465.50	- 2,465.50	- 2,465.50	- 2,465.50	- 2,465.50	- 2,465.50	- 2,465.50
Total:	**108,606.02**	5,430.30	5,430.30	5,430.30	5,430.30	5,430.30	5,430.30	5,430.30	5,430.30	5,430.30	5,430.30	5,430.30	5,430.30	5,430.30	5,430.30	5,430.30	5,430.30	5,430.30	5,430.30	5,430.30	5,430.30
	40,561.33	**- 4,848.48**	**- 4,329.00**	**- 3,865.18**	**- 3,451.05**	**- 3,081.30**	**- 2,751.16**	**- 2,456.39**	**- 2,193.21**	**- 1,958.22**	**- 1,748.41**	**- 1,561.08**	**- 1,393.82**	**- 1,244.48**	**- 1,111.15**	**- 992.10**	**- 885.80**	**- 790.89**	**- 706.15**	**- 630.49**	**- 562.94**
OPEX_Heating																					
CoE		- 5,862.70	- 6,132.69	- 6,402.68	- 6,672.68	- 6,942.67	- 7,212.66	- 7,482.65	- 7,752.65	- 8,022.64	- 8,292.63	- 8,562.62	- 8,832.62	- 9,102.61	- 9,372.60	- 9,642.60	- 9,912.59	- 10,182.58	- 10,452.57	- 10,722.57	- 10,992.56
Maintenance		- 450.69	- 450.69	- 450.69	- 450.69	- 450.69	- 450.69	- 450.69	- 450.69	- 450.69	- 450.69	- 450.69	- 450.69	- 450.69	- 450.69	- 450.69	- 450.69	- 450.69	- 450.69	- 450.69	- 450.69
	Total:	6,313.39	6,583.39	6,853.38	7,123.37	7,393.36	7,663.36	7,933.35	8,203.34	8,473.33	8,743.33	9,013.32	9,283.31	9,553.30	9,823.30	10,093.29	10,363.28	10,633.28	10,903.27	11,173.26	11,443.25
Net emissions impact (Gas)	[t CO2e]	17.95	17.95	17.95	17.95	17.95	17.95	17.95	17.95	17.95	17.95	17.95	17.95	17.95	17.95	17.95	17.95	17.95	17.95	17.95	17.95
Net emissions impact (RE)	[t CO2e]	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26
	59,298.44	**- 5,636.96**	**- 5,248.23**	**- 4,878.10**	**- 4,527.03**	**- 4,195.19**	**- 3,882.49**	**- 3,588.64**	**- 3,313.19**	**- 3,055.57**	**- 2,815.12**	**- 2,591.11**	**- 2,382.79**	**- 2,189.37**	**- 2,010.04**	**- 1,844.01**	**- 1,690.48**	**- 1,548.68**	**- 1,417.86**	**- 1,297.29**	**- 1,186.29**
NPC Heating	**- 99,859.77**	- 10,485.44	- 9,577.24	- 8,743.28	- 7,978.09	- 7,276.49	- 6,633.65	- 6,045.04	- 5,506.40	- 5,013.79	- 4,563.53	- 4,152.20	- 3,776.62	- 3,433.86	- 3,121.19	- 2,836.10	- 2,576.28	- 2,339.57	- 2,124.01	- 1,927.79	- 1,749.23
CAPEX_Non-Heating																					
Building																					
Material	60,927.23	- 3,046.36	- 3,046.36	- 3,046.36	- 3,046.36	- 3,046.36	- 3,046.36	- 3,046.36	- 3,046.36	- 3,046.36	- 3,046.36	- 3,046.36	- 3,046.36	- 3,046.36	- 3,046.36	- 3,046.36	- 3,046.36	- 3,046.36	- 3,046.36	- 3,046.36	- 3,046.36
Labour	61,497.18	- 3,074.86	- 3,074.86	- 3,074.86	- 3,074.86	- 3,074.86	- 3,074.86	- 3,074.86	- 3,074.86	- 3,074.86	- 3,074.86	- 3,074.86	- 3,074.86	- 3,074.86	- 3,074.86	- 3,074.86	- 3,074.86	- 3,074.86	- 3,074.86	- 3,074.86	- 3,074.86
Total:	**122,424.40**	6,121.22	6,121.22	6,121.22	6,121.22	6,121.22	6,121.22	6,121.22	6,121.22	6,121.22	6,121.22	6,121.22	6,121.22	6,121.22	6,121.22	6,121.22	6,121.22	6,121.22	6,121.22	6,121.22	6,121.22
Aquaponics																					
Aquaculture system	15,885.00	- 794.25	- 794.25	- 794.25	- 794.25	- 794.25	- 794.25	- 794.25	- 794.25	- 794.25	- 794.25	- 794.25	- 794.25	- 794.25	- 794.25	- 794.25	- 794.25	- 794.25	- 794.25	- 794.25	- 794.25
NFT system 1: Horizontal	20,658.75	- 1,032.94	- 1,032.94	- 1,032.94	- 1,032.94	- 1,032.94	- 1,032.94	- 1,032.94	- 1,032.94	- 1,032.94	- 1,032.94	- 1,032.94	- 1,032.94	- 1,032.94	- 1,032.94	- 1,032.94	- 1,032.94	- 1,032.94	- 1,032.94	- 1,032.94	- 1,032.94
NFT system 2: Vertical	41,077.50	- 2,053.88	- 2,053.88	- 2,053.88	- 2,053.88	- 2,053.88	- 2,053.88	- 2,053.88	- 2,053.88	- 2,053.88	- 2,053.88	- 2,053.88	- 2,053.88	- 2,053.88	- 2,053.88	- 2,053.88	- 2,053.88	- 2,053.88	- 2,053.88	- 2,053.88	- 2,053.88
Growing lights	37,134.28	- 1,856.71	- 1,856.71	- 1,856.71	- 1,856.71	- 1,856.71	- 1,856.71	- 1,856.71	- 1,856.71	- 1,856.71	- 1,856.71	- 1,856.71	- 1,856.71	- 1,856.71	- 1,856.71	- 1,856.71	- 1,856.71	- 1,856.71	- 1,856.71	- 1,856.71	- 1,856.71
Water	248.74	- 12.44	- 12.44	- 12.44	- 12.44	- 12.44	- 12.44	- 12.44	- 12.44	- 12.44	- 12.44	- 12.44	- 12.44	- 12.44	- 12.44	- 12.44	- 12.44	- 12.44	- 12.44	- 12.44	- 12.44
Total:	**115,004.28**	5,750.21	5,750.21	5,750.21	5,750.21	5,750.21	5,750.21	5,750.21	5,750.21	5,750.21	5,750.21	5,750.21	5,750.21	5,750.21	5,750.21	5,750.21	5,750.21	5,750.21	5,750.21	5,750.21	5,750.21
Soil-based cultivation																					
Growing beds	1,856.25	- 92.81	- 92.81	- 92.81	- 92.81	- 92.81	- 92.81	- 92.81	- 92.81	- 92.81	- 92.81	- 92.81	- 92.81	- 92.81	- 92.81	- 92.81	- 92.81	- 92.81	- 92.81	- 92.81	- 92.81
Soil	3,712.50	- 185.63	- 185.63	- 185.63	- 185.63	- 185.63	- 185.63	- 185.63	- 185.63	- 185.63	- 185.63	- 185.63	- 185.63	- 185.63	- 185.63	- 185.63	- 185.63	- 185.63	- 185.63	- 185.63	- 185.63
Total:	**5,568.75**	278.44	278.44	278.44	278.44	278.44	278.44	278.44	278.44	278.44	278.44	278.44	278.44	278.44	278.44	278.44	278.44	278.44	278.44	278.44	278.44
	90,752.78	**- 10,848.10**	**- 9,685.80**	**- 8,648.04**	**- 7,721.46**	**- 6,894.16**	**- 6,155.50**	**- 5,495.98**	**- 4,907.13**	**- 4,381.37**	**- 3,911.93**	**- 3,492.80**	**- 3,118.57**	**- 2,784.44**	**- 2,486.10**	**- 2,219.74**	**- 1,981.91**	**- 1,769.56**	**- 1,579.96**	**- 1,410.68**	**- 1,259.54**
OPEX_Non-Heating																					
Electricity	Grow lights	- 3,347.69	- 3,501.87	- 3,656.04	- 3,810.21	- 3,964.38	- 4,118.55	- 4,272.72	- 4,426.89	- 4,581.06	- 4,735.23	- 4,889.40	- 5,043.57	- 5,197.74	- 5,351.91	- 5,506.08	- 5,660.25	- 5,814.42	- 5,968.59	- 6,122.76	- 6,276.93
	Pumps	- 477.29	- 499.27	- 521.25	- 543.23	- 565.21	- 587.19	- 609.17	- 631.15	- 653.13	- 675.11	- 697.09	- 719.07	- 741.05	- 763.03	- 785.01	- 806.99	- 828.97	- 850.95	- 872.93	- 894.91
Labor		- 4,122.00	- 4,122.00	- 4,122.00	- 4,122.00	- 4,122.00	- 4,122.00	- 4,122.00	- 4,122.00	- 4,122.00	- 4,122.00	- 4,122.00	- 4,122.00	- 4,122.00	- 4,122.00	- 4,122.00	- 4,122.00	- 4,122.00	- 4,122.00	- 4,122.00	- 4,122.00
Fish feed		- 5,435.10	- 5,435.10	- 5,435.10	- 5,435.10	- 5,435.10	- 5,435.10	- 5,435.10	- 5,435.10	- 5,435.10	- 5,435.10	- 5,435.10	- 5,435.10	- 5,435.10	- 5,435.10	- 5,435.10	- 5,435.10	- 5,435.10	- 5,435.10	- 5,435.10	- 5,435.10
Maintenance	Building	- 1,508.54	- 1,508.54	- 1,508.54	- 1,508.54	- 1,508.54	- 1,508.54	- 1,508.54	- 1,508.54	- 1,508.54	- 1,508.54	- 1,508.54	- 1,508.54	- 1,508.54	- 1,508.54	- 1,508.54	- 1,508.54	- 1,508.54	- 1,508.54	- 1,508.54	- 1,508.54
	Aquaponics	- 2,340.00	- 2,340.00	- 2,340.00	- 2,340.00	- 2,340.00	- 2,340.00	- 2,340.00	- 2,340.00	- 2,340.00	- 2,340.00	- 2,340.00	- 2,340.00	- 2,340.00	- 2,340.00	- 2,340.00	- 2,340.00	- 2,340.00	- 2,340.00	- 2,340.00	- 2,340.00
	136,624.23	**- 15,384.49**	**- 13,876.57**	**- 12,515.18**	**- 11,286.21**	**- 10,176.93**	**- 9,175.79**	**- 8,272.35**	**- 7,457.17**	**- 6,721.71**	**- 6,058.24**	**- 5,459.78**	**- 4,920.02**	**- 4,433.24**	**- 3,994.30**	**- 3,598.52**	**- 3,241.70**	**- 2,920.03**	**- 2,630.07**	**- 2,368.73**	**- 2,133.20**
NPC Total	**-327,236.78**	- 36,718.03	- 33,139.61	- 29,906.50	- 26,985.76	- 24,347.58	- 21,964.94	- 19,813.37	- 17,870.70	- 16,116.86	- 14,533.70	- 13,104.78	- 11,815.21	- 10,651.54	- 9,601.59	- 8,654.36	- 7,799.88	- 7,029.16	- 6,334.05	- 5,707.20	- 5,141.97
AG yield																					
Fish [CAD/kg]	8.8	3,960.00	3,960.00	3,960.00	3,960.00	3,960.00	3,960.00	3,960.00	3,960.00	3,960.00	3,960.00	3,960.00	3,960.00	3,960.00	3,960.00	3,960.00	3,960.00	3,960.00	3,960.00	3,960.00	3,960.00
Basil: NFT [CAD/kg]	7.5	26,730.00	26,730.00	26,730.00	26,730.00	26,730.00	26,730.00	26,730.00	26,730.00	26,730.00	26,730.00	26,730.00	26,730.00	26,730.00	26,730.00	26,730.00	26,730.00	26,730.00	26,730.00	26,730.00	26,730.00
Lettuce: Soil [CAD/kg]	5	8,910.00	8,910.00	8,910.00	8,910.00	8,910.00	8,910.00	8,910.00	8,910.00	8,910.00	8,910.00	8,910.00	8,910.00	8,910.00	8,910.00	8,910.00	8,910.00	8,910.00	8,910.00	8,910.00	8,910.00
Additional income																					
Carbon offsets (Gas)		1,127.68	1,281.46	1,435.23	1,589.01	1,742.78	1,763.28	1,783.79	1,804.29	1,824.79	1,845.30	1,865.80	1,886.30	1,906.81	1,927.31	1,947.81	1,968.32	1,988.82	2,009.32	2,029.83	2,050.33
Carbon offsets (RE)	Assumption	3,074.59	3,493.85	3,913.11	4,332.37	4,751.63	4,807.53	4,863.43	4,919.34	4,975.24	5,031.14	5,087.04	5,142.94	5,198.84	5,254.75	5,310.65	5,366.55	5,422.45	5,478.35	5,534.25	5,590.15
Savings of cooling		757.47	756.81	790.13	823.45	856.76	890.08	923.40	956.72	990.04	1,023.36	1,056.68	1,090.00	1,123.31	1,156.63	1,189.95	1,223.27	1,256.59	1,289.91	1,323.23	1,356.54
	329,210.65	**38,102.31**	**34,354.15**	**30,971.77**	**27,919.82**	**25,166.31**	**22,498.24**	**20,113.00**	**17,980.61**	**16,074.28**	**14,370.03**	**12,846.46**	**11,484.40**	**10,266.74**	**9,178.17**	**8,205.01**	**7,335.02**	**6,557.27**	**5,861.97**	**5,240.39**	**4,684.72**
NPV Total	**1,973.87**	1,384.28	1,214.54	1,065.27	934.05	818.72	533.29	299.63	109.91	- 42.59	- 163.67	- 258.32	- 330.81	- 384.80	- 423.42	- 449.35	- 464.86	- 471.89	- 472.08	- 466.81	- 457.25
	Cumulative	1,384.28	2,598.82	3,664.09	4,598.15	5,416.87	5,950.16	6,249.80	6,359.71	6,317.12	6,153.45	5,895.13	5,564.32	5,179.53	4,756.11	4,306.76	3,841.89	3,370.00	2,897.92	2,431.11	1,973.87

Discount rate 12 [%]

GSHP - CLOSED-LOOP HORIZONTAL

481 [m2] 10000 [l]

Lifespan		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Years		**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**	**2036**	**2037**	**2038**	**2039**	**2040**	**2041**	**2042**	**2043**	**2044**	**2045**
Electricity rates [CAD/kWh]		0.104	0.160	0.167	0.175	0.182	0.189	0.197	0.204	0.212	0.219	0.226	0.234	0.241	0.248	0.256	0.263	0.271	0.278	0.285	0.293	0.300
Carbon offset price [CAD/t]		95	110	125	140	155	170	172	174	176	178	180	182	184	186	188	190	192	194	196	198	200
CAPEX_Heating																						
Hydronic radiant heating		20,240.49	-1,012.02	-1,012.02	-1,012.02	-1,012.02	-1,012.02	-1,012.02	-1,012.02	-1,012.02	-1,012.02	-1,012.02	-1,012.02	-1,012.02	-1,012.02	-1,012.02	-1,012.02	-1,012.02	-1,012.02	-1,012.02	-1,012.02	-1,012.02
Ground loop installation		45,414.65	-2,270.73	-2,270.73	-2,270.73	-2,270.73	-2,270.73	-2,270.73	-2,270.73	-2,270.73	-2,270.73	-2,270.73	-2,270.73	-2,270.73	-2,270.73	-2,270.73	-2,270.73	-2,270.73	-2,270.73	-2,270.73	-2,270.73	-2,270.73
Heat pump		55,505.00	-2,775.25	-2,775.25	-2,775.25	-2,775.25	-2,775.25	-2,775.25	-2,775.25	-2,775.25	-2,775.25	-2,775.25	-2,775.25	-2,775.25	-2,775.25	-2,775.25	-2,775.25	-2,775.25	-2,775.25	-2,775.25	-2,775.25	-2,775.25
	Total:	**121,160.14**	6,058.01	6,058.01	6,058.01	6,058.01	6,058.01	6,058.01	6,058.01	6,058.01	6,058.01	6,058.01	6,058.01	6,058.01	6,058.01	6,058.01	6,058.01	6,058.01	6,058.01	6,058.01	6,058.01	6,058.01
		45,249.94	**-5,408.93**	**-4,829.41**	**-4,311.97**	**-3,849.97**	**-3,437.48**	**-3,069.17**	**-2,740.33**	**-2,446.73**	**-2,184.58**	**-1,950.52**	**-1,741.53**	**-1,554.94**	**-1,388.34**	**-1,239.59**	**-1,106.78**	**-988.19**	**-882.31**	**-787.78**	**-703.38**	**-628.01**
OPEX_Heating																						
CoE			-6,417.11	-6,712.63	-7,008.16	-7,303.68	-7,599.21	-7,894.73	-8,190.26	-8,485.78	-8,781.31	-9,076.83	-9,372.35	-9,667.88	-9,963.40	-10,258.93	-10,554.45	-10,849.98	-11,145.50	-11,441.03	-11,736.55	-12,032.08
Maintenance			-493.32	-493.32	-493.32	-493.32	-493.32	-493.32	-493.32	-493.32	-493.32	-493.32	-493.32	-493.32	-493.32	-493.32	-493.32	-493.32	-493.32	-493.32	-493.32	-493.32
		Total:	6,910.42	7,205.95	7,501.47	7,797.00	8,092.52	8,388.05	8,683.57	8,979.10	9,274.62	9,570.14	9,865.67	10,161.19	10,456.72	10,752.24	11,047.77	11,343.29	11,638.82	11,934.34	12,229.87	12,525.39
Net emissions impact (Gas)		[t CO2e]	19.65	19.65	19.65	19.65	19.65	19.65	19.65	19.65	19.65	19.65	19.65	19.65	19.65	19.65	19.65	19.65	19.65	19.65	19.65	19.65
Net emissions impact (RE)		[t CO2e]	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28
		64,906.04	**-6,170.02**	**-5,744.54**	**-5,339.40**	**-4,955.13**	**-4,591.91**	**-4,249.65**	**-3,928.01**	**-3,626.51**	**-3,344.52**	**-3,081.33**	**-2,836.14**	**-2,608.13**	**-2,396.41**	**-2,200.12**	**-2,018.39**	**-1,850.34**	**-1,695.13**	**-1,551.94**	**-1,419.97**	**-1,298.47**
NPC Heating		**-110,155.98**	-11,578.96	-10,573.94	-9,651.37	-8,805.11	-8,029.39	-7,318.82	-6,668.34	-6,073.23	-5,529.10	-5,031.85	-4,577.68	-4,163.06	-3,784.75	-3,439.71	-3,125.16	-2,838.53	-2,577.44	-2,339.72	-2,123.35	-1,926.48
CAPEX_Non-Heating																						
Building																						
	Material	69,137.60	-3,456.88	-3,456.88	-3,456.88	-3,456.88	-3,456.88	-3,456.88	-3,456.88	-3,456.88	-3,456.88	-3,456.88	-3,456.88	-3,456.88	-3,456.88	-3,456.88	-3,456.88	-3,456.88	-3,456.88	-3,456.88	-3,456.88	-3,456.88
	Labour	69,801.60	-3,490.08	-3,490.08	-3,490.08	-3,490.08	-3,490.08	-3,490.08	-3,490.08	-3,490.08	-3,490.08	-3,490.08	-3,490.08	-3,490.08	-3,490.08	-3,490.08	-3,490.08	-3,490.08	-3,490.08	-3,490.08	-3,490.08	-3,490.08
	Total:	**138,939.19**	6,946.96	6,946.96	6,946.96	6,946.96	6,946.96	6,946.96	6,946.96	6,946.96	6,946.96	6,946.96	6,946.96	6,946.96	6,946.96	6,946.96	6,946.96	6,946.96	6,946.96	6,946.96	6,946.96	6,946.96
Aquaponics																						
	Aquaculture system	17,650.00	-882.50	-882.50	-882.50	-882.50	-882.50	-882.50	-882.50	-882.50	-882.50	-882.50	-882.50	-882.50	-882.50	-882.50	-882.50	-882.50	-882.50	-882.50	-882.50	-882.50
	NFT system 1: Horizontal	22,954.17	-1,147.71	-1,147.71	-1,147.71	-1,147.71	-1,147.71	-1,147.71	-1,147.71	-1,147.71	-1,147.71	-1,147.71	-1,147.71	-1,147.71	-1,147.71	-1,147.71	-1,147.71	-1,147.71	-1,147.71	-1,147.71	-1,147.71	-1,147.71
	NFT system 2: Vertical	45,641.67	-2,282.08	-2,282.08	-2,282.08	-2,282.08	-2,282.08	-2,282.08	-2,282.08	-2,282.08	-2,282.08	-2,282.08	-2,282.08	-2,282.08	-2,282.08	-2,282.08	-2,282.08	-2,282.08	-2,282.08	-2,282.08	-2,282.08	-2,282.08
	Growing lights	41,260.32	-2,063.02	-2,063.02	-2,063.02	-2,063.02	-2,063.02	-2,063.02	-2,063.02	-2,063.02	-2,063.02	-2,063.02	-2,063.02	-2,063.02	-2,063.02	-2,063.02	-2,063.02	-2,063.02	-2,063.02	-2,063.02	-2,063.02	-2,063.02
	Water	276.38	-13.82	-13.82	-13.82	-13.82	-13.82	-13.82	-13.82	-13.82	-13.82	-13.82	-13.82	-13.82	-13.82	-13.82	-13.82	-13.82	-13.82	-13.82	-13.82	-13.82
	Total:	**127,782.53**	6,389.13	6,389.13	6,389.13	6,389.13	6,389.13	6,389.13	6,389.13	6,389.13	6,389.13	6,389.13	6,389.13	6,389.13	6,389.13	6,389.13	6,389.13	6,389.13	6,389.13	6,389.13	6,389.13	6,389.13
Soil-based cultivation																						
	Growing beds	2,062.50	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13
	Soil	4,125.00	-206.25	-206.25	-206.25	-206.25	-206.25	-206.25	-206.25	-206.25	-206.25	-206.25	-206.25	-206.25	-206.25	-206.25	-206.25	-206.25	-206.25	-206.25	-206.25	-206.25
	Total:	**6,187.50**	309.38	309.38	309.38	309.38	309.38	309.38	309.38	309.38	309.38	309.38	309.38	309.38	309.38	309.38	309.38	309.38	309.38	309.38	309.38	309.38
		101,924.00	**-12,183.45**	**-10,878.08**	**-9,712.57**	**-8,671.94**	**-7,742.80**	**-6,913.22**	**-6,172.51**	**-5,511.17**	**-4,920.69**	**-4,393.47**	**-3,922.74**	**-3,502.45**	**-3,127.19**	**-2,792.13**	**-2,492.97**	**-2,225.87**	**-1,987.38**	**-1,774.45**	**-1,584.33**	**-1,414.58**
OPEX_Non-Heating																						
Electricity		Grow lights	-3,719.66	-3,890.96	-4,062.26	-4,233.56	-4,404.86	-4,576.16	-4,747.46	-4,918.76	-5,090.06	-5,261.36	-5,432.66	-5,603.96	-5,775.26	-5,946.56	-6,117.86	-6,289.16	-6,460.46	-6,631.76	-6,803.06	-6,974.36
		Pumps	-530.32	-554.74	-579.16	-603.59	-628.01	-652.43	-676.85	-701.28	-725.70	-750.12	-774.55	-798.97	-823.39	-847.81	-872.24	-896.66	-921.08	-945.50	-969.93	-994.35
Labor			-4,580.00	-4,580.00	-4,580.00	-4,580.00	-4,580.00	-4,580.00	-4,580.00	-4,580.00	-4,580.00	-4,580.00	-4,580.00	-4,580.00	-4,580.00	-4,580.00	-4,580.00	-4,580.00	-4,580.00	-4,580.00	-4,580.00	-4,580.00
Fish feed			-6,039.00	-6,039.00	-6,039.00	-6,039.00	-6,039.00	-6,039.00	-6,039.00	-6,039.00	-6,039.00	-6,039.00	-6,039.00	-6,039.00	-6,039.00	-6,039.00	-6,039.00	-6,039.00	-6,039.00	-6,039.00	-6,039.00	-6,039.00
Maintenance		Building	-1,661.38	-1,661.38	-1,661.38	-1,661.38	-1,661.38	-1,661.38	-1,661.38	-1,661.38	-1,661.38	-1,661.38	-1,661.38	-1,661.38	-1,661.38	-1,661.38	-1,661.38	-1,661.38	-1,661.38	-1,661.38	-1,661.38	-1,661.38
		Aquaponics	-2,600.00	-2,600.00	-2,600.00	-2,600.00	-2,600.00	-2,600.00	-2,600.00	-2,600.00	-2,600.00	-2,600.00	-2,600.00	-2,600.00	-2,600.00	-2,600.00	-2,600.00	-2,600.00	-2,600.00	-2,600.00	-2,600.00	-2,600.00
		151,694.31	**-17,080.68**	**-15,406.63**	**-13,895.23**	**-12,530.84**	**-11,299.31**	**-10,187.83**	**-9,184.81**	**-8,279.77**	**-7,463.24**	**-6,726.62**	**-6,062.18**	**-5,462.90**	**-4,922.44**	**-4,435.08**	**-3,995.65**	**-3,599.48**	**-3,242.32**	**-2,920.38**	**-2,630.21**	**-2,368.69**
NPC Total		**-363,774.29**	-40,843.08	-36,858.65	-33,259.17	-30,007.89	-27,071.50	-24,419.87	-22,025.67	-19,864.18	-17,913.02	-16,151.94	-14,562.60	-13,128.41	-11,834.38	-10,666.93	-9,613.79	-8,663.87	-7,807.15	-7,034.55	-6,337.89	-5,709.75
AG yield																						
Fish [CAD/kg]		8.8	4,400.00	4,400.00	4,400.00	4,400.00	4,400.00	4,400.00	4,400.00	4,400.00	4,400.00	4,400.00	4,400.00	4,400.00	4,400.00	4,400.00	4,400.00	4,400.00	4,400.00	4,400.00	4,400.00	4,400.00
Basil: NFT [CAD/kg]		7.5	29,700.00	29,700.00	29,700.00	29,700.00	29,700.00	29,700.00	29,700.00	29,700.00	29,700.00	29,700.00	29,700.00	29,700.00	29,700.00	29,700.00	29,700.00	29,700.00	29,700.00	29,700.00	29,700.00	29,700.00
Lettuce: Soil [CAD/kg]		5	9,900.00	9,900.00	9,900.00	9,900.00	9,900.00	9,900.00	9,900.00	9,900.00	9,900.00	9,900.00	9,900.00	9,900.00	9,900.00	9,900.00	9,900.00	9,900.00	9,900.00	9,900.00	9,900.00	9,900.00
Additional income																						
Carbon offsets (Gas)			1,234.32	1,402.64	1,570.96	1,739.27	1,907.59	1,930.03	1,952.47	1,974.92	1,997.36	2,019.80	2,042.24	2,064.68	2,087.13	2,109.57	2,132.01	2,154.45	2,176.90	2,199.34	2,221.78	2,244.22
Carbon offsets (RE)		Assumption	3,365.34	3,824.24	4,283.15	4,742.06	5,200.97	5,262.16	5,323.35	5,384.54	5,445.72	5,506.91	5,568.10	5,629.29	5,690.48	5,751.66	5,812.85	5,874.04	5,935.23	5,996.42	6,057.60	6,118.79
Savings of cooling			1,018.39	1,024.67	1,069.78	1,114.89	1,160.00	1,205.11	1,250.23	1,295.34	1,340.45	1,385.56	1,430.67	1,475.78	1,520.89	1,566.00	1,611.12	1,656.23	1,701.34	1,746.45	1,791.56	1,836.67
		365,236.65	**42,290.48**	**38,125.20**	**34,367.00**	**30,976.46**	**27,917.95**	**24,957.74**	**22,311.38**	**19,945.59**	**17,830.62**	**15,939.90**	**14,249.64**	**12,738.60**	**11,387.77**	**10,180.18**	**9,100.62**	**8,135.54**	**7,272.78**	**6,501.51**	**5,812.03**	**5,195.65**
NPV Total		**1,462.36**	1,447.40	1,266.54	1,107.82	968.58	846.45	537.88	285.71	81.40	-82.40	-212.04	-312.95	-389.81	-446.60	-486.75	-513.17	-528.34	-534.37	-533.04	-525.86	-514.10
		Cumulative	1,447.40	2,713.94	3,821.76	4,790.34	5,636.79	6,174.66	6,460.38	6,541.78	6,459.38	6,247.34	5,934.39	5,544.58	5,097.98	4,611.23	4,098.06	3,569.72	3,035.35	2,502.32	1,976.46	1,462.36

Discount rate 12 [%]

GSHP - CLOSED-LOOP HORIZONTAL

525 [m2] 11000 [l]

Lifespan		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Years		**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**	**2036**	**2037**	**2038**	**2039**	**2040**	**2041**	**2042**	**2043**	**2044**	**2045**
Electricity rates [CAD/kWh]		0.104	0.160	0.167	0.175	0.182	0.189	0.197	0.204	0.212	0.219	0.226	0.234	0.241	0.248	0.256	0.263	0.271	0.278	0.285	0.293	0.300
Carbon offset price [CAD/t]		95	110	125	140	155	170	172	174	176	178	180	182	184	186	188	190	192	194	196	198	200
CAPEX_Heating																						
Hydronic radiant heating		22,102.48	-1,105.12	-1,105.12	-1,105.12	-1,105.12	-1,105.12	-1,105.12	-1,105.12	-1,105.12	-1,105.12	-1,105.12	-1,105.12	-1,105.12	-1,105.12	-1,105.12	-1,105.12	-1,105.12	-1,105.12	-1,105.12	-1,105.12	-1,105.12
Ground loop installation		49,500.09	-2,475.00	-2,475.00	-2,475.00	-2,475.00	-2,475.00	-2,475.00	-2,475.00	-2,475.00	-2,475.00	-2,475.00	-2,475.00	-2,475.00	-2,475.00	-2,475.00	-2,475.00	-2,475.00	-2,475.00	-2,475.00	-2,475.00	-2,475.00
Heat pump		55,505.00	-2,775.25	-2,775.25	-2,775.25	-2,775.25	-2,775.25	-2,775.25	-2,775.25	-2,775.25	-2,775.25	-2,775.25	-2,775.25	-2,775.25	-2,775.25	-2,775.25	-2,775.25	-2,775.25	-2,775.25	-2,775.25	-2,775.25	-2,775.25
Total:		**127,107.57**	6,355.38	6,355.38	6,355.38	6,355.38	6,355.38	6,355.38	6,355.38	6,355.38	6,355.38	6,355.38	6,355.38	6,355.38	6,355.38	6,355.38	6,355.38	6,355.38	6,355.38	6,355.38	6,355.38	6,355.38
		47,471.14	**-5,674.45**	**-5,066.47**	**-4,523.63**	**-4,038.96**	**-3,606.21**	**-3,219.83**	**-2,874.85**	**-2,566.83**	**-2,291.81**	**-2,046.26**	**-1,827.02**	**-1,631.27**	**-1,456.49**	**-1,300.44**	**-1,161.10**	**-1,036.70**	**-925.62**	**-826.45**	**-737.90**	**-658.84**
OPEX_Heating																						
CoE			-6,963.72	-7,284.42	-7,605.12	-7,925.81	-8,246.51	-8,567.21	-8,887.91	-9,208.61	-9,529.30	-9,850.00	-10,170.70	-10,491.40	-10,812.09	-11,132.79	-11,453.49	-11,774.19	-12,094.88	-12,415.58	-12,736.28	-13,056.98
Maintenance			-535.34	-535.34	-535.34	-535.34	-535.34	-535.34	-535.34	-535.34	-535.34	-535.34	-535.34	-535.34	-535.34	-535.34	-535.34	-535.34	-535.34	-535.34	-535.34	-535.34
Total:			7,499.06	7,819.76	8,140.45	8,461.15	8,781.85	9,102.55	9,423.24	9,743.94	10,064.64	10,385.34	10,706.03	11,026.73	11,347.43	11,668.13	11,988.83	12,309.52	12,630.22	12,950.92	13,271.62	13,592.31
Net emissions impact (Gas)	[t CO2e]		21.33	21.33	21.33	21.33	21.33	21.33	21.33	21.33	21.33	21.33	21.33	21.33	21.33	21.33	21.33	21.33	21.33	21.33	21.33	21.33
Net emissions impact (RE)	[t CO2e]		0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
		70,434.79	**-6,695.59**	**-6,233.86**	**-5,794.21**	**-5,377.21**	**-4,983.06**	**-4,611.63**	**-4,262.60**	**-3,935.41**	**-3,629.41**	**-3,343.80**	**-3,077.73**	**-2,830.29**	**-2,600.54**	**-2,387.53**	**-2,190.31**	**-2,007.95**	**-1,839.52**	**-1,684.13**	**-1,540.92**	**-1,409.07**
NPC Heating		**-117,905.93**	-12,370.03	-11,300.33	-10,317.85	-9,416.17	-8,589.27	-7,831.47	-7,137.45	-6,502.25	-5,921.22	-5,390.06	-4,904.75	-4,461.56	-4,057.03	-3,687.97	-3,351.42	-3,044.65	-2,765.15	-2,510.58	-2,278.83	-2,067.91
CAPEX_Non-Heating																						
Building																						
Material		70,527.84	-3,526.39	-3,526.39	-3,526.39	-3,526.39	-3,526.39	-3,526.39	-3,526.39	-3,526.39	-3,526.39	-3,526.39	-3,526.39	-3,526.39	-3,526.39	-3,526.39	-3,526.39	-3,526.39	-3,526.39	-3,526.39	-3,526.39	-3,526.39
Labour		76,036.14	-3,801.81	-3,801.81	-3,801.81	-3,801.81	-3,801.81	-3,801.81	-3,801.81	-3,801.81	-3,801.81	-3,801.81	-3,801.81	-3,801.81	-3,801.81	-3,801.81	-3,801.81	-3,801.81	-3,801.81	-3,801.81	-3,801.81	-3,801.81
Total:		**146,563.98**	7,328.20	7,328.20	7,328.20	7,328.20	7,328.20	7,328.20	7,328.20	7,328.20	7,328.20	7,328.20	7,328.20	7,328.20	7,328.20	7,328.20	7,328.20	7,328.20	7,328.20	7,328.20	7,328.20	7,328.20
Aquaponics																						
Aquaculture system		19,415.00	-970.75	-970.75	-970.75	-970.75	-970.75	-970.75	-970.75	-970.75	-970.75	-970.75	-970.75	-970.75	-970.75	-970.75	-970.75	-970.75	-970.75	-970.75	-970.75	-970.75
NFT system 1: Horizontal		25,249.58	-1,262.48	-1,262.48	-1,262.48	-1,262.48	-1,262.48	-1,262.48	-1,262.48	-1,262.48	-1,262.48	-1,262.48	-1,262.48	-1,262.48	-1,262.48	-1,262.48	-1,262.48	-1,262.48	-1,262.48	-1,262.48	-1,262.48	-1,262.48
NFT system 2: Vertical		50,205.83	-2,510.29	-2,510.29	-2,510.29	-2,510.29	-2,510.29	-2,510.29	-2,510.29	-2,510.29	-2,510.29	-2,510.29	-2,510.29	-2,510.29	-2,510.29	-2,510.29	-2,510.29	-2,510.29	-2,510.29	-2,510.29	-2,510.29	-2,510.29
Growing lights		45,386.35	-2,269.32	-2,269.32	-2,269.32	-2,269.32	-2,269.32	-2,269.32	-2,269.32	-2,269.32	-2,269.32	-2,269.32	-2,269.32	-2,269.32	-2,269.32	-2,269.32	-2,269.32	-2,269.32	-2,269.32	-2,269.32	-2,269.32	-2,269.32
Water		304.02	-15.20	-15.20	-15.20	-15.20	-15.20	-15.20	-15.20	-15.20	-15.20	-15.20	-15.20	-15.20	-15.20	-15.20	-15.20	-15.20	-15.20	-15.20	-15.20	-15.20
Total:		**140,560.78**	7,028.04	7,028.04	7,028.04	7,028.04	7,028.04	7,028.04	7,028.04	7,028.04	7,028.04	7,028.04	7,028.04	7,028.04	7,028.04	7,028.04	7,028.04	7,028.04	7,028.04	7,028.04	7,028.04	7,028.04
Soil-based cultivation																						
Growing beds		2,268.75	-113.44	-113.44	-113.44	-113.44	-113.44	-113.44	-113.44	-113.44	-113.44	-113.44	-113.44	-113.44	-113.44	-113.44	-113.44	-113.44	-113.44	-113.44	-113.44	-113.44
Soil		4,537.50	-226.88	-226.88	-226.88	-226.88	-226.88	-226.88	-226.88	-226.88	-226.88	-226.88	-226.88	-226.88	-226.88	-226.88	-226.88	-226.88	-226.88	-226.88	-226.88	-226.88
Total:		**6,806.25**	340.31	340.31	340.31	340.31	340.31	340.31	340.31	340.31	340.31	340.31	340.31	340.31	340.31	340.31	340.31	340.31	340.31	340.31	340.31	340.31
		109,775.06	**-13,121.92**	**-11,716.00**	**-10,460.71**	**-9,339.92**	**-8,339.22**	**-7,445.73**	**-6,647.97**	**-5,935.69**	**-5,299.72**	**-4,731.90**	**-4,224.91**	**-3,772.24**	**-3,368.07**	**-3,007.21**	**-2,685.00**	**-2,397.33**	**-2,140.47**	**-1,911.13**	**-1,706.37**	**-1,523.54**
OPEX_Non-Heating																						
Electricity	Grow lights		-4,091.63	-4,280.06	-4,468.49	-4,656.92	-4,845.35	-5,033.78	-5,222.21	-5,410.64	-5,599.07	-5,787.50	-5,975.93	-6,164.36	-6,352.79	-6,541.22	-6,729.65	-6,918.08	-7,106.51	-7,294.94	-7,483.37	-7,671.80
	Pumps		-583.35	-610.22	-637.08	-663.95	-690.81	-717.68	-744.54	-771.41	-798.27	-825.14	-852.00	-878.86	-905.73	-932.59	-959.46	-986.32	-1,013.19	-1,040.05	-1,066.92	-1,093.78
Labor			-5,038.00	-5,038.00	-5,038.00	-5,038.00	-5,038.00	-5,038.00	-5,038.00	-5,038.00	-5,038.00	-5,038.00	-5,038.00	-5,038.00	-5,038.00	-5,038.00	-5,038.00	-5,038.00	-5,038.00	-5,038.00	-5,038.00	-5,038.00
Fish feed			-6,642.90	-6,642.90	-6,642.90	-6,642.90	-6,642.90	-6,642.90	-6,642.90	-6,642.90	-6,642.90	-6,642.90	-6,642.90	-6,642.90	-6,642.90	-6,642.90	-6,642.90	-6,642.90	-6,642.90	-6,642.90	-6,642.90	-6,642.90
Maintenance	Building		-1,814.21	-1,814.21	-1,814.21	-1,814.21	-1,814.21	-1,814.21	-1,814.21	-1,814.21	-1,814.21	-1,814.21	-1,814.21	-1,814.21	-1,814.21	-1,814.21	-1,814.21	-1,814.21	-1,814.21	-1,814.21	-1,814.21	-1,814.21
	Aquaponics		-2,860.00	-2,860.00	-2,860.00	-2,860.00	-2,860.00	-2,860.00	-2,860.00	-2,860.00	-2,860.00	-2,860.00	-2,860.00	-2,860.00	-2,860.00	-2,860.00	-2,860.00	-2,860.00	-2,860.00	-2,860.00	-2,860.00	-2,860.00
		166,764.38	**-18,776.87**	**-16,936.69**	**-15,275.29**	**-13,775.48**	**-12,421.70**	**-11,199.87**	**-10,097.28**	**-9,102.38**	**-8,204.76**	**-7,395.00**	**-6,664.57**	**-6,005.77**	**-5,411.64**	**-4,875.87**	**-4,392.79**	**-3,957.25**	**-3,564.62**	**-3,210.69**	**-2,891.69**	**-2,604.18**
NPC Total		**-394,445.37**	-44,268.82	-39,953.02	-36,053.85	-32,531.57	-29,350.18	-26,477.07	-23,882.70	-21,540.32	-19,425.71	-17,516.96	-15,794.23	-14,239.56	-12,836.73	-11,571.04	-10,429.21	-9,399.23	-8,470.23	-7,632.41	-6,876.88	-6,195.64
AG yield																						
Fish [CAD/kg]		8.8	4,840.00	4,840.00	4,840.00	4,840.00	4,840.00	4,840.00	4,840.00	4,840.00	4,840.00	4,840.00	4,840.00	4,840.00	4,840.00	4,840.00	4,840.00	4,840.00	4,840.00	4,840.00	4,840.00	4,840.00
Basil: NFT [CAD/kg]		7.5	32,670.00	32,670.00	32,670.00	32,670.00	32,670.00	32,670.00	32,670.00	32,670.00	32,670.00	32,670.00	32,670.00	32,670.00	32,670.00	32,670.00	32,670.00	32,670.00	32,670.00	32,670.00	32,670.00	32,670.00
Lettuce: Soil [CAD/kg]		5	10,890.00	10,890.00	10,890.00	10,890.00	10,890.00	10,890.00	10,890.00	10,890.00	10,890.00	10,890.00	10,890.00	10,890.00	10,890.00	10,890.00	10,890.00	10,890.00	10,890.00	10,890.00	10,890.00	10,890.00
Additional income																						
Carbon offsets (Gas)			1,339.46	1,522.12	1,704.77	1,887.42	2,070.08	2,094.43	2,118.79	2,143.14	2,167.49	2,191.85	2,216.20	2,240.56	2,264.91	2,289.26	2,313.62	2,337.97	2,362.33	2,386.68	2,411.03	2,435.39
Carbon offsets (RE)	Assumption		3,652.00	4,150.00	4,648.00	5,146.00	5,644.00	5,710.40	5,776.80	5,843.20	5,909.60	5,976.00	6,042.40	6,108.80	6,175.20	6,241.60	6,308.00	6,374.40	6,440.79	6,507.19	6,573.59	6,639.99
Savings of cooling			1,147.96	1,156.88	1,207.81	1,258.74	1,309.68	1,360.61	1,411.54	1,462.47	1,513.40	1,564.34	1,615.27	1,666.20	1,717.13	1,768.06	1,819.00	1,869.93	1,920.86	1,971.79	2,022.72	2,073.65
		401,218.21	**46,475.00**	**41,892.54**	**37,758.52**	**34,029.45**	**30,666.01**	**27,414.01**	**24,506.83**	**21,907.92**	**19,584.58**	**17,507.62**	**15,650.89**	**13,991.05**	**12,507.23**	**11,180.75**	**9,994.95**	**8,934.89**	**7,987.25**	**7,140.11**	**6,382.81**	**5,705.82**
NPV Total		**6,772.84**	2,206.18	1,939.51	1,704.67	1,497.88	1,315.83	936.94	624.13	367.60	158.88	-9.34	-143.34	-248.51	-329.51	-390.29	-434.27	-464.34	-482.98	-492.30	-494.08	-489.82
	Cumulative		2,206.18	4,145.69	5,850.36	7,348.23	8,664.06	9,601.00	10,225.14	10,592.74	10,751.61	10,742.27	10,598.93	10,350.42	10,020.91	9,630.62	9,196.36	8,732.02	8,249.04	7,756.74	7,262.66	6,772.84

C.1.5. Hybrid-1BN

Increasing greenhouse size per page.

Discount rate 12 [%]

Hybrid 1: Biodigester & Natural gas

260 [m2] 5000 [l]

Lifespan	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Years	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**	**2036**	**2037**	**2038**	**2039**	**2040**	**2041**	**2042**	**2043**	**2044**	**2045**
Gas price [CAD/kWh]	0.013	0.014	0.015	0.015	0.016	0.016	0.017	0.017	0.018	0.019	0.019	0.020	0.020	0.021	0.022	0.022	0.023	0.023	0.024	0.024	0.025
Carbon offset price [CAD/t]	95	110	125	140	155	170	172	174	176	178	180	182	184	186	188	190	192	194	196	198	200
CAPEX_Heating																					
Hydronic radiant heating	10,930.51	-546.53	-546.53	-546.53	-546.53	-546.53	-546.53	-546.53	-546.53	-546.53	-546.53	-546.53	-546.53	-546.53	-546.53	-546.53	-546.53	-546.53	-546.53	-546.53	-546.53
Biogas boiler (incl. burner)	19,690.00	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50
Buffer tank	1,420.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00
Biodigester	7,000.00	-350.00	-350.00	-350.00	-350.00	-350.00	-350.00	-350.00	-350.00	-350.00	-350.00	-350.00	-350.00	-350.00	-350.00	-350.00	-350.00	-350.00	-350.00	-350.00	-350.00
Grid access	3,000.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00
Total:	**42,040.51**	2,102.03	2,102.03	2,102.03	2,102.03	2,102.03	2,102.03	2,102.03	2,102.03	2,102.03	2,102.03	2,102.03	2,102.03	2,102.03	2,102.03	2,102.03	2,102.03	2,102.03	2,102.03	2,102.03	2,102.03
	15,700.96	**-1,876.81**	**-1,675.72**	**-1,496.18**	**-1,335.88**	**-1,192.75**	**-1,064.95**	**-950.85**	**-848.97**	**-758.01**	**-676.80**	**-604.28**	**-539.54**	**-481.73**	**-430.12**	**-384.03**	**-342.89**	**-306.15**	**-273.35**	**-244.06**	**-217.91**
OPEX_Heating																					
Fuel (Natural gas)		-850.23	-885.70	-921.17	-956.64	-992.11	-1,027.58	-1,063.05	-1,098.52	-1,134.00	-1,169.47	-1,204.94	-1,240.41	-1,275.88	-1,311.35	-1,346.82	-1,382.29	-1,417.76	-1,453.23	-1,488.70	-1,524.17
Water [CAD/m3]	10.93	-552.07	-552.07	-552.07	-552.07	-552.07	-552.07	-552.07	-552.07	-552.07	-552.07	-552.07	-552.07	-552.07	-552.07	-552.07	-552.07	-552.07	-552.07	-552.07	-552.07
Maintenance		-534.26	-534.26	-534.26	-534.26	-534.26	-534.26	-534.26	-534.26	-534.26	-534.26	-534.26	-534.26	-534.26	-534.26	-534.26	-534.26	-534.26	-534.26	-534.26	-534.26
Cooling		-328.75	-327.51	-341.93	-356.35	-370.77	-385.19	-399.60	-414.02	-428.44	-442.86	-457.28	-471.70	-486.12	-500.54	-514.95	-529.37	-543.79	-558.21	-572.63	-587.05
Transport		-1,262.75	-1,262.75	-1,262.75	-1,262.75	-1,262.75	-1,262.75	-1,262.75	-1,262.75	-1,262.75	-1,262.75	-1,262.75	-1,262.75	-1,262.75	-1,262.75	-1,262.75	-1,262.75	-1,262.75	-1,262.75	-1,262.75	-1,262.75
Labour		-841.83	-841.83	-841.83	-841.83	-841.83	-841.83	-841.83	-841.83	-841.83	-841.83	-841.83	-841.83	-841.83	-841.83	-841.83	-841.83	-841.83	-841.83	-841.83	-841.83
	Total:	4,369.90	4,404.13	4,454.02	4,503.91	4,553.80	4,603.69	4,653.57	4,703.46	4,753.35	4,803.24	4,853.13	4,903.02	4,952.91	5,002.80	5,052.69	5,102.58	5,152.46	5,202.35	5,252.24	5,302.13
Net emissions impact	[t CO2e]	11.49	11.49	11.49	11.49	11.49	11.49	11.49	11.49	11.49	11.49	11.49	11.49	11.49	11.49	11.49	11.49	11.49	11.49	11.49	11.49
	34,781.12	**-3,901.70**	**-3,510.95**	**-3,170.28**	**-2,862.31**	**-2,583.95**	**-2,332.37**	**-2,105.04**	**-1,899.65**	**-1,714.11**	**-1,546.52**	**-1,395.16**	**-1,258.48**	**-1,135.08**	**-1,023.67**	**-923.11**	**-832.34**	**-750.43**	**-676.51**	**-609.82**	**-549.65**
NPC Heating	**-50,482.08**	-5,778.50	-5,186.67	-4,666.46	-4,198.19	-3,776.69	-3,397.32	-3,055.89	-2,748.62	-2,472.12	-2,223.31	-1,999.44	-1,798.02	-1,616.81	-1,453.79	-1,307.14	-1,175.23	-1,056.58	-949.86	-853.88	-767.57
CAPEX_Non-Heating																					
Building																					
Material	42,069.34	-2,103.47	-2,103.47	-2,103.47	-2,103.47	-2,103.47	-2,103.47	-2,103.47	-2,103.47	-2,103.47	-2,103.47	-2,103.47	-2,103.47	-2,103.47	-2,103.47	-2,103.47	-2,103.47	-2,103.47	-2,103.47	-2,103.47	-2,103.47
Labour	37,362.98	-1,868.15	-1,868.15	-1,868.15	-1,868.15	-1,868.15	-1,868.15	-1,868.15	-1,868.15	-1,868.15	-1,868.15	-1,868.15	-1,868.15	-1,868.15	-1,868.15	-1,868.15	-1,868.15	-1,868.15	-1,868.15	-1,868.15	-1,868.15
Total:	**79,432.33**	3,971.62	3,971.62	3,971.62	3,971.62	3,971.62	3,971.62	3,971.62	3,971.62	3,971.62	3,971.62	3,971.62	3,971.62	3,971.62	3,971.62	3,971.62	3,971.62	3,971.62	3,971.62	3,971.62	3,971.62
Aquaponics																					
Aquaculture system	8,825.00	-441.25	-441.25	-441.25	-441.25	-441.25	-441.25	-441.25	-441.25	-441.25	-441.25	-441.25	-441.25	-441.25	-441.25	-441.25	-441.25	-441.25	-441.25	-441.25	-441.25
NFT system 1: Horizontal	11,477.08	-573.85	-573.85	-573.85	-573.85	-573.85	-573.85	-573.85	-573.85	-573.85	-573.85	-573.85	-573.85	-573.85	-573.85	-573.85	-573.85	-573.85	-573.85	-573.85	-573.85
NFT system 2: Vertical	22,820.83	-1,141.04	-1,141.04	-1,141.04	-1,141.04	-1,141.04	-1,141.04	-1,141.04	-1,141.04	-1,141.04	-1,141.04	-1,141.04	-1,141.04	-1,141.04	-1,141.04	-1,141.04	-1,141.04	-1,141.04	-1,141.04	-1,141.04	-1,141.04
Growing lights	20,630.16	-1,031.51	-1,031.51	-1,031.51	-1,031.51	-1,031.51	-1,031.51	-1,031.51	-1,031.51	-1,031.51	-1,031.51	-1,031.51	-1,031.51	-1,031.51	-1,031.51	-1,031.51	-1,031.51	-1,031.51	-1,031.51	-1,031.51	-1,031.51
Water	138.19	-6.91	-6.91	-6.91	-6.91	-6.91	-6.91	-6.91	-6.91	-6.91	-6.91	-6.91	-6.91	-6.91	-6.91	-6.91	-6.91	-6.91	-6.91	-6.91	-6.91
Total:	**63,891.27**	3,194.56	3,194.56	3,194.56	3,194.56	3,194.56	3,194.56	3,194.56	3,194.56	3,194.56	3,194.56	3,194.56	3,194.56	3,194.56	3,194.56	3,194.56	3,194.56	3,194.56	3,194.56	3,194.56	3,194.56
Soil-based cultivation																					
Growing beds	1,031.25	-51.56	-51.56	-51.56	-51.56	-51.56	-51.56	-51.56	-51.56	-51.56	-51.56	-51.56	-51.56	-51.56	-51.56	-51.56	-51.56	-51.56	-51.56	-51.56	-51.56
Soil	2,062.50	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13
Total:	**3,093.75**	154.69	154.69	154.69	154.69	154.69	154.69	154.69	154.69	154.69	154.69	154.69	154.69	154.69	154.69	154.69	154.69	154.69	154.69	154.69	154.69
	54,682.80	-6,536.49	-5,836.15	-5,210.85	-4,652.54	-4,154.06	-3,708.98	-3,311.59	-2,956.78	-2,639.98	-2,357.12	-2,104.57	-1,879.08	-1,677.75	-1,497.99	-1,337.50	-1,194.19	-1,066.24	-952.00	-850.00	-758.93
OPEX_Non-Heating																					
Electricity	Grow lights	-1,859.83	-1,945.48	-2,031.13	-2,116.78	-2,202.43	-2,288.08	-2,373.73	-2,459.38	-2,545.03	-2,630.68	-2,716.33	-2,801.98	-2,887.63	-2,973.28	-3,058.93	-3,144.58	-3,230.23	-3,315.88	-3,401.53	-3,487.18
	Pumps	-265.16	-277.37	-289.58	-301.79	-314.00	-326.22	-338.43	-350.64	-362.85	-375.06	-387.27	-399.48	-411.70	-423.91	-436.12	-448.33	-460.54	-472.75	-484.96	-497.17
Labor		-2,290.00	-2,290.00	-2,290.00	-2,290.00	-2,290.00	-2,290.00	-2,290.00	-2,290.00	-2,290.00	-2,290.00	-2,290.00	-2,290.00	-2,290.00	-2,290.00	-2,290.00	-2,290.00	-2,290.00	-2,290.00	-2,290.00	-2,290.00
Fish feed		-3,019.50	-3,019.50	-3,019.50	-3,019.50	-3,019.50	-3,019.50	-3,019.50	-3,019.50	-3,019.50	-3,019.50	-3,019.50	-3,019.50	-3,019.50	-3,019.50	-3,019.50	-3,019.50	-3,019.50	-3,019.50	-3,019.50	-3,019.50
Maintenance	Building	-897.20	-897.20	-897.20	-897.20	-897.20	-897.20	-897.20	-897.20	-897.20	-897.20	-897.20	-897.20	-897.20	-897.20	-897.20	-897.20	-897.20	-897.20	-897.20	-897.20
	Aquaponics	-1,300.00	-1,300.00	-1,300.00	-1,300.00	-1,300.00	-1,300.00	-1,300.00	-1,300.00	-1,300.00	-1,300.00	-1,300.00	-1,300.00	-1,300.00	-1,300.00	-1,300.00	-1,300.00	-1,300.00	-1,300.00	-1,300.00	-1,300.00
	76,343.93	**-8,599.72**	**-7,756.34**	**-6,994.96**	**-6,307.69**	**-5,687.39**	**-5,127.61**	**-4,622.49**	**-4,166.75**	**-3,755.60**	**-3,384.72**	**-3,050.21**	**-2,748.52**	**-2,476.46**	**-2,231.15**	**-2,009.98**	**-1,810.59**	**-1,630.85**	**-1,468.84**	**-1,322.83**	**-1,191.24**
NPC Total	**-181,508.82**	-20,914.71	-18,779.15	-16,872.27	-15,158.42	-13,618.14	-12,233.91	-10,989.97	-9,872.15	-8,867.70	-7,965.16	-7,154.22	-6,425.62	-5,771.02	-5,182.93	-4,654.61	-4,180.00	-3,753.67	-3,370.70	-3,026.71	-2,717.74
AG yield																					
Fish [CAD/kg]	8.8	2,200.00	2,200.00	2,200.00	2,200.00	2,200.00	2,200.00	2,200.00	2,200.00	2,200.00	2,200.00	2,200.00	2,200.00	2,200.00	2,200.00	2,200.00	2,200.00	2,200.00	2,200.00	2,200.00	2,200.00
Basil: NFT [CAD/kg]	7.5	14,850.00	14,850.00	14,850.00	14,850.00	14,850.00	14,850.00	14,850.00	14,850.00	14,850.00	14,850.00	14,850.00	14,850.00	14,850.00	14,850.00	14,850.00	14,850.00	14,850.00	14,850.00	14,850.00	14,850.00
Lettuce: Soil [CAD/kg]	5	4,950.00	4,950.00	4,950.00	4,950.00	4,950.00	4,950.00	4,950.00	4,950.00	4,950.00	4,950.00	4,950.00	4,950.00	4,950.00	4,950.00	4,950.00	4,950.00	4,950.00	4,950.00	4,950.00	4,950.00
Additional income																					
Carbon offsets (Renewables)		730.64	830.27	929.90	1,029.54	1,129.17	1,142.45	1,155.74	1,169.02	1,182.31	1,195.59	1,208.87	1,222.16	1,235.44	1,248.73	1,262.01	1,275.30	1,288.58	1,301.86	1,315.15	1,328.43
Farm waste [CAD/t]	50	1,262.75	1,262.75	1,262.75	1,262.75	1,262.75	1,262.75	1,262.75	1,262.75	1,262.75	1,262.75	1,262.75	1,262.75	1,262.75	1,262.75	1,262.75	1,262.75	1,262.75	1,262.75	1,262.75	1,262.75
AG waste [CAD/t]	50	89.93	89.93	89.93	89.93	89.93	89.93	89.93	89.93	89.93	89.93	89.93	89.93	89.93	89.93	89.93	89.93	89.93	89.93	89.93	89.93
	182,373.51	**21,502.96**	**19,278.50**	**17,283.86**	**15,495.34**	**13,891.65**	**12,409.99**	**11,086.36**	**9,903.90**	**8,847.56**	**7,903.88**	**7,060.86**	**6,307.75**	**5,634.96**	**5,033.93**	**4,497.01**	**4,017.36**	**3,588.86**	**3,206.07**	**2,864.10**	**2,558.61**
NPV Total	**864.69**	588.24	499.34	411.59	336.91	273.51	176.08	96.39	31.75	-20.14	-61.27	-93.37	-117.88	-136.06	-149.00	-157.60	-162.65	-164.81	-164.64	-162.61	-159.13
	Cumulative	3,560.55	6,698.16	9,462.59	11,897.78	14,042.55	15,801.82	17,233.58	18,387.80	19,307.53	20,029.77	20,586.27	21,004.27	21,307.04	21,514.49	21,643.56	21,708.67	21,722.05	21,694.02	21,633.32	21,547.26

Discount rate 12 [%]

Hybrid 1: Biodigester & Natural gas

304 [m2] 6000 [l]

		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Lifespan		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Years		**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**	**2036**	**2037**	**2038**	**2039**	**2040**	**2041**	**2042**	**2043**	**2044**	**2045**
Gas price [CAD/kWh]		0.013	0.014	0.015	0.015	0.016	0.016	0.017	0.017	0.018	0.019	0.019	0.020	0.020	0.021	0.022	0.022	0.023	0.023	0.024	0.024	0.025
Carbon offset price [CAD/t]		95	110	125	140	155	170	172	174	176	178	180	182	184	186	188	190	192	194	196	198	200
CAPEX_Heating																						
Hydronic radiant heating		12,792.51	-639.63	-639.63	-639.63	-639.63	-639.63	-639.63	-639.63	-639.63	-639.63	-639.63	-639.63	-639.63	-639.63	-639.63	-639.63	-639.63	-639.63	-639.63	-639.63	-639.63
Biogas boiler (incl. burner)		19,690.00	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50
Buffer tank		1,420.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00
Biodigester		14,000.00	-700.00	-700.00	-700.00	-700.00	-700.00	-700.00	-700.00	-700.00	-700.00	-700.00	-700.00	-700.00	-700.00	-700.00	-700.00	-700.00	-700.00	-700.00	-700.00	-700.00
Grid access		3,000.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00
	Total:	**50,902.51**	2,545.13	2,545.13	2,545.13	2,545.13	2,545.13	2,545.13	2,545.13	2,545.13	2,545.13	2,545.13	2,545.13	2,545.13	2,545.13	2,545.13	2,545.13	2,545.13	2,545.13	2,545.13	2,545.13	2,545.13
		19,010.67	**-2,272.43**	**-2,028.96**	**-1,811.57**	**-1,617.47**	**-1,444.17**	**-1,289.44**	**-1,151.29**	**-1,027.93**	**-917.80**	**-819.46**	**-731.66**	**-653.27**	**-583.28**	**-520.78**	**-464.98**	**-415.17**	**-370.68**	**-330.97**	**-295.51**	**-263.84**
OPEX_Heating																						
Fuel (Natural gas)			-322.54	-336.00	-349.45	-362.91	-376.37	-389.82	-403.28	-416.73	-430.19	-443.65	-457.10	-470.56	-484.01	-497.47	-510.93	-524.38	-537.84	-551.29	-564.75	-578.21
Water [CAD/m3]		10.93	-1,256.60	-1,256.60	-1,256.60	-1,256.60	-1,256.60	-1,256.60	-1,256.60	-1,256.60	-1,256.60	-1,256.60	-1,256.60	-1,256.60	-1,256.60	-1,256.60	-1,256.60	-1,256.60	-1,256.60	-1,256.60	-1,256.60	-1,256.60
Maintenance			-1,007.84	-1,007.84	-1,007.84	-1,007.84	-1,007.84	-1,007.84	-1,007.84	-1,007.84	-1,007.84	-1,007.84	-1,007.84	-1,007.84	-1,007.84	-1,007.84	-1,007.84	-1,007.84	-1,007.84	-1,007.84	-1,007.84	-1,007.84
Cooling			-434.95	-432.79	-451.84	-470.90	-489.95	-509.01	-528.06	-547.11	-566.17	-585.22	-604.27	-623.33	-642.38	-661.43	-680.49	-699.54	-718.60	-737.65	-756.70	-775.76
Transport			-2,874.20	-2,874.20	-2,874.20	-2,874.20	-2,874.20	-2,874.20	-2,874.20	-2,874.20	-2,874.20	-2,874.20	-2,874.20	-2,874.20	-2,874.20	-2,874.20	-2,874.20	-2,874.20	-2,874.20	-2,874.20	-2,874.20	-2,874.20
Labour			-1,916.14	-1,916.14	-1,916.14	-1,916.14	-1,916.14	-1,916.14	-1,916.14	-1,916.14	-1,916.14	-1,916.14	-1,916.14	-1,916.14	-1,916.14	-1,916.14	-1,916.14	-1,916.14	-1,916.14	-1,916.14	-1,916.14	-1,916.14
		Total:	7,812.27	7,823.56	7,856.07	7,888.58	7,921.09	7,953.60	7,986.11	8,018.62	8,051.13	8,083.64	8,116.15	8,148.66	8,181.17	8,213.68	8,246.19	8,278.70	8,311.21	8,343.72	8,376.23	8,408.74
Net emissions impact		[t CO2e]	5.52	5.52	5.52	5.52	5.52	5.52	5.52	5.52	5.52	5.52	5.52	5.52	5.52	5.52	5.52	5.52	5.52	5.52	5.52	5.52
		59,675.66	**-6,975.24**	**-6,236.90**	**-5,591.80**	**-5,013.34**	**-4,494.64**	**-4,029.54**	**-3,612.51**	**-3,238.59**	**-2,903.32**	**-2,602.72**	**-2,333.20**	**-2,091.56**	**-1,874.91**	**-1,680.68**	**-1,506.55**	**-1,350.43**	**-1,210.48**	**-1,085.01**	**-972.54**	**-871.71**
NPC Heating		**-78,686.33**	-9,247.68	-8,265.85	-7,403.37	-6,630.81	-5,938.81	-5,318.98	-4,763.80	-4,266.52	-3,821.12	-3,422.18	-3,064.86	-2,744.83	-2,458.19	-2,201.46	-1,971.53	-1,765.60	-1,581.16	-1,415.98	-1,268.04	-1,135.55
CAPEX_Non-Heating																						
Building																						
	Material	48,687.79	-2,434.39	-2,434.39	-2,434.39	-2,434.39	-2,434.39	-2,434.39	-2,434.39	-2,434.39	-2,434.39	-2,434.39	-2,434.39	-2,434.39	-2,434.39	-2,434.39	-2,434.39	-2,434.39	-2,434.39	-2,434.39	-2,434.39	-2,434.39
	Labour	43,396.53	-2,169.83	-2,169.83	-2,169.83	-2,169.83	-2,169.83	-2,169.83	-2,169.83	-2,169.83	-2,169.83	-2,169.83	-2,169.83	-2,169.83	-2,169.83	-2,169.83	-2,169.83	-2,169.83	-2,169.83	-2,169.83	-2,169.83	-2,169.83
	Total:	**92,084.32**	4,604.22	4,604.22	4,604.22	4,604.22	4,604.22	4,604.22	4,604.22	4,604.22	4,604.22	4,604.22	4,604.22	4,604.22	4,604.22	4,604.22	4,604.22	4,604.22	4,604.22	4,604.22	4,604.22	4,604.22
Aquaponics																						
	Aquaculture system	10,590.00	-529.50	-529.50	-529.50	-529.50	-529.50	-529.50	-529.50	-529.50	-529.50	-529.50	-529.50	-529.50	-529.50	-529.50	-529.50	-529.50	-529.50	-529.50	-529.50	-529.50
	NFT system 1: Horizontal	13,772.50	-688.63	-688.63	-688.63	-688.63	-688.63	-688.63	-688.63	-688.63	-688.63	-688.63	-688.63	-688.63	-688.63	-688.63	-688.63	-688.63	-688.63	-688.63	-688.63	-688.63
	NFT system 2: Vertical	27,385.00	-1,369.25	-1,369.25	-1,369.25	-1,369.25	-1,369.25	-1,369.25	-1,369.25	-1,369.25	-1,369.25	-1,369.25	-1,369.25	-1,369.25	-1,369.25	-1,369.25	-1,369.25	-1,369.25	-1,369.25	-1,369.25	-1,369.25	-1,369.25
	Growing lights	24,756.19	-1,237.81	-1,237.81	-1,237.81	-1,237.81	-1,237.81	-1,237.81	-1,237.81	-1,237.81	-1,237.81	-1,237.81	-1,237.81	-1,237.81	-1,237.81	-1,237.81	-1,237.81	-1,237.81	-1,237.81	-1,237.81	-1,237.81	-1,237.81
	Water	165.83	-8.29	-8.29	-8.29	-8.29	-8.29	-8.29	-8.29	-8.29	-8.29	-8.29	-8.29	-8.29	-8.29	-8.29	-8.29	-8.29	-8.29	-8.29	-8.29	-8.29
	Total:	**76,669.52**	3,833.48	3,833.48	3,833.48	3,833.48	3,833.48	3,833.48	3,833.48	3,833.48	3,833.48	3,833.48	3,833.48	3,833.48	3,833.48	3,833.48	3,833.48	3,833.48	3,833.48	3,833.48	3,833.48	3,833.48
Soil-based cultivation																						
	Growing beds	1,237.50	-61.88	-61.88	-61.88	-61.88	-61.88	-61.88	-61.88	-61.88	-61.88	-61.88	-61.88	-61.88	-61.88	-61.88	-61.88	-61.88	-61.88	-61.88	-61.88	-61.88
	Soil	2,475.00	-123.75	-123.75	-123.75	-123.75	-123.75	-123.75	-123.75	-123.75	-123.75	-123.75	-123.75	-123.75	-123.75	-123.75	-123.75	-123.75	-123.75	-123.75	-123.75	-123.75
	Total:	**3,712.50**	185.63	185.63	185.63	185.63	185.63	185.63	185.63	185.63	185.63	185.63	185.63	185.63	185.63	185.63	185.63	185.63	185.63	185.63	185.63	185.63
		64,411.38	-7,699.39	-6,874.46	-6,137.91	-5,480.27	-4,893.10	-4,368.84	-3,900.75	-3,482.81	-3,109.65	-2,776.48	-2,479.00	-2,213.39	-1,976.24	-1,764.50	-1,575.45	-1,406.65	-1,255.94	-1,121.37	-1,001.23	-893.95
OPEX_Non-Heating																						
Electricity	Grow lights		-2,231.80	-2,334.58	-2,437.36	-2,540.14	-2,642.92	-2,745.70	-2,848.48	-2,951.26	-3,054.04	-3,156.82	-3,259.60	-3,362.38	-3,465.16	-3,567.94	-3,670.72	-3,773.50	-3,876.28	-3,979.06	-4,081.84	-4,184.62
	Pumps		-318.19	-332.85	-347.50	-362.15	-376.81	-391.46	-406.11	-420.77	-435.42	-450.07	-464.73	-479.38	-494.03	-508.69	-523.34	-538.00	-552.65	-567.30	-581.96	-596.61
Labor			-2,748.00	-2,748.00	-2,748.00	-2,748.00	-2,748.00	-2,748.00	-2,748.00	-2,748.00	-2,748.00	-2,748.00	-2,748.00	-2,748.00	-2,748.00	-2,748.00	-2,748.00	-2,748.00	-2,748.00	-2,748.00	-2,748.00	-2,748.00
Fish feed			-3,623.40	-3,623.40	-3,623.40	-3,623.40	-3,623.40	-3,623.40	-3,623.40	-3,623.40	-3,623.40	-3,623.40	-3,623.40	-3,623.40	-3,623.40	-3,623.40	-3,623.40	-3,623.40	-3,623.40	-3,623.40	-3,623.40	-3,623.40
Maintenance	Building		-1,050.03	-1,050.03	-1,050.03	-1,050.03	-1,050.03	-1,050.03	-1,050.03	-1,050.03	-1,050.03	-1,050.03	-1,050.03	-1,050.03	-1,050.03	-1,050.03	-1,050.03	-1,050.03	-1,050.03	-1,050.03	-1,050.03	-1,050.03
	Aquaponics		-1,560.00	-1,560.00	-1,560.00	-1,560.00	-1,560.00	-1,560.00	-1,560.00	-1,560.00	-1,560.00	-1,560.00	-1,560.00	-1,560.00	-1,560.00	-1,560.00	-1,560.00	-1,560.00	-1,560.00	-1,560.00	-1,560.00	-1,560.00
		91,414.01	**-10,295.91**	**-9,286.40**	**-8,375.01**	**-7,552.32**	**-6,809.78**	**-6,139.65**	**-5,534.96**	**-4,989.35**	**-4,497.13**	**-4,053.10**	**-3,652.60**	**-3,291.39**	**-2,965.66**	**-2,671.94**	**-2,407.11**	**-2,168.36**	**-1,953.14**	**-1,759.15**	**-1,584.30**	**-1,426.73**
NPC Total		**-234,511.71**	-27,242.98	-24,426.71	-21,916.29	-19,663.40	-17,641.69	-15,827.48	-14,199.50	-12,738.69	-11,427.90	-10,251.76	-9,196.46	-8,249.61	-7,400.09	-6,637.90	-5,954.09	-5,340.61	-4,790.24	-4,296.50	-3,853.57	-3,456.23
AG yield																						
Fish [CAD/kg]		8.8	2,640.00	2,640.00	2,640.00	2,640.00	2,640.00	2,640.00	2,640.00	2,640.00	2,640.00	2,640.00	2,640.00	2,640.00	2,640.00	2,640.00	2,640.00	2,640.00	2,640.00	2,640.00	2,640.00	2,640.00
Basil: NFT [CAD/kg]		7.5	17,820.00	17,820.00	17,820.00	17,820.00	17,820.00	17,820.00	17,820.00	17,820.00	17,820.00	17,820.00	17,820.00	17,820.00	17,820.00	17,820.00	17,820.00	17,820.00	17,820.00	17,820.00	17,820.00	17,820.00
Lettuce: Soil [CAD/kg]		5	5,940.00	5,940.00	5,940.00	5,940.00	5,940.00	5,940.00	5,940.00	5,940.00	5,940.00	5,940.00	5,940.00	5,940.00	5,940.00	5,940.00	5,940.00	5,940.00	5,940.00	5,940.00	5,940.00	5,940.00
Additional income																						
Carbon offsets (Renewables)			1,663.04	1,889.82	2,116.60	2,343.37	2,570.15	2,600.39	2,630.63	2,660.86	2,691.10	2,721.34	2,751.57	2,781.81	2,812.05	2,842.29	2,872.52	2,902.76	2,933.00	2,963.23	2,993.47	3,023.71
Farm waste [CAD/t]		50	2,874.20	2,874.20	2,874.20	2,874.20	2,874.20	2,874.20	2,874.20	2,874.20	2,874.20	2,874.20	2,874.20	2,874.20	2,874.20	2,874.20	2,874.20	2,874.20	2,874.20	2,874.20	2,874.20	2,874.20
AG waste [CAD/t]		50	89.93	89.93	89.93	89.93	89.93	89.93	89.93	89.93	89.93	89.93	89.93	89.93	89.93	89.93	89.93	89.93	89.93	89.93	89.93	89.93
		237,410.90	**27,702.83**	**24,915.45**	**22,407.36**	**20,150.69**	**18,120.37**	**16,194.22**	**14,472.80**	**12,934.36**	**11,559.44**	**10,330.66**	**9,232.50**	**8,251.06**	**7,373.95**	**6,590.07**	**5,889.52**	**5,263.43**	**4,703.89**	**4,203.84**	**3,756.94**	**3,357.54**
NPV Total		**2,899.19**	459.85	488.75	491.07	487.29	478.68	366.74	273.30	195.67	131.54	78.90	36.04	1.45	-26.14	-47.83	-64.58	-77.19	-86.35	-92.67	-96.64	-98.69
	Cumulative		3,560.55	6,698.16	9,462.59	11,897.78	14,042.55	15,801.82	17,233.58	18,387.80	19,307.53	20,029.77	20,586.27	21,004.27	21,307.04	21,514.49	21,643.56	21,708.67	21,722.05	21,694.02	21,633.32	21,547.26

Discount rate 12 [%]

Hybrid 1: Biodigester & Natural gas

348 [m2]   7000 [l]

Lifespan	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Years	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**	**2036**	**2037**	**2038**	**2039**	**2040**	**2041**	**2042**	**2043**	**2044**	**2045**
Gas price [CAD/kWh]	0.013	0.014	0.015	0.015	0.016	0.016	0.017	0.017	0.018	0.019	0.019	0.020	0.020	0.021	0.022	0.022	0.023	0.023	0.024	0.024	0.025
Carbon offset price [CAD/t]	95	110	125	140	155	170	172	174	176	178	180	182	184	186	188	190	192	194	196	198	200
CAPEX_Heating																					
Hydronic radiant heating	14,654.50	-732.73	-732.73	-732.73	-732.73	-732.73	-732.73	-732.73	-732.73	-732.73	-732.73	-732.73	-732.73	-732.73	-732.73	-732.73	-732.73	-732.73	-732.73	-732.73	-732.73
Biogas boiler (incl. burner)	19,690.00	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50
Buffer tank	1,420.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00
Biodigester	14,000.00	-700.00	-700.00	-700.00	-700.00	-700.00	-700.00	-700.00	-700.00	-700.00	-700.00	-700.00	-700.00	-700.00	-700.00	-700.00	-700.00	-700.00	-700.00	-700.00	-700.00
Grid access	3,000.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00
Total:	**52,764.50**	2,638.23	2,638.23	2,638.23	2,638.23	2,638.23	2,638.23	2,638.23	2,638.23	2,638.23	2,638.23	2,638.23	2,638.23	2,638.23	2,638.23	2,638.23	2,638.23	2,638.23	2,638.23	2,638.23	2,638.23
	19,706.07	**-2,355.56**	**-2,103.18**	**-1,877.84**	**-1,676.64**	**-1,497.00**	**-1,336.61**	**-1,193.40**	**-1,065.53**	**-951.37**	**-849.44**	**-758.43**	**-677.17**	**-604.61**	**-539.83**	**-481.99**	**-430.35**	**-384.24**	**-343.07**	**-306.32**	**-273.50**
OPEX_Heating																					
Fuel (Natural gas)		-542.51	-565.14	-587.78	-610.41	-633.04	-655.67	-678.31	-700.94	-723.57	-746.20	-768.84	-791.47	-814.10	-836.74	-859.37	-882.00	-904.63	-927.27	-949.90	-972.53
Water [CAD/m3]	10.93	-1,232.92	-1,232.92	-1,232.92	-1,232.92	-1,232.92	-1,232.92	-1,232.92	-1,232.92	-1,232.92	-1,232.92	-1,232.92	-1,232.92	-1,232.92	-1,232.92	-1,232.92	-1,232.92	-1,232.92	-1,232.92	-1,232.92	-1,232.92
Maintenance		-1,018.03	-1,018.03	-1,018.03	-1,018.03	-1,018.03	-1,018.03	-1,018.03	-1,018.03	-1,018.03	-1,018.03	-1,018.03	-1,018.03	-1,018.03	-1,018.03	-1,018.03	-1,018.03	-1,018.03	-1,018.03	-1,018.03	-1,018.03
Cooling		-541.16	-538.07	-561.76	-585.45	-609.14	-632.82	-656.51	-680.20	-703.89	-727.58	-751.27	-774.96	-798.64	-822.33	-846.02	-869.71	-893.40	-917.09	-940.78	-964.46
Transport		-2,820.04	-2,820.04	-2,820.04	-2,820.04	-2,820.04	-2,820.04	-2,820.04	-2,820.04	-2,820.04	-2,820.04	-2,820.04	-2,820.04	-2,820.04	-2,820.04	-2,820.04	-2,820.04	-2,820.04	-2,820.04	-2,820.04	-2,820.04
Labour		-1,880.03	-1,880.03	-1,880.03	-1,880.03	-1,880.03	-1,880.03	-1,880.03	-1,880.03	-1,880.03	-1,880.03	-1,880.03	-1,880.03	-1,880.03	-1,880.03	-1,880.03	-1,880.03	-1,880.03	-1,880.03	-1,880.03	-1,880.03
Total:		8,034.69	8,054.24	8,100.56	8,146.88	8,193.20	8,239.52	8,285.84	8,332.16	8,378.49	8,424.81	8,471.13	8,517.45	8,563.77	8,610.09	8,656.41	8,702.73	8,749.06	8,795.38	8,841.70	8,888.02
Net emissions impact	[t CO2e]	8.30	8.30	8.30	8.30	8.30	8.30	8.30	8.30	8.30	8.30	8.30	8.30	8.30	8.30	8.30	8.30	8.30	8.30	8.30	8.30
	61,921.54	**-7,173.83**	**-6,420.79**	**-5,765.82**	**-5,177.49**	**-4,649.04**	**-4,174.40**	**-3,748.09**	**-3,365.22**	**-3,021.37**	**-2,712.56**	**-2,435.25**	**-2,186.22**	**-1,962.60**	**-1,761.80**	**-1,581.49**	**-1,419.60**	**-1,274.25**	**-1,143.75**	**-1,026.58**	**-921.39**
NPC Heating	**-81,627.61**	-9,529.39	-8,523.97	-7,643.65	-6,854.13	-6,146.04	-5,511.01	-4,941.49	-4,430.76	-3,972.74	-3,562.00	-3,193.67	-2,863.38	-2,567.21	-2,301.63	-2,063.49	-1,849.96	-1,658.49	-1,486.82	-1,332.90	-1,194.89
CAPEX_Non-Heating																					
Building																					
Material	52,233.67	-2,611.68	-2,611.68	-2,611.68	-2,611.68	-2,611.68	-2,611.68	-2,611.68	-2,611.68	-2,611.68	-2,611.68	-2,611.68	-2,611.68	-2,611.68	-2,611.68	-2,611.68	-2,611.68	-2,611.68	-2,611.68	-2,611.68	-2,611.68
Labour	49,430.08	-2,471.50	-2,471.50	-2,471.50	-2,471.50	-2,471.50	-2,471.50	-2,471.50	-2,471.50	-2,471.50	-2,471.50	-2,471.50	-2,471.50	-2,471.50	-2,471.50	-2,471.50	-2,471.50	-2,471.50	-2,471.50	-2,471.50	-2,471.50
Total:	**101,663.75**	5,083.19	5,083.19	5,083.19	5,083.19	5,083.19	5,083.19	5,083.19	5,083.19	5,083.19	5,083.19	5,083.19	5,083.19	5,083.19	5,083.19	5,083.19	5,083.19	5,083.19	5,083.19	5,083.19	5,083.19
Aquaponics																					
Aquaculture system	12,355.00	-617.75	-617.75	-617.75	-617.75	-617.75	-617.75	-617.75	-617.75	-617.75	-617.75	-617.75	-617.75	-617.75	-617.75	-617.75	-617.75	-617.75	-617.75	-617.75	-617.75
NFT system 1: Horizontal	16,067.92	-803.40	-803.40	-803.40	-803.40	-803.40	-803.40	-803.40	-803.40	-803.40	-803.40	-803.40	-803.40	-803.40	-803.40	-803.40	-803.40	-803.40	-803.40	-803.40	-803.40
NFT system 2: Vertical	31,949.17	-1,597.46	-1,597.46	-1,597.46	-1,597.46	-1,597.46	-1,597.46	-1,597.46	-1,597.46	-1,597.46	-1,597.46	-1,597.46	-1,597.46	-1,597.46	-1,597.46	-1,597.46	-1,597.46	-1,597.46	-1,597.46	-1,597.46	-1,597.46
Growing lights	28,882.22	-1,444.11	-1,444.11	-1,444.11	-1,444.11	-1,444.11	-1,444.11	-1,444.11	-1,444.11	-1,444.11	-1,444.11	-1,444.11	-1,444.11	-1,444.11	-1,444.11	-1,444.11	-1,444.11	-1,444.11	-1,444.11	-1,444.11	-1,444.11
Water	193.47	-9.67	-9.67	-9.67	-9.67	-9.67	-9.67	-9.67	-9.67	-9.67	-9.67	-9.67	-9.67	-9.67	-9.67	-9.67	-9.67	-9.67	-9.67	-9.67	-9.67
Total:	**89,447.77**	4,472.39	4,472.39	4,472.39	4,472.39	4,472.39	4,472.39	4,472.39	4,472.39	4,472.39	4,472.39	4,472.39	4,472.39	4,472.39	4,472.39	4,472.39	4,472.39	4,472.39	4,472.39	4,472.39	4,472.39
Soil-based cultivation																					
Growing beds	1,443.75	-72.19	-72.19	-72.19	-72.19	-72.19	-72.19	-72.19	-72.19	-72.19	-72.19	-72.19	-72.19	-72.19	-72.19	-72.19	-72.19	-72.19	-72.19	-72.19	-72.19
Soil	2,887.50	-144.38	-144.38	-144.38	-144.38	-144.38	-144.38	-144.38	-144.38	-144.38	-144.38	-144.38	-144.38	-144.38	-144.38	-144.38	-144.38	-144.38	-144.38	-144.38	-144.38
Total:	**4,331.25**	216.56	216.56	216.56	216.56	216.56	216.56	216.56	216.56	216.56	216.56	216.56	216.56	216.56	216.56	216.56	216.56	216.56	216.56	216.56	216.56
	72,992.44	-8,725.12	-7,790.29	-6,955.62	-6,210.37	-5,544.97	-4,950.87	-4,420.42	-3,946.80	-3,523.93	-3,146.37	-2,809.26	-2,508.26	-2,239.52	-1,999.57	-1,785.33	-1,594.05	-1,423.26	-1,270.76	-1,134.61	-1,013.05
OPEX_Non-Heating																					
Electricity — Grow lights		-2,603.76	-2,723.67	-2,843.58	-2,963.49	-3,083.40	-3,203.31	-3,323.22	-3,443.13	-3,563.04	-3,682.95	-3,802.86	-3,922.77	-4,042.68	-4,162.59	-4,282.50	-4,402.41	-4,522.32	-4,642.23	-4,762.14	-4,882.06
Pumps		-371.22	-388.32	-405.42	-422.51	-439.61	-456.70	-473.80	-490.89	-507.99	-525.09	-542.18	-559.28	-576.37	-593.47	-610.57	-627.66	-644.76	-661.85	-678.95	-696.04
Labor		-3,206.00	-3,206.00	-3,206.00	-3,206.00	-3,206.00	-3,206.00	-3,206.00	-3,206.00	-3,206.00	-3,206.00	-3,206.00	-3,206.00	-3,206.00	-3,206.00	-3,206.00	-3,206.00	-3,206.00	-3,206.00	-3,206.00	-3,206.00
Fish feed		-4,227.30	-4,227.30	-4,227.30	-4,227.30	-4,227.30	-4,227.30	-4,227.30	-4,227.30	-4,227.30	-4,227.30	-4,227.30	-4,227.30	-4,227.30	-4,227.30	-4,227.30	-4,227.30	-4,227.30	-4,227.30	-4,227.30	-4,227.30
Maintenance — Building		-1,202.87	-1,202.87	-1,202.87	-1,202.87	-1,202.87	-1,202.87	-1,202.87	-1,202.87	-1,202.87	-1,202.87	-1,202.87	-1,202.87	-1,202.87	-1,202.87	-1,202.87	-1,202.87	-1,202.87	-1,202.87	-1,202.87	-1,202.87
Aquaponics		-1,820.00	-1,820.00	-1,820.00	-1,820.00	-1,820.00	-1,820.00	-1,820.00	-1,820.00	-1,820.00	-1,820.00	-1,820.00	-1,820.00	-1,820.00	-1,820.00	-1,820.00	-1,820.00	-1,820.00	-1,820.00	-1,820.00	-1,820.00
	106,484.08	**-11,992.10**	**-10,816.46**	**-9,755.07**	**-8,796.95**	**-7,932.16**	**-7,151.70**	**-6,447.42**	**-5,811.96**	**-5,238.65**	**-4,721.48**	**-4,255.00**	**-3,834.27**	**-3,454.85**	**-3,112.72**	**-2,804.25**	**-2,526.14**	**-2,275.44**	**-2,049.46**	**-1,845.78**	**-1,662.22**
NPC Total	**-261,104.13**	-30,246.62	-27,130.71	-24,354.34	-21,861.45	-19,623.18	-17,613.57	-15,809.33	-14,189.52	-12,735.32	-11,429.85	-10,257.93	-9,205.92	-8,261.58	-7,413.93	-6,653.07	-5,970.15	-5,357.19	-4,807.04	-4,313.29	-3,870.16
AG yield																					
Fish [CAD/kg]	8.8	3,080.00	3,080.00	3,080.00	3,080.00	3,080.00	3,080.00	3,080.00	3,080.00	3,080.00	3,080.00	3,080.00	3,080.00	3,080.00	3,080.00	3,080.00	3,080.00	3,080.00	3,080.00	3,080.00	3,080.00
Basil: NFT [CAD/kg]	7.5	20,790.00	20,790.00	20,790.00	20,790.00	20,790.00	20,790.00	20,790.00	20,790.00	20,790.00	20,790.00	20,790.00	20,790.00	20,790.00	20,790.00	20,790.00	20,790.00	20,790.00	20,790.00	20,790.00	20,790.00
Lettuce: Soil [CAD/kg]	5	6,930.00	6,930.00	6,930.00	6,930.00	6,930.00	6,930.00	6,930.00	6,930.00	6,930.00	6,930.00	6,930.00	6,930.00	6,930.00	6,930.00	6,930.00	6,930.00	6,930.00	6,930.00	6,930.00	6,930.00
Additional income																					
Carbon offsets (Renewables)		1,631.70	1,854.21	2,076.71	2,299.22	2,521.72	2,551.39	2,581.06	2,610.72	2,640.39	2,670.06	2,699.73	2,729.39	2,759.06	2,788.73	2,818.39	2,848.06	2,877.73	2,907.40	2,937.06	2,966.73
Farm waste [CAD/t]	50	2,820.04	2,820.04	2,820.04	2,820.04	2,820.04	2,820.04	2,820.04	2,820.04	2,820.04	2,820.04	2,820.04	2,820.04	2,820.04	2,820.04	2,820.04	2,820.04	2,820.04	2,820.04	2,820.04	2,820.04
AG waste [CAD/t]	50	89.93	89.93	89.93	89.93	89.93	89.93	89.93	89.93	89.93	89.93	89.93	89.93	89.93	89.93	89.93	89.93	89.93	89.93	89.93	89.93
	269,531.28	**31,555.06**	**28,351.54**	**25,472.25**	**22,884.49**	**20,558.83**	**18,371.13**	**16,416.22**	**14,669.32**	**13,108.30**	**11,713.39**	**10,466.92**	**9,353.08**	**8,357.76**	**7,468.36**	**6,673.60**	**5,963.41**	**5,328.79**	**4,761.71**	**4,254.97**	**3,802.15**
NPV Total	**8,427.15**	1,308.45	1,220.83	1,117.92	1,023.04	935.66	757.56	606.88	479.80	372.98	283.54	208.99	147.16	96.18	54.43	20.53	-6.74	-28.40	-45.34	-58.32	-68.00
Cumulative		3,560.55	6,698.16	9,462.59	11,897.78	14,042.55	15,801.82	17,233.58	18,387.80	19,307.53	20,029.77	20,586.27	21,004.27	21,307.04	21,514.49	21,643.56	21,708.67	21,722.05	21,694.02	21,633.32	21,547.26

Discount rate 12 [%]

Hybrid 1: Biodigester & Natural gas

392 [m2] 8000 [l]

Lifespan	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Years	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**	**2036**	**2037**	**2038**	**2039**	**2040**	**2041**	**2042**	**2043**	**2044**	**2045**
Gas price [CAD/kWh]	0.013	0.014	0.015	0.015	0.016	0.016	0.017	0.017	0.018	0.019	0.019	0.020	0.020	0.021	0.022	0.022	0.023	0.023	0.024	0.024	0.025
Carbon offset price [CAD/t]	95	110	125	140	155	170	172	174	176	178	180	182	184	186	188	190	192	194	196	198	200
CAPEX_Heating																					
Hydronic radiant heating	16,516.50	-825.82	-825.82	-825.82	-825.82	-825.82	-825.82	-825.82	-825.82	-825.82	-825.82	-825.82	-825.82	-825.82	-825.82	-825.82	-825.82	-825.82	-825.82	-825.82	-825.82
Biogas boiler (incl. burner)	19,690.00	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50	-984.50
Buffer tank	1,420.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00	-71.00
Biodigester	14,000.00	-700.00	-700.00	-700.00	-700.00	-700.00	-700.00	-700.00	-700.00	-700.00	-700.00	-700.00	-700.00	-700.00	-700.00	-700.00	-700.00	-700.00	-700.00	-700.00	-700.00
Grid access	3,000.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00
Total:	**54,626.50**	2,731.32	2,731.32	2,731.32	2,731.32	2,731.32	2,731.32	2,731.32	2,731.32	2,731.32	2,731.32	2,731.32	2,731.32	2,731.32	2,731.32	2,731.32	2,731.32	2,731.32	2,731.32	2,731.32	2,731.32
	20,401.48	**-2,438.68**	**-2,177.40**	**-1,944.10**	**-1,735.81**	**-1,549.83**	**-1,383.77**	**-1,235.51**	**-1,103.14**	**-984.94**	**-879.41**	**-785.19**	**-701.06**	**-625.95**	**-558.88**	**-499.00**	**-445.54**	**-397.80**	**-355.18**	**-317.13**	**-283.15**
OPEX_Heating																					
Fuel (Natural gas)		-802.36	-835.83	-869.31	-902.78	-936.25	-969.73	-1,003.20	-1,036.67	-1,070.15	-1,103.62	-1,137.09	-1,170.57	-1,204.04	-1,237.51	-1,270.99	-1,304.46	-1,337.93	-1,371.41	-1,404.88	-1,438.35
Water [CAD/m3]	10.93	-1,172.23	-1,172.23	-1,172.23	-1,172.23	-1,172.23	-1,172.23	-1,172.23	-1,172.23	-1,172.23	-1,172.23	-1,172.23	-1,172.23	-1,172.23	-1,172.23	-1,172.23	-1,172.23	-1,172.23	-1,172.23	-1,172.23	-1,172.23
Maintenance		-1,004.91	-1,004.91	-1,004.91	-1,004.91	-1,004.91	-1,004.91	-1,004.91	-1,004.91	-1,004.91	-1,004.91	-1,004.91	-1,004.91	-1,004.91	-1,004.91	-1,004.91	-1,004.91	-1,004.91	-1,004.91	-1,004.91	-1,004.91
Cooling		-648.89	-646.56	-675.03	-703.49	-731.95	-760.42	-788.88	-817.35	-845.81	-874.28	-902.74	-931.21	-959.67	-988.14	-1,016.60	-1,045.07	-1,073.53	-1,102.00	-1,130.46	-1,158.93
Transport		-2,681.22	-2,681.22	-2,681.22	-2,681.22	-2,681.22	-2,681.22	-2,681.22	-2,681.22	-2,681.22	-2,681.22	-2,681.22	-2,681.22	-2,681.22	-2,681.22	-2,681.22	-2,681.22	-2,681.22	-2,681.22	-2,681.22	-2,681.22
Labour		-1,787.48	-1,787.48	-1,787.48	-1,787.48	-1,787.48	-1,787.48	-1,787.48	-1,787.48	-1,787.48	-1,787.48	-1,787.48	-1,787.48	-1,787.48	-1,787.48	-1,787.48	-1,787.48	-1,787.48	-1,787.48	-1,787.48	-1,787.48
Total:		8,097.09	8,128.23	8,190.17	8,252.10	8,314.04	8,375.98	8,437.92	8,499.86	8,561.79	8,623.73	8,685.67	8,747.61	8,809.55	8,871.49	8,933.42	8,995.36	9,057.30	9,119.24	9,181.18	9,243.11
Net emissions impact	[t CO2e]	11.56	11.56	11.56	11.56	11.56	11.56	11.56	11.56	11.56	11.56	11.56	11.56	11.56	11.56	11.56	11.56	11.56	11.56	11.56	11.56
	63,063.40	**-7,229.54**	**-6,479.77**	**-5,829.60**	**-5,244.36**	**-4,717.61**	**-4,243.53**	**-3,816.89**	**-3,432.95**	**-3,087.47**	**-2,776.61**	**-2,496.92**	**-2,245.29**	**-2,018.92**	**-1,815.28**	**-1,632.10**	**-1,467.34**	**-1,319.14**	**-1,185.86**	**-1,066.00**	**-958.20**
NPC Heating	**-83,464.88**	-9,668.23	-8,657.17	-7,773.70	-6,980.17	-6,267.44	-5,627.31	-5,052.40	-4,536.09	-4,072.41	-3,656.02	-3,282.11	-2,946.36	-2,644.87	-2,374.16	-2,131.11	-1,912.88	-1,716.95	-1,541.04	-1,383.12	-1,241.35
CAPEX_Non-Heating																					
Building																					
Material	58,484.42	-2,924.22	-2,924.22	-2,924.22	-2,924.22	-2,924.22	-2,924.22	-2,924.22	-2,924.22	-2,924.22	-2,924.22	-2,924.22	-2,924.22	-2,924.22	-2,924.22	-2,924.22	-2,924.22	-2,924.22	-2,924.22	-2,924.22	-2,924.22
Labour	55,463.63	-2,773.18	-2,773.18	-2,773.18	-2,773.18	-2,773.18	-2,773.18	-2,773.18	-2,773.18	-2,773.18	-2,773.18	-2,773.18	-2,773.18	-2,773.18	-2,773.18	-2,773.18	-2,773.18	-2,773.18	-2,773.18	-2,773.18	-2,773.18
Total:	**113,948.05**	5,697.40	5,697.40	5,697.40	5,697.40	5,697.40	5,697.40	5,697.40	5,697.40	5,697.40	5,697.40	5,697.40	5,697.40	5,697.40	5,697.40	5,697.40	5,697.40	5,697.40	5,697.40	5,697.40	5,697.40
Aquaponics																					
Aquaculture system	14,120.00	-706.00	-706.00	-706.00	-706.00	-706.00	-706.00	-706.00	-706.00	-706.00	-706.00	-706.00	-706.00	-706.00	-706.00	-706.00	-706.00	-706.00	-706.00	-706.00	-706.00
NFT system 1: Horizontal	18,363.33	-918.17	-918.17	-918.17	-918.17	-918.17	-918.17	-918.17	-918.17	-918.17	-918.17	-918.17	-918.17	-918.17	-918.17	-918.17	-918.17	-918.17	-918.17	-918.17	-918.17
NFT system 2: Vertical	36,513.33	-1,825.67	-1,825.67	-1,825.67	-1,825.67	-1,825.67	-1,825.67	-1,825.67	-1,825.67	-1,825.67	-1,825.67	-1,825.67	-1,825.67	-1,825.67	-1,825.67	-1,825.67	-1,825.67	-1,825.67	-1,825.67	-1,825.67	-1,825.67
Growing lights	33,008.25	-1,650.41	-1,650.41	-1,650.41	-1,650.41	-1,650.41	-1,650.41	-1,650.41	-1,650.41	-1,650.41	-1,650.41	-1,650.41	-1,650.41	-1,650.41	-1,650.41	-1,650.41	-1,650.41	-1,650.41	-1,650.41	-1,650.41	-1,650.41
Water	221.11	-11.06	-11.06	-11.06	-11.06	-11.06	-11.06	-11.06	-11.06	-11.06	-11.06	-11.06	-11.06	-11.06	-11.06	-11.06	-11.06	-11.06	-11.06	-11.06	-11.06
Total:	**102,226.03**	5,111.30	5,111.30	5,111.30	5,111.30	5,111.30	5,111.30	5,111.30	5,111.30	5,111.30	5,111.30	5,111.30	5,111.30	5,111.30	5,111.30	5,111.30	5,111.30	5,111.30	5,111.30	5,111.30	5,111.30
Soil-based cultivation																					
Growing beds	1,650.00	-82.50	-82.50	-82.50	-82.50	-82.50	-82.50	-82.50	-82.50	-82.50	-82.50	-82.50	-82.50	-82.50	-82.50	-82.50	-82.50	-82.50	-82.50	-82.50	-82.50
Soil	3,300.00	-165.00	-165.00	-165.00	-165.00	-165.00	-165.00	-165.00	-165.00	-165.00	-165.00	-165.00	-165.00	-165.00	-165.00	-165.00	-165.00	-165.00	-165.00	-165.00	-165.00
Total:	**4,950.00**	247.50	247.50	247.50	247.50	247.50	247.50	247.50	247.50	247.50	247.50	247.50	247.50	247.50	247.50	247.50	247.50	247.50	247.50	247.50	247.50
	82,583.69	-9,871.61	-8,813.94	-7,869.59	-7,026.42	-6,273.59	-5,601.42	-5,001.27	-4,465.42	-3,986.98	-3,559.80	-3,178.39	-2,837.85	-2,533.80	-2,262.32	-2,019.93	-1,803.51	-1,610.27	-1,437.74	-1,283.70	-1,146.16
OPEX_Non-Heating																					
Electricity – Grow lights		-2,975.73	-3,112.77	-3,249.81	-3,386.85	-3,523.89	-3,660.93	-3,797.97	-3,935.01	-4,072.05	-4,209.09	-4,346.13	-4,483.17	-4,620.21	-4,757.25	-4,894.29	-5,031.33	-5,168.37	-5,305.41	-5,442.45	-5,579.49
Pumps		-424.26	-443.79	-463.33	-482.87	-502.41	-521.95	-541.48	-561.02	-580.56	-600.10	-619.64	-639.17	-658.71	-678.25	-697.79	-717.33	-736.86	-756.40	-775.94	-795.48
Labor		-3,664.00	-3,664.00	-3,664.00	-3,664.00	-3,664.00	-3,664.00	-3,664.00	-3,664.00	-3,664.00	-3,664.00	-3,664.00	-3,664.00	-3,664.00	-3,664.00	-3,664.00	-3,664.00	-3,664.00	-3,664.00	-3,664.00	-3,664.00
Fish feed		-4,831.20	-4,831.20	-4,831.20	-4,831.20	-4,831.20	-4,831.20	-4,831.20	-4,831.20	-4,831.20	-4,831.20	-4,831.20	-4,831.20	-4,831.20	-4,831.20	-4,831.20	-4,831.20	-4,831.20	-4,831.20	-4,831.20	-4,831.20
Maintenance – Building		-1,355.71	-1,355.71	-1,355.71	-1,355.71	-1,355.71	-1,355.71	-1,355.71	-1,355.71	-1,355.71	-1,355.71	-1,355.71	-1,355.71	-1,355.71	-1,355.71	-1,355.71	-1,355.71	-1,355.71	-1,355.71	-1,355.71	-1,355.71
Aquaponics		-2,080.00	-2,080.00	-2,080.00	-2,080.00	-2,080.00	-2,080.00	-2,080.00	-2,080.00	-2,080.00	-2,080.00	-2,080.00	-2,080.00	-2,080.00	-2,080.00	-2,080.00	-2,080.00	-2,080.00	-2,080.00	-2,080.00	-2,080.00
	121,554.16	**-13,688.29**	**-12,346.51**	**-11,135.12**	**-10,041.58**	**-9,054.55**	**-8,163.74**	**-7,359.88**	**-6,634.56**	**-5,980.18**	**-5,389.86**	**-4,857.39**	**-4,377.14**	**-3,944.05**	**-3,553.51**	**-3,201.38**	**-2,883.92**	**-2,597.73**	**-2,339.77**	**-2,107.26**	**-1,897.71**
NPC Total	**-287,602.73**	-33,228.13	-29,817.62	-26,778.41	-24,048.17	-21,595.57	-19,392.47	-17,413.55	-15,636.07	-14,039.57	-12,605.69	-11,317.90	-10,161.35	-9,122.71	-8,189.99	-7,352.42	-6,600.30	-5,924.95	-5,318.55	-4,774.08	-4,285.22
AG yield																					
Fish [CAD/kg]	8.8	3,520.00	3,520.00	3,520.00	3,520.00	3,520.00	3,520.00	3,520.00	3,520.00	3,520.00	3,520.00	3,520.00	3,520.00	3,520.00	3,520.00	3,520.00	3,520.00	3,520.00	3,520.00	3,520.00	3,520.00
Basil: NFT [CAD/kg]	7.5	23,760.00	23,760.00	23,760.00	23,760.00	23,760.00	23,760.00	23,760.00	23,760.00	23,760.00	23,760.00	23,760.00	23,760.00	23,760.00	23,760.00	23,760.00	23,760.00	23,760.00	23,760.00	23,760.00	23,760.00
Lettuce: Soil [CAD/kg]	5	7,920.00	7,920.00	7,920.00	7,920.00	7,920.00	7,920.00	7,920.00	7,920.00	7,920.00	7,920.00	7,920.00	7,920.00	7,920.00	7,920.00	7,920.00	7,920.00	7,920.00	7,920.00	7,920.00	7,920.00
Additional income																					
Carbon offsets (Renewables)		1,551.38	1,762.93	1,974.48	2,186.03	2,397.58	2,425.79	2,453.99	2,482.20	2,510.41	2,538.62	2,566.82	2,595.03	2,623.24	2,651.44	2,679.65	2,707.86	2,736.06	2,764.27	2,792.48	2,820.68
Farm waste [CAD/t]	50	2,681.22	2,681.22	2,681.22	2,681.22	2,681.22	2,681.22	2,681.22	2,681.22	2,681.22	2,681.22	2,681.22	2,681.22	2,681.22	2,681.22	2,681.22	2,681.22	2,681.22	2,681.22	2,681.22	2,681.22
AG waste [CAD/t]	50	89.93	89.93	89.93	89.93	89.93	89.93	89.93	89.93	89.93	89.93	89.93	89.93	89.93	89.93	89.93	89.93	89.93	89.93	89.93	89.93
	300,486.73	**35,287.96**	**31,675.76**	**28,432.50**	**25,520.61**	**22,906.30**	**20,466.34**	**18,286.28**	**16,338.43**	**14,598.05**	**13,043.06**	**11,653.70**	**10,412.33**	**9,303.18**	**8,312.19**	**7,426.75**	**6,635.63**	**5,928.77**	**5,297.22**	**4,732.93**	**4,228.76**
NPV Total	**12,884.00**	2,059.83	1,858.14	1,654.09	1,472.44	1,310.73	1,073.88	872.73	702.36	558.48	437.37	335.80	250.97	180.47	122.19	74.33	35.32	3.82	-21.34	-41.15	-56.47
Cumulative		3,560.55	6,698.16	9,462.59	11,897.78	14,042.55	15,801.82	17,233.58	18,387.80	19,307.53	20,029.77	20,586.27	21,004.27	21,307.04	21,514.49	21,643.56	21,708.67	21,722.05	21,694.02	21,633.32	21,547.26

Discount rate 12 [%]

Hybrid 1: Biodigester & Natural gas

436 [m2] 9000 [l]

Lifespan	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Years	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**	**2036**	**2037**	**2038**	**2039**	**2040**	**2041**	**2042**	**2043**	**2044**	**2045**
Gas price [CAD/kWh]	0.013	0.014	0.015	0.015	0.016	0.016	0.017	0.017	0.018	0.019	0.019	0.020	0.020	0.021	0.022	0.022	0.023	0.023	0.024	0.024	0.025
Carbon offset price [CAD/t]	95	110	125	140	155	170	172	174	176	178	180	182	184	186	188	190	192	194	196	198	200
CAPEX_Heating																					
Hydronic radiant heating	18,378.49	-918.92	-918.92	-918.92	-918.92	-918.92	-918.92	-918.92	-918.92	-918.92	-918.92	-918.92	-918.92	-918.92	-918.92	-918.92	-918.92	-918.92	-918.92	-918.92	-918.92
Biogas boiler (incl. burner)	24,690.00	-1,234.50	-1,234.50	-1,234.50	-1,234.50	-1,234.50	-1,234.50	-1,234.50	-1,234.50	-1,234.50	-1,234.50	-1,234.50	-1,234.50	-1,234.50	-1,234.50	-1,234.50	-1,234.50	-1,234.50	-1,234.50	-1,234.50	-1,234.50
Buffer tank	1,775.00	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75
Biodigester	14,000.00	-700.00	-700.00	-700.00	-700.00	-700.00	-700.00	-700.00	-700.00	-700.00	-700.00	-700.00	-700.00	-700.00	-700.00	-700.00	-700.00	-700.00	-700.00	-700.00	-700.00
Grid access	3,000.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00
Total:	**61,843.49**	3,092.17	3,092.17	3,092.17	3,092.17	3,092.17	3,092.17	3,092.17	3,092.17	3,092.17	3,092.17	3,092.17	3,092.17	3,092.17	3,092.17	3,092.17	3,092.17	3,092.17	3,092.17	3,092.17	3,092.17
	23,096.82	**-2,760.87**	**-2,465.06**	**-2,200.95**	**-1,965.13**	**-1,754.58**	**-1,566.59**	**-1,398.74**	**-1,248.88**	**-1,115.07**	**-995.60**	**-888.93**	**-793.68**	**-708.65**	**-632.72**	**-564.93**	**-504.40**	**-450.36**	**-402.11**	**-359.02**	**-320.56**
OPEX_Heating																					
Fuel (Natural gas)		-881.79	-918.57	-955.36	-992.15	-1,028.93	-1,065.72	-1,102.51	-1,139.29	-1,176.08	-1,212.87	-1,249.65	-1,286.44	-1,323.23	-1,360.01	-1,396.80	-1,433.59	-1,470.37	-1,507.16	-1,543.95	-1,580.73
Water [CAD/m3]	10.93	-1,288.27	-1,288.27	-1,288.27	-1,288.27	-1,288.27	-1,288.27	-1,288.27	-1,288.27	-1,288.27	-1,288.27	-1,288.27	-1,288.27	-1,288.27	-1,288.27	-1,288.27	-1,288.27	-1,288.27	-1,288.27	-1,288.27	-1,288.27
Maintenance		-1,104.38	-1,104.38	-1,104.38	-1,104.38	-1,104.38	-1,104.38	-1,104.38	-1,104.38	-1,104.38	-1,104.38	-1,104.38	-1,104.38	-1,104.38	-1,104.38	-1,104.38	-1,104.38	-1,104.38	-1,104.38	-1,104.38	-1,104.38
Cooling		-757.47	-756.81	-790.13	-823.45	-856.76	-890.08	-923.40	-956.72	-990.04	-1,023.36	-1,056.68	-1,090.00	-1,123.31	-1,156.63	-1,189.95	-1,223.27	-1,256.59	-1,289.91	-1,323.23	-1,356.54
Transport		-2,946.63	-2,946.63	-2,946.63	-2,946.63	-2,946.63	-2,946.63	-2,946.63	-2,946.63	-2,946.63	-2,946.63	-2,946.63	-2,946.63	-2,946.63	-2,946.63	-2,946.63	-2,946.63	-2,946.63	-2,946.63	-2,946.63	-2,946.63
Labour		-1,964.42	-1,964.42	-1,964.42	-1,964.42	-1,964.42	-1,964.42	-1,964.42	-1,964.42	-1,964.42	-1,964.42	-1,964.42	-1,964.42	-1,964.42	-1,964.42	-1,964.42	-1,964.42	-1,964.42	-1,964.42	-1,964.42	-1,964.42
Total:		8,942.95	8,979.08	9,049.18	9,119.29	9,189.39	9,259.50	9,329.60	9,399.71	9,469.81	9,539.92	9,610.03	9,680.13	9,750.24	9,820.34	9,890.45	9,960.55	10,030.66	10,100.76	10,170.87	10,240.97
Net emissions impact [t CO2e]		12.71	12.71	12.71	12.71	12.71	12.71	12.71	12.71	12.71	12.71	12.71	12.71	12.71	12.71	12.71	12.71	12.71	12.71	12.71	12.71
	69,727.87	**-7,984.78**	**-7,158.07**	**-6,441.03**	**-5,795.47**	**-5,214.31**	**-4,691.15**	**-4,220.24**	**-3,796.39**	**-3,414.91**	**-3,071.60**	**-2,762.65**	**-2,484.65**	**-2,234.50**	**-2,009.44**	**-1,806.95**	**-1,624.78**	**-1,460.91**	**-1,313.50**	**-1,180.91**	**-1,061.65**
NPC Heating	**-92,824.70**	-10,745.65	-9,623.13	-8,641.98	-7,760.61	-6,968.89	-6,257.74	-5,618.98	-5,045.26	-4,529.98	-4,067.20	-3,651.58	-3,278.33	-2,943.15	-2,642.16	-2,371.88	-2,129.18	-1,911.27	-1,715.60	-1,539.93	-1,382.20
CAPEX_Non-Heating																					
Building																					
Material	60,927.23	-3,046.36	-3,046.36	-3,046.36	-3,046.36	-3,046.36	-3,046.36	-3,046.36	-3,046.36	-3,046.36	-3,046.36	-3,046.36	-3,046.36	-3,046.36	-3,046.36	-3,046.36	-3,046.36	-3,046.36	-3,046.36	-3,046.36	-3,046.36
Labour	61,497.18	-3,074.86	-3,074.86	-3,074.86	-3,074.86	-3,074.86	-3,074.86	-3,074.86	-3,074.86	-3,074.86	-3,074.86	-3,074.86	-3,074.86	-3,074.86	-3,074.86	-3,074.86	-3,074.86	-3,074.86	-3,074.86	-3,074.86	-3,074.86
Total:	**122,424.40**	6,121.22	6,121.22	6,121.22	6,121.22	6,121.22	6,121.22	6,121.22	6,121.22	6,121.22	6,121.22	6,121.22	6,121.22	6,121.22	6,121.22	6,121.22	6,121.22	6,121.22	6,121.22	6,121.22	6,121.22
Aquaponics																					
Aquaculture system	15,885.00	-794.25	-794.25	-794.25	-794.25	-794.25	-794.25	-794.25	-794.25	-794.25	-794.25	-794.25	-794.25	-794.25	-794.25	-794.25	-794.25	-794.25	-794.25	-794.25	-794.25
NFT system 1: Horizontal	20,658.75	-1,032.94	-1,032.94	-1,032.94	-1,032.94	-1,032.94	-1,032.94	-1,032.94	-1,032.94	-1,032.94	-1,032.94	-1,032.94	-1,032.94	-1,032.94	-1,032.94	-1,032.94	-1,032.94	-1,032.94	-1,032.94	-1,032.94	-1,032.94
NFT system 2: Vertical	41,077.50	-2,053.88	-2,053.88	-2,053.88	-2,053.88	-2,053.88	-2,053.88	-2,053.88	-2,053.88	-2,053.88	-2,053.88	-2,053.88	-2,053.88	-2,053.88	-2,053.88	-2,053.88	-2,053.88	-2,053.88	-2,053.88	-2,053.88	-2,053.88
Growing lights	37,134.28	-1,856.71	-1,856.71	-1,856.71	-1,856.71	-1,856.71	-1,856.71	-1,856.71	-1,856.71	-1,856.71	-1,856.71	-1,856.71	-1,856.71	-1,856.71	-1,856.71	-1,856.71	-1,856.71	-1,856.71	-1,856.71	-1,856.71	-1,856.71
Water	248.74	-12.44	-12.44	-12.44	-12.44	-12.44	-12.44	-12.44	-12.44	-12.44	-12.44	-12.44	-12.44	-12.44	-12.44	-12.44	-12.44	-12.44	-12.44	-12.44	-12.44
Total:	**115,004.28**	5,750.21	5,750.21	5,750.21	5,750.21	5,750.21	5,750.21	5,750.21	5,750.21	5,750.21	5,750.21	5,750.21	5,750.21	5,750.21	5,750.21	5,750.21	5,750.21	5,750.21	5,750.21	5,750.21	5,750.21
Soil-based cultivation																					
Growing beds	1,856.25	-92.81	-92.81	-92.81	-92.81	-92.81	-92.81	-92.81	-92.81	-92.81	-92.81	-92.81	-92.81	-92.81	-92.81	-92.81	-92.81	-92.81	-92.81	-92.81	-92.81
Soil	3,712.50	-185.63	-185.63	-185.63	-185.63	-185.63	-185.63	-185.63	-185.63	-185.63	-185.63	-185.63	-185.63	-185.63	-185.63	-185.63	-185.63	-185.63	-185.63	-185.63	-185.63
Total:	**5,568.75**	278.44	278.44	278.44	278.44	278.44	278.44	278.44	278.44	278.44	278.44	278.44	278.44	278.44	278.44	278.44	278.44	278.44	278.44	278.44	278.44
	90,752.78	-10,848.10	-9,685.80	-8,648.04	-7,721.46	-6,894.16	-6,155.50	-5,495.98	-4,907.13	-4,381.37	-3,911.93	-3,492.80	-3,118.57	-2,784.44	-2,486.10	-2,219.74	-1,981.91	-1,769.56	-1,579.96	-1,410.68	-1,259.54
OPEX_Non-Heating																					
Electricity Grow lights		-3,347.69	-3,501.87	-3,656.04	-3,810.21	-3,964.38	-4,118.55	-4,272.72	-4,426.89	-4,581.06	-4,735.23	-4,889.40	-5,043.57	-5,197.74	-5,351.91	-5,506.08	-5,660.25	-5,814.42	-5,968.59	-6,122.76	-6,276.93
Pumps		-477.29	-499.27	-521.25	-543.23	-565.21	-587.19	-609.17	-631.15	-653.13	-675.11	-697.09	-719.07	-741.05	-763.03	-785.01	-806.99	-828.97	-850.95	-872.93	-894.91
Labor		-4,122.00	-4,122.00	-4,122.00	-4,122.00	-4,122.00	-4,122.00	-4,122.00	-4,122.00	-4,122.00	-4,122.00	-4,122.00	-4,122.00	-4,122.00	-4,122.00	-4,122.00	-4,122.00	-4,122.00	-4,122.00	-4,122.00	-4,122.00
Fish feed		-5,435.10	-5,435.10	-5,435.10	-5,435.10	-5,435.10	-5,435.10	-5,435.10	-5,435.10	-5,435.10	-5,435.10	-5,435.10	-5,435.10	-5,435.10	-5,435.10	-5,435.10	-5,435.10	-5,435.10	-5,435.10	-5,435.10	-5,435.10
Maintenance Building		-1,508.54	-1,508.54	-1,508.54	-1,508.54	-1,508.54	-1,508.54	-1,508.54	-1,508.54	-1,508.54	-1,508.54	-1,508.54	-1,508.54	-1,508.54	-1,508.54	-1,508.54	-1,508.54	-1,508.54	-1,508.54	-1,508.54	-1,508.54
Aquaponics		-2,340.00	-2,340.00	-2,340.00	-2,340.00	-2,340.00	-2,340.00	-2,340.00	-2,340.00	-2,340.00	-2,340.00	-2,340.00	-2,340.00	-2,340.00	-2,340.00	-2,340.00	-2,340.00	-2,340.00	-2,340.00	-2,340.00	-2,340.00
	136,624.23	**-15,384.49**	**-13,876.57**	**-12,515.18**	**-11,286.21**	**-10,176.93**	**-9,175.79**	**-8,272.35**	**-7,457.17**	**-6,721.71**	**-6,058.24**	**-5,459.78**	**-4,920.02**	**-4,433.24**	**-3,994.30**	**-3,598.52**	**-3,241.70**	**-2,920.03**	**-2,630.07**	**-2,368.73**	**-2,133.20**
NPC Total	**-320,201.71**	-36,978.24	-33,185.51	-29,805.20	-26,768.28	-24,039.98	-21,589.03	-19,387.32	-17,409.56	-15,633.05	-14,037.37	-12,604.16	-11,316.92	-10,160.83	-9,122.56	-8,190.13	-7,352.79	-6,600.85	-5,925.64	-5,319.34	-4,774.94
AG yield																					
Fish [CAD/kg]	8.8	3,960.00	3,960.00	3,960.00	3,960.00	3,960.00	3,960.00	3,960.00	3,960.00	3,960.00	3,960.00	3,960.00	3,960.00	3,960.00	3,960.00	3,960.00	3,960.00	3,960.00	3,960.00	3,960.00	3,960.00
Basil: NFT [CAD/kg]	7.5	26,730.00	26,730.00	26,730.00	26,730.00	26,730.00	26,730.00	26,730.00	26,730.00	26,730.00	26,730.00	26,730.00	26,730.00	26,730.00	26,730.00	26,730.00	26,730.00	26,730.00	26,730.00	26,730.00	26,730.00
Lettuce: Soil [CAD/kg]	5	8,910.00	8,910.00	8,910.00	8,910.00	8,910.00	8,910.00	8,910.00	8,910.00	8,910.00	8,910.00	8,910.00	8,910.00	8,910.00	8,910.00	8,910.00	8,910.00	8,910.00	8,910.00	8,910.00	8,910.00
Additional income																					
Carbon offsets (Renewables)		1,704.94	1,937.44	2,169.93	2,402.42	2,634.91	2,665.91	2,696.91	2,727.91	2,758.91	2,789.91	2,820.91	2,851.91	2,882.91	2,913.91	2,944.90	2,975.90	3,006.90	3,037.90	3,068.90	3,099.90
Farm waste [CAD/t]	50	2,946.63	2,946.63	2,946.63	2,946.63	2,946.63	2,946.63	2,946.63	2,946.63	2,946.63	2,946.63	2,946.63	2,946.63	2,946.63	2,946.63	2,946.63	2,946.63	2,946.63	2,946.63	2,946.63	2,946.63
AG waste [CAD/t]	50	89.93	89.93	89.93	89.93	89.93	89.93	89.93	89.93	89.93	89.93	89.93	89.93	89.93	89.93	89.93	89.93	89.93	89.93	89.93	89.93
	337,004.04	**39,590.62**	**35,534.11**	**31,892.37**	**28,623.08**	**25,688.25**	**22,951.64**	**20,506.56**	**18,321.95**	**16,370.06**	**14,626.10**	**13,067.93**	**11,675.75**	**10,431.89**	**9,320.53**	**8,327.56**	**7,440.38**	**6,647.71**	**5,939.49**	**5,306.71**	**4,741.35**
NPV Total	**16,802.33**	2,612.39	2,348.61	2,087.17	1,854.80	1,648.26	1,362.61	1,119.24	912.38	737.01	588.73	463.77	358.83	271.06	197.97	137.43	87.59	46.86	13.84	-12.63	-33.59
Cumulative		3,560.55	6,698.16	9,462.59	11,897.78	14,042.55	15,801.82	17,233.58	18,387.80	19,307.53	20,029.77	20,586.27	21,004.27	21,307.04	21,514.49	21,643.56	21,708.67	21,722.05	21,694.02	21,633.32	21,547.26

Discount rate 12 [%]

Hybrid 1: Biodigester & Natural gas

481 [m2] 10000 [l]

Lifespan	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Years	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**	**2036**	**2037**	**2038**	**2039**	**2040**	**2041**	**2042**	**2043**	**2044**	**2045**
Gas price [CAD/kWh]	0.013	0.014	0.015	0.015	0.016	0.016	0.017	0.017	0.018	0.019	0.019	0.020	0.020	0.021	0.022	0.022	0.023	0.023	0.024	0.024	0.025
Carbon offset price [CAD/t]	95	110	125	140	155	170	172	174	176	178	180	182	184	186	188	190	192	194	196	198	200
CAPEX_Heating																					
Hydronic radiant heating	20,240.49	-1,012.02	-1,012.02	-1,012.02	-1,012.02	-1,012.02	-1,012.02	-1,012.02	-1,012.02	-1,012.02	-1,012.02	-1,012.02	-1,012.02	-1,012.02	-1,012.02	-1,012.02	-1,012.02	-1,012.02	-1,012.02	-1,012.02	-1,012.02
Biogas boiler (incl. burner)	24,690.00	-1,234.50	-1,234.50	-1,234.50	-1,234.50	-1,234.50	-1,234.50	-1,234.50	-1,234.50	-1,234.50	-1,234.50	-1,234.50	-1,234.50	-1,234.50	-1,234.50	-1,234.50	-1,234.50	-1,234.50	-1,234.50	-1,234.50	-1,234.50
Buffer tank	1,775.00	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75
Biodigester	14,000.00	-700.00	-700.00	-700.00	-700.00	-700.00	-700.00	-700.00	-700.00	-700.00	-700.00	-700.00	-700.00	-700.00	-700.00	-700.00	-700.00	-700.00	-700.00	-700.00	-700.00
Grid access	3,000.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00
Total:	**63,705.49**	3,185.27	3,185.27	3,185.27	3,185.27	3,185.27	3,185.27	3,185.27	3,185.27	3,185.27	3,185.27	3,185.27	3,185.27	3,185.27	3,185.27	3,185.27	3,185.27	3,185.27	3,185.27	3,185.27	3,185.27
	23,792.23	**-2,844.00**	**-2,539.28**	**-2,267.22**	**-2,024.30**	**-1,807.41**	**-1,613.76**	**-1,440.86**	**-1,286.48**	**-1,148.64**	**-1,025.57**	**-915.69**	**-817.58**	**-729.98**	**-651.77**	**-581.94**	**-519.59**	**-463.92**	**-414.21**	**-369.83**	**-330.21**
OPEX_Heating																					
Fuel (Natural gas)		-1,206.47	-1,256.80	-1,307.13	-1,357.46	-1,407.79	-1,458.13	-1,508.46	-1,558.79	-1,609.12	-1,659.45	-1,709.78	-1,760.12	-1,810.45	-1,860.78	-1,911.11	-1,961.44	-2,011.77	-2,062.11	-2,112.44	-2,162.77
Water [CAD/m3]	10.93	-1,175.08	-1,175.08	-1,175.08	-1,175.08	-1,175.08	-1,175.08	-1,175.08	-1,175.08	-1,175.08	-1,175.08	-1,175.08	-1,175.08	-1,175.08	-1,175.08	-1,175.08	-1,175.08	-1,175.08	-1,175.08	-1,175.08	-1,175.08
Maintenance		-1,059.27	-1,059.27	-1,059.27	-1,059.27	-1,059.27	-1,059.27	-1,059.27	-1,059.27	-1,059.27	-1,059.27	-1,059.27	-1,059.27	-1,059.27	-1,059.27	-1,059.27	-1,059.27	-1,059.27	-1,059.27	-1,059.27	-1,059.27
Cooling		-1,018.39	-1,024.67	-1,069.78	-1,114.89	-1,160.00	-1,205.11	-1,250.23	-1,295.34	-1,340.45	-1,385.56	-1,430.67	-1,475.78	-1,520.89	-1,566.00	-1,611.12	-1,656.23	-1,701.34	-1,746.45	-1,791.56	-1,836.67
Transport		-2,687.73	-2,687.73	-2,687.73	-2,687.73	-2,687.73	-2,687.73	-2,687.73	-2,687.73	-2,687.73	-2,687.73	-2,687.73	-2,687.73	-2,687.73	-2,687.73	-2,687.73	-2,687.73	-2,687.73	-2,687.73	-2,687.73	-2,687.73
Labour		-1,791.82	-1,791.82	-1,791.82	-1,791.82	-1,791.82	-1,791.82	-1,791.82	-1,791.82	-1,791.82	-1,791.82	-1,791.82	-1,791.82	-1,791.82	-1,791.82	-1,791.82	-1,791.82	-1,791.82	-1,791.82	-1,791.82	-1,791.82
Total:		8,938.76	8,995.37	9,090.81	9,186.25	9,281.70	9,377.14	9,472.58	9,568.03	9,663.47	9,758.91	9,854.36	9,949.80	10,045.24	10,140.68	10,236.13	10,331.57	10,427.01	10,522.46	10,617.90	10,713.34
Net emissions impact	[t CO2e]	16.74	16.74	16.74	16.74	16.74	16.74	16.74	16.74	16.74	16.74	16.74	16.74	16.74	16.74	16.74	16.74	16.74	16.74	16.74	16.74
	70,804.01	**-7,981.03**	**-7,171.05**	**-6,470.66**	**-5,838.03**	**-5,266.68**	**-4,750.75**	**-4,284.92**	**-3,864.37**	**-3,484.74**	**-3,142.11**	**-2,832.89**	**-2,553.87**	**-2,302.11**	**-2,074.98**	**-1,870.10**	**-1,685.30**	**-1,518.64**	**-1,368.34**	**-1,232.81**	**-1,110.62**
NPC Heating	**-94,596.23**	-10,825.03	-9,710.33	-8,737.88	-7,862.33	-7,074.09	-6,364.51	-5,725.77	-5,150.84	-4,633.39	-4,167.68	-3,748.58	-3,371.45	-3,032.09	-2,726.76	-2,452.04	-2,204.89	-1,982.55	-1,782.55	-1,602.64	-1,440.82
CAPEX_Non-Heating																					
Building																					
Material	69,137.60	-3,456.88	-3,456.88	-3,456.88	-3,456.88	-3,456.88	-3,456.88	-3,456.88	-3,456.88	-3,456.88	-3,456.88	-3,456.88	-3,456.88	-3,456.88	-3,456.88	-3,456.88	-3,456.88	-3,456.88	-3,456.88	-3,456.88	-3,456.88
Labour	69,801.60	-3,490.08	-3,490.08	-3,490.08	-3,490.08	-3,490.08	-3,490.08	-3,490.08	-3,490.08	-3,490.08	-3,490.08	-3,490.08	-3,490.08	-3,490.08	-3,490.08	-3,490.08	-3,490.08	-3,490.08	-3,490.08	-3,490.08	-3,490.08
Total:	**138,939.19**	6,946.96	6,946.96	6,946.96	6,946.96	6,946.96	6,946.96	6,946.96	6,946.96	6,946.96	6,946.96	6,946.96	6,946.96	6,946.96	6,946.96	6,946.96	6,946.96	6,946.96	6,946.96	6,946.96	6,946.96
Aquaponics																					
Aquaculture system	17,650.00	-882.50	-882.50	-882.50	-882.50	-882.50	-882.50	-882.50	-882.50	-882.50	-882.50	-882.50	-882.50	-882.50	-882.50	-882.50	-882.50	-882.50	-882.50	-882.50	-882.50
NFT system 1: Horizontal	22,954.17	-1,147.71	-1,147.71	-1,147.71	-1,147.71	-1,147.71	-1,147.71	-1,147.71	-1,147.71	-1,147.71	-1,147.71	-1,147.71	-1,147.71	-1,147.71	-1,147.71	-1,147.71	-1,147.71	-1,147.71	-1,147.71	-1,147.71	-1,147.71
NFT system 2: Vertical	45,641.67	-2,282.08	-2,282.08	-2,282.08	-2,282.08	-2,282.08	-2,282.08	-2,282.08	-2,282.08	-2,282.08	-2,282.08	-2,282.08	-2,282.08	-2,282.08	-2,282.08	-2,282.08	-2,282.08	-2,282.08	-2,282.08	-2,282.08	-2,282.08
Growing lights	41,260.32	-2,063.02	-2,063.02	-2,063.02	-2,063.02	-2,063.02	-2,063.02	-2,063.02	-2,063.02	-2,063.02	-2,063.02	-2,063.02	-2,063.02	-2,063.02	-2,063.02	-2,063.02	-2,063.02	-2,063.02	-2,063.02	-2,063.02	-2,063.02
Water	276.38	-13.82	-13.82	-13.82	-13.82	-13.82	-13.82	-13.82	-13.82	-13.82	-13.82	-13.82	-13.82	-13.82	-13.82	-13.82	-13.82	-13.82	-13.82	-13.82	-13.82
Total:	**127,782.53**	6,389.13	6,389.13	6,389.13	6,389.13	6,389.13	6,389.13	6,389.13	6,389.13	6,389.13	6,389.13	6,389.13	6,389.13	6,389.13	6,389.13	6,389.13	6,389.13	6,389.13	6,389.13	6,389.13	6,389.13
Soil-based cultivation																					
Growing beds	2,062.50	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13
Soil	4,125.00	-206.25	-206.25	-206.25	-206.25	-206.25	-206.25	-206.25	-206.25	-206.25	-206.25	-206.25	-206.25	-206.25	-206.25	-206.25	-206.25	-206.25	-206.25	-206.25	-206.25
Total:	**6,187.50**	309.38	309.38	309.38	309.38	309.38	309.38	309.38	309.38	309.38	309.38	309.38	309.38	309.38	309.38	309.38	309.38	309.38	309.38	309.38	309.38
	101,924.00	-12,183.45	-10,878.08	-9,712.57	-8,671.94	-7,742.80	-6,913.22	-6,172.51	-5,511.17	-4,920.69	-4,393.47	-3,922.74	-3,502.45	-3,127.19	-2,792.13	-2,492.97	-2,225.87	-1,987.38	-1,774.45	-1,584.33	-1,414.58
OPEX_Non-Heating																					
Electricity – Grow lights		-3,719.66	-3,890.96	-4,062.26	-4,233.56	-4,404.86	-4,576.16	-4,747.46	-4,918.76	-5,090.06	-5,261.36	-5,432.66	-5,603.96	-5,775.26	-5,946.56	-6,117.86	-6,289.16	-6,460.46	-6,631.76	-6,803.06	-6,974.36
Pumps		-530.32	-554.74	-579.16	-603.59	-628.01	-652.43	-676.85	-701.28	-725.70	-750.12	-774.55	-798.97	-823.39	-847.81	-872.24	-896.66	-921.08	-945.50	-969.93	-994.35
Labor		-4,580.00	-4,580.00	-4,580.00	-4,580.00	-4,580.00	-4,580.00	-4,580.00	-4,580.00	-4,580.00	-4,580.00	-4,580.00	-4,580.00	-4,580.00	-4,580.00	-4,580.00	-4,580.00	-4,580.00	-4,580.00	-4,580.00	-4,580.00
Fish feed		-6,039.00	-6,039.00	-6,039.00	-6,039.00	-6,039.00	-6,039.00	-6,039.00	-6,039.00	-6,039.00	-6,039.00	-6,039.00	-6,039.00	-6,039.00	-6,039.00	-6,039.00	-6,039.00	-6,039.00	-6,039.00	-6,039.00	-6,039.00
Maintenance – Building		-1,661.38	-1,661.38	-1,661.38	-1,661.38	-1,661.38	-1,661.38	-1,661.38	-1,661.38	-1,661.38	-1,661.38	-1,661.38	-1,661.38	-1,661.38	-1,661.38	-1,661.38	-1,661.38	-1,661.38	-1,661.38	-1,661.38	-1,661.38
Aquaponics		-2,600.00	-2,600.00	-2,600.00	-2,600.00	-2,600.00	-2,600.00	-2,600.00	-2,600.00	-2,600.00	-2,600.00	-2,600.00	-2,600.00	-2,600.00	-2,600.00	-2,600.00	-2,600.00	-2,600.00	-2,600.00	-2,600.00	-2,600.00
	151,694.31	**-17,080.68**	**-15,406.63**	**-13,895.23**	**-12,530.84**	**-11,299.31**	**-10,187.83**	**-9,184.81**	**-8,279.77**	**-7,463.24**	**-6,726.62**	**-6,062.18**	**-5,462.90**	**-4,922.44**	**-4,435.08**	**-3,995.65**	**-3,599.48**	**-3,242.32**	**-2,920.38**	**-2,630.21**	**-2,368.69**
NPC Total	**-348,214.54**	-40,089.15	-35,995.05	-32,345.68	-29,065.11	-26,116.21	-23,465.56	-21,083.10	-18,941.79	-17,017.31	-15,287.78	-13,733.50	-12,336.79	-11,081.72	-9,953.97	-8,940.67	-8,030.24	-7,212.26	-6,477.38	-5,817.18	-5,224.10
AG yield																					
Fish [CAD/kg]	8.8	4,400.00	4,400.00	4,400.00	4,400.00	4,400.00	4,400.00	4,400.00	4,400.00	4,400.00	4,400.00	4,400.00	4,400.00	4,400.00	4,400.00	4,400.00	4,400.00	4,400.00	4,400.00	4,400.00	4,400.00
Basil: NFT [CAD/kg]	7.5	29,700.00	29,700.00	29,700.00	29,700.00	29,700.00	29,700.00	29,700.00	29,700.00	29,700.00	29,700.00	29,700.00	29,700.00	29,700.00	29,700.00	29,700.00	29,700.00	29,700.00	29,700.00	29,700.00	29,700.00
Lettuce: Soil [CAD/kg]	5	9,900.00	9,900.00	9,900.00	9,900.00	9,900.00	9,900.00	9,900.00	9,900.00	9,900.00	9,900.00	9,900.00	9,900.00	9,900.00	9,900.00	9,900.00	9,900.00	9,900.00	9,900.00	9,900.00	9,900.00
Additional income																					
Carbon offsets (Renewables)		1,555.14	1,767.21	1,979.28	2,191.34	2,403.41	2,431.68	2,459.96	2,488.23	2,516.51	2,544.78	2,573.06	2,601.33	2,629.61	2,657.88	2,686.16	2,714.43	2,742.71	2,770.99	2,799.26	2,827.54
Farm waste [CAD/t]	50	2,687.73	2,687.73	2,687.73	2,687.73	2,687.73	2,687.73	2,687.73	2,687.73	2,687.73	2,687.73	2,687.73	2,687.73	2,687.73	2,687.73	2,687.73	2,687.73	2,687.73	2,687.73	2,687.73	2,687.73
AG waste [CAD/t]	50	89.93	89.93	89.93	89.93	89.93	89.93	89.93	89.93	89.93	89.93	89.93	89.93	89.93	89.93	89.93	89.93	89.93	89.93	89.93	89.93
	366,307.46	**43,154.29**	**38,699.67**	**34,704.22**	**31,120.68**	**27,906.66**	**24,930.98**	**22,272.60**	**19,897.67**	**17,775.97**	**15,880.51**	**14,187.15**	**12,674.36**	**11,322.87**	**10,115.49**	**9,036.85**	**8,073.23**	**7,212.36**	**6,443.29**	**5,756.22**	**5,142.41**
NPV Total	**18,092.92**	3,065.13	2,704.62	2,358.54	2,055.57	1,790.45	1,465.42	1,189.50	955.87	758.66	592.73	453.65	337.57	241.15	161.52	96.19	43.00	0.10	-34.10	-60.97	-81.69
Cumulative		3,560.55	6,698.16	9,462.59	11,897.78	14,042.55	15,801.82	17,233.58	18,387.80	19,307.53	20,029.77	20,586.27	21,004.27	21,307.04	21,514.49	21,643.56	21,708.67	21,722.05	21,694.02	21,633.32	21,547.26

Discount rate 12 [%]

Hybrid 1: Biodigester & Natural gas

525 [m2] 11000 [l]

Lifespan	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Years	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**	**2036**	**2037**	**2038**	**2039**	**2040**	**2041**	**2042**	**2043**	**2044**	**2045**
Gas price [CAD/kWh]	0.013	0.014	0.015	0.015	0.016	0.016	0.017	0.017	0.018	0.019	0.019	0.020	0.020	0.021	0.022	0.022	0.023	0.023	0.024	0.024	0.025
Carbon offset price [CAD/t]	95	110	125	140	155	170	172	174	176	178	180	182	184	186	188	190	192	194	196	198	200
CAPEX_Heating																					
Hydronic radiant heating	22,102.48	-1,105.12	-1,105.12	-1,105.12	-1,105.12	-1,105.12	-1,105.12	-1,105.12	-1,105.12	-1,105.12	-1,105.12	-1,105.12	-1,105.12	-1,105.12	-1,105.12	-1,105.12	-1,105.12	-1,105.12	-1,105.12	-1,105.12	-1,105.12
Biogas boiler (incl. burner)	24,690.00	-1,234.50	-1,234.50	-1,234.50	-1,234.50	-1,234.50	-1,234.50	-1,234.50	-1,234.50	-1,234.50	-1,234.50	-1,234.50	-1,234.50	-1,234.50	-1,234.50	-1,234.50	-1,234.50	-1,234.50	-1,234.50	-1,234.50	-1,234.50
Buffer tank	1,775.00	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75	-88.75
Biodigester	14,000.00	-700.00	-700.00	-700.00	-700.00	-700.00	-700.00	-700.00	-700.00	-700.00	-700.00	-700.00	-700.00	-700.00	-700.00	-700.00	-700.00	-700.00	-700.00	-700.00	-700.00
Grid access	3,000.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00	-150.00
Total:	**65,567.48**	3,278.37	3,278.37	3,278.37	3,278.37	3,278.37	3,278.37	3,278.37	3,278.37	3,278.37	3,278.37	3,278.37	3,278.37	3,278.37	3,278.37	3,278.37	3,278.37	3,278.37	3,278.37	3,278.37	3,278.37
	24,487.63	**-2,927.12**	**-2,613.50**	**-2,333.48**	**-2,083.47**	**-1,860.24**	**-1,660.93**	**-1,482.97**	**-1,324.08**	**-1,182.21**	**-1,055.55**	**-942.45**	**-841.48**	**-751.32**	**-670.82**	**-598.95**	**-534.77**	**-477.48**	**-426.32**	**-380.64**	**-339.86**
OPEX_Heating																					
Fuel (Natural gas)		-1,309.23	-1,363.85	-1,418.47	-1,473.09	-1,527.71	-1,582.33	-1,636.95	-1,691.57	-1,746.19	-1,800.81	-1,855.42	-1,910.04	-1,964.66	-2,019.28	-2,073.90	-2,128.52	-2,183.14	-2,237.76	-2,292.38	-2,347.00
Water [CAD/m3]	10.93	-1,275.17	-1,275.17	-1,275.17	-1,275.17	-1,275.17	-1,275.17	-1,275.17	-1,275.17	-1,275.17	-1,275.17	-1,275.17	-1,275.17	-1,275.17	-1,275.17	-1,275.17	-1,275.17	-1,275.17	-1,275.17	-1,275.17	-1,275.17
Maintenance		-1,149.50	-1,149.50	-1,149.50	-1,149.50	-1,149.50	-1,149.50	-1,149.50	-1,149.50	-1,149.50	-1,149.50	-1,149.50	-1,149.50	-1,149.50	-1,149.50	-1,149.50	-1,149.50	-1,149.50	-1,149.50	-1,149.50	-1,149.50
Cooling		-1,147.96	-1,156.88	-1,207.81	-1,258.74	-1,309.68	-1,360.61	-1,411.54	-1,462.47	-1,513.40	-1,564.34	-1,615.27	-1,666.20	-1,717.13	-1,768.06	-1,819.00	-1,869.93	-1,920.86	-1,971.79	-2,022.72	-2,073.65
Transport		-2,916.67	-2,916.67	-2,916.67	-2,916.67	-2,916.67	-2,916.67	-2,916.67	-2,916.67	-2,916.67	-2,916.67	-2,916.67	-2,916.67	-2,916.67	-2,916.67	-2,916.67	-2,916.67	-2,916.67	-2,916.67	-2,916.67	-2,916.67
Labour		-1,944.45	-1,944.45	-1,944.45	-1,944.45	-1,944.45	-1,944.45	-1,944.45	-1,944.45	-1,944.45	-1,944.45	-1,944.45	-1,944.45	-1,944.45	-1,944.45	-1,944.45	-1,944.45	-1,944.45	-1,944.45	-1,944.45	-1,944.45
Total:		9,742.99	9,806.53	9,912.08	10,017.63	10,123.18	10,228.73	10,334.28	10,439.84	10,545.39	10,650.94	10,756.49	10,862.04	10,967.59	11,073.14	11,178.69	11,284.24	11,389.79	11,495.34	11,600.90	11,706.45
Net emissions impact	[t CO2e]	18.16	18.16	18.16	18.16	18.16	18.16	18.16	18.16	18.16	18.16	18.16	18.16	18.16	18.16	18.16	18.16	18.16	18.16	18.16	18.16
	77,244.80	**-8,699.10**	**-7,817.71**	**-7,055.22**	**-6,366.39**	**-5,744.17**	**-5,182.19**	**-4,674.71**	**-4,216.47**	**-3,802.77**	**-3,429.32**	**-3,092.23**	**-2,788.01**	**-2,513.49**	**-2,265.78**	**-2,042.31**	**-1,840.70**	**-1,658.86**	**-1,494.85**	**-1,346.94**	**-1,213.57**
NPC Heating	**-101,732.43**	-11,626.22	-10,431.21	-9,388.71	-8,449.85	-7,604.40	-6,843.12	-6,157.68	-5,540.55	-4,984.99	-4,484.87	-4,034.69	-3,629.49	-3,264.81	-2,936.60	-2,641.25	-2,375.48	-2,136.34	-1,921.17	-1,727.58	-1,553.43
CAPEX_Non-Heating																					
Building																					
Material	70,527.84	-3,526.39	-3,526.39	-3,526.39	-3,526.39	-3,526.39	-3,526.39	-3,526.39	-3,526.39	-3,526.39	-3,526.39	-3,526.39	-3,526.39	-3,526.39	-3,526.39	-3,526.39	-3,526.39	-3,526.39	-3,526.39	-3,526.39	-3,526.39
Labour	76,036.14	-3,801.81	-3,801.81	-3,801.81	-3,801.81	-3,801.81	-3,801.81	-3,801.81	-3,801.81	-3,801.81	-3,801.81	-3,801.81	-3,801.81	-3,801.81	-3,801.81	-3,801.81	-3,801.81	-3,801.81	-3,801.81	-3,801.81	-3,801.81
Total:	**146,563.98**	7,328.20	7,328.20	7,328.20	7,328.20	7,328.20	7,328.20	7,328.20	7,328.20	7,328.20	7,328.20	7,328.20	7,328.20	7,328.20	7,328.20	7,328.20	7,328.20	7,328.20	7,328.20	7,328.20	7,328.20
Aquaponics																					
Aquaculture system	19,415.00	-970.75	-970.75	-970.75	-970.75	-970.75	-970.75	-970.75	-970.75	-970.75	-970.75	-970.75	-970.75	-970.75	-970.75	-970.75	-970.75	-970.75	-970.75	-970.75	-970.75
NFT system 1: Horizontal	25,249.58	-1,262.48	-1,262.48	-1,262.48	-1,262.48	-1,262.48	-1,262.48	-1,262.48	-1,262.48	-1,262.48	-1,262.48	-1,262.48	-1,262.48	-1,262.48	-1,262.48	-1,262.48	-1,262.48	-1,262.48	-1,262.48	-1,262.48	-1,262.48
NFT system 2: Vertical	50,205.83	-2,510.29	-2,510.29	-2,510.29	-2,510.29	-2,510.29	-2,510.29	-2,510.29	-2,510.29	-2,510.29	-2,510.29	-2,510.29	-2,510.29	-2,510.29	-2,510.29	-2,510.29	-2,510.29	-2,510.29	-2,510.29	-2,510.29	-2,510.29
Growing lights	45,386.35	-2,269.32	-2,269.32	-2,269.32	-2,269.32	-2,269.32	-2,269.32	-2,269.32	-2,269.32	-2,269.32	-2,269.32	-2,269.32	-2,269.32	-2,269.32	-2,269.32	-2,269.32	-2,269.32	-2,269.32	-2,269.32	-2,269.32	-2,269.32
Water	304.02	-15.20	-15.20	-15.20	-15.20	-15.20	-15.20	-15.20	-15.20	-15.20	-15.20	-15.20	-15.20	-15.20	-15.20	-15.20	-15.20	-15.20	-15.20	-15.20	-15.20
Total:	**140,560.78**	7,028.04	7,028.04	7,028.04	7,028.04	7,028.04	7,028.04	7,028.04	7,028.04	7,028.04	7,028.04	7,028.04	7,028.04	7,028.04	7,028.04	7,028.04	7,028.04	7,028.04	7,028.04	7,028.04	7,028.04
Soil-based cultivation																					
Growing beds	2,268.75	-113.44	-113.44	-113.44	-113.44	-113.44	-113.44	-113.44	-113.44	-113.44	-113.44	-113.44	-113.44	-113.44	-113.44	-113.44	-113.44	-113.44	-113.44	-113.44	-113.44
Soil	4,537.50	-226.88	-226.88	-226.88	-226.88	-226.88	-226.88	-226.88	-226.88	-226.88	-226.88	-226.88	-226.88	-226.88	-226.88	-226.88	-226.88	-226.88	-226.88	-226.88	-226.88
Total:	**6,806.25**	340.31	340.31	340.31	340.31	340.31	340.31	340.31	340.31	340.31	340.31	340.31	340.31	340.31	340.31	340.31	340.31	340.31	340.31	340.31	340.31
	109,775.06	-13,121.92	-11,716.00	-10,460.71	-9,339.92	-8,339.22	-7,445.73	-6,647.97	-5,935.69	-5,299.72	-4,731.90	-4,224.91	-3,772.24	-3,368.07	-3,007.21	-2,685.00	-2,397.33	-2,140.47	-1,911.13	-1,706.37	-1,523.54
OPEX_Non-Heating																					
Electricity — Grow lights		-4,091.63	-4,280.06	-4,468.49	-4,656.92	-4,845.35	-5,033.78	-5,222.21	-5,410.64	-5,599.07	-5,787.50	-5,975.93	-6,164.36	-6,352.79	-6,541.22	-6,729.65	-6,918.08	-7,106.51	-7,294.94	-7,483.37	-7,671.80
Pumps		-583.35	-610.22	-637.08	-663.95	-690.81	-717.68	-744.54	-771.41	-798.27	-825.14	-852.00	-878.86	-905.73	-932.59	-959.46	-986.32	-1,013.19	-1,040.05	-1,066.92	-1,093.78
Labor		-5,038.00	-5,038.00	-5,038.00	-5,038.00	-5,038.00	-5,038.00	-5,038.00	-5,038.00	-5,038.00	-5,038.00	-5,038.00	-5,038.00	-5,038.00	-5,038.00	-5,038.00	-5,038.00	-5,038.00	-5,038.00	-5,038.00	-5,038.00
Fish feed		-6,642.90	-6,642.90	-6,642.90	-6,642.90	-6,642.90	-6,642.90	-6,642.90	-6,642.90	-6,642.90	-6,642.90	-6,642.90	-6,642.90	-6,642.90	-6,642.90	-6,642.90	-6,642.90	-6,642.90	-6,642.90	-6,642.90	-6,642.90
Maintenance — Building		-1,814.21	-1,814.21	-1,814.21	-1,814.21	-1,814.21	-1,814.21	-1,814.21	-1,814.21	-1,814.21	-1,814.21	-1,814.21	-1,814.21	-1,814.21	-1,814.21	-1,814.21	-1,814.21	-1,814.21	-1,814.21	-1,814.21	-1,814.21
Aquaponics		-2,860.00	-2,860.00	-2,860.00	-2,860.00	-2,860.00	-2,860.00	-2,860.00	-2,860.00	-2,860.00	-2,860.00	-2,860.00	-2,860.00	-2,860.00	-2,860.00	-2,860.00	-2,860.00	-2,860.00	-2,860.00	-2,860.00	-2,860.00
	166,764.38	**-18,776.87**	**-16,936.69**	**-15,275.29**	**-13,775.48**	**-12,421.70**	**-11,199.87**	**-10,097.28**	**-9,102.38**	**-8,204.76**	**-7,395.00**	**-6,664.57**	**-6,005.77**	**-5,411.64**	**-4,875.87**	**-4,392.79**	**-3,957.25**	**-3,564.62**	**-3,210.69**	**-2,891.69**	**-2,604.18**
NPC Total	**-378,271.86**	-43,525.01	-39,083.90	-35,124.71	-31,565.25	-28,365.32	-25,488.73	-22,902.93	-20,578.62	-18,489.47	-16,611.76	-14,924.17	-13,407.50	-12,044.51	-10,819.68	-9,719.05	-8,730.06	-7,841.42	-7,042.99	-6,325.64	-5,681.15
AG yield																					
Fish [CAD/kg]	8.8	4,840.00	4,840.00	4,840.00	4,840.00	4,840.00	4,840.00	4,840.00	4,840.00	4,840.00	4,840.00	4,840.00	4,840.00	4,840.00	4,840.00	4,840.00	4,840.00	4,840.00	4,840.00	4,840.00	4,840.00
Basil: NFT [CAD/kg]	7.5	32,670.00	32,670.00	32,670.00	32,670.00	32,670.00	32,670.00	32,670.00	32,670.00	32,670.00	32,670.00	32,670.00	32,670.00	32,670.00	32,670.00	32,670.00	32,670.00	32,670.00	32,670.00	32,670.00	32,670.00
Lettuce: Soil [CAD/kg]	5	10,890.00	10,890.00	10,890.00	10,890.00	10,890.00	10,890.00	10,890.00	10,890.00	10,890.00	10,890.00	10,890.00	10,890.00	10,890.00	10,890.00	10,890.00	10,890.00	10,890.00	10,890.00	10,890.00	10,890.00
Additional income																					
Carbon offsets (Renewables)		1,687.61	1,917.74	2,147.87	2,378.00	2,608.13	2,638.81	2,669.50	2,700.18	2,730.87	2,761.55	2,792.23	2,822.92	2,853.60	2,884.28	2,914.97	2,945.65	2,976.34	3,007.02	3,037.70	3,068.39
Farm waste [CAD/t]	50	2,916.67	2,916.67	2,916.67	2,916.67	2,916.67	2,916.67	2,916.67	2,916.67	2,916.67	2,916.67	2,916.67	2,916.67	2,916.67	2,916.67	2,916.67	2,916.67	2,916.67	2,916.67	2,916.67	2,916.67
AG waste [CAD/t]	50	89.93	89.93	89.93	89.93	89.93	89.93	89.93	89.93	89.93	89.93	89.93	89.93	89.93	89.93	89.93	89.93	89.93	89.93	89.93	89.93
	402,323.02	**47,405.55**	**42,509.84**	**38,119.01**	**34,181.09**	**30,649.41**	**27,381.09**	**24,461.28**	**21,852.82**	**19,522.51**	**17,440.69**	**15,580.87**	**13,919.37**	**12,435.04**	**11,108.99**	**9,924.35**	**8,866.03**	**7,920.57**	**7,075.92**	**6,321.35**	**5,647.25**
NPV Total	**24,051.15**	3,880.54	3,425.94	2,994.30	2,615.83	2,284.09	1,892.36	1,558.35	1,274.20	1,033.04	828.93	656.70	511.87	390.52	289.31	205.30	135.97	79.14	32.93	-4.29	-33.91
Cumulative		3,560.55	6,698.16	9,462.59	11,897.78	14,042.55	15,801.82	17,233.58	18,387.80	19,307.53	20,029.77	20,586.27	21,004.27	21,307.04	21,514.49	21,643.56	21,708.67	21,722.05	21,694.02	21,633.32	21,547.26

C.1.6. Hybrid-2GB

Increasing greenhouse size per page.

Discount rate 12 [%]

Hybrid 2: GSHP & Biomass

260 [m2] 5000 [l]

Lifespan	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Years	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**	**2036**	**2037**	**2038**	**2039**	**2040**	**2041**	**2042**	**2043**	**2044**	**2045**
Electricity rates [CAD/kWh]	0.104	0.160	0.167	0.175	0.182	0.189	0.197	0.204	0.212	0.219	0.226	0.234	0.241	0.248	0.256	0.263	0.271	0.278	0.285	0.293	0.300
Wood chip: Alberta waste rec	95	97	99	101	103	105	107	109	111	114	116	118	120	123	125	128	130	133	136	138	141
Carbon offset price [CAD/t]	95	110	125	140	155	170	172	174	176	178	180	182	184	186	188	190	192	194	196	198	200
CAPEX_Heating																					
Hydronic radiant heating	10,930.51	- 546.53	- 546.53	- 546.53	- 546.53	- 546.53	- 546.53	- 546.53	- 546.53	- 546.53	- 546.53	- 546.53	- 546.53	- 546.53	- 546.53	- 546.53	- 546.53	- 546.53	- 546.53	- 546.53	- 546.53
Biomass boiler	8,600.00	- 430.00	- 430.00	- 430.00	- 430.00	- 430.00	- 430.00	- 430.00	- 430.00	- 430.00	- 430.00	- 430.00	- 430.00	- 430.00	- 430.00	- 430.00	- 430.00	- 430.00	- 430.00	- 430.00	- 430.00
Ground loop installation	6,905.96	- 345.30	- 345.30	- 345.30	- 345.30	- 345.30	- 345.30	- 345.30	- 345.30	- 345.30	- 345.30	- 345.30	- 345.30	- 345.30	- 345.30	- 345.30	- 345.30	- 345.30	- 345.30	- 345.30	- 345.30
Heat pump	13,660.00	- 683.00	- 683.00	- 683.00	- 683.00	- 683.00	- 683.00	- 683.00	- 683.00	- 683.00	- 683.00	- 683.00	- 683.00	- 683.00	- 683.00	- 683.00	- 683.00	- 683.00	- 683.00	- 683.00	- 683.00
Total:	**40,096.47**	2,004.82	2,004.82	2,004.82	2,004.82	2,004.82	2,004.82	2,004.82	2,004.82	2,004.82	2,004.82	2,004.82	2,004.82	2,004.82	2,004.82	2,004.82	2,004.82	2,004.82	2,004.82	2,004.82	2,004.82
	14,974.92	**- 1,790.02**	**- 1,598.23**	**- 1,426.99**	**- 1,274.10**	**- 1,137.59**	**- 1,015.71**	**- 906.88**	**- 809.71**	**- 722.96**	**- 645.50**	**- 576.34**	**- 514.59**	**- 459.45**	**- 410.23**	**- 366.27**	**- 327.03**	**- 291.99**	**- 260.71**	**- 232.77**	**- 207.83**
OPEX_Heating																					
Fuel (Wood chip)		- 1,617.38	- 1,649.72	- 1,682.72	- 1,716.37	- 1,750.70	- 1,785.72	- 1,821.43	- 1,857.86	- 1,895.02	- 1,932.92	- 1,971.57	- 2,011.01	- 2,051.23	- 2,092.25	- 2,134.10	- 2,176.78	- 2,220.31	- 2,264.72	- 2,310.01	- 2,356.21
CoE		- 1,363.35	- 1,426.13	- 1,488.92	- 1,551.71	- 1,614.49	- 1,677.28	- 1,740.06	- 1,802.85	- 1,865.63	- 1,928.42	- 1,991.21	- 2,053.99	- 2,116.78	- 2,179.56	- 2,242.35	- 2,305.14	- 2,367.92	- 2,430.71	- 2,493.49	- 2,556.28
Maintenance		- 363.75	- 363.75	- 363.75	- 363.75	- 363.75	- 363.75	- 363.75	- 363.75	- 363.75	- 363.75	- 363.75	- 363.75	- 363.75	- 363.75	- 363.75	- 363.75	- 363.75	- 363.75	- 363.75	- 363.75
Transport		- 834.56	- 834.56	- 834.56	- 834.56	- 834.56	- 834.56	- 834.56	- 834.56	- 834.56	- 834.56	- 834.56	- 834.56	- 834.56	- 834.56	- 834.56	- 834.56	- 834.56	- 834.56	- 834.56	- 834.56
Labour		- 272.62	- 272.62	- 272.62	- 272.62	- 272.62	- 272.62	- 272.62	- 272.62	- 272.62	- 272.62	- 272.62	- 272.62	- 272.62	- 272.62	- 272.62	- 272.62	- 272.62	- 272.62	- 272.62	- 272.62
Total:		4,451.66	4,546.79	4,642.57	4,739.01	4,836.13	4,933.92	5,032.42	5,131.64	5,231.58	5,332.27	5,433.71	5,535.93	5,638.94	5,742.75	5,847.38	5,952.84	6,059.17	6,166.36	6,274.44	6,383.42
Net emissions impact (Gas)	[t CO2e]	4.61	4.61	4.61	4.61	4.61	4.61	4.61	4.61	4.61	4.61	4.61	4.61	4.61	4.61	4.61	4.61	4.61	4.61	4.61	4.61
Net emissions impact (RE)	[t CO2e]	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45
	37,676.14	**- 3,974.69**	**- 3,624.67**	**- 3,304.49**	**- 3,011.73**	**- 2,744.15**	**- 2,499.68**	**- 2,276.41**	**- 2,072.58**	**- 1,886.56**	**- 1,716.85**	**- 1,562.06**	**- 1,420.94**	**- 1,292.30**	**- 1,175.08**	**- 1,068.29**	**- 971.04**	**- 882.48**	**- 801.87**	**- 728.50**	**- 661.75**
NPC Heating	**- 52,651.05**	- 5,764.72	- 5,222.91	- 4,731.48	- 4,285.83	- 3,881.74	- 3,515.39	- 3,183.29	- 2,882.30	- 2,609.52	- 2,362.35	- 2,138.40	- 1,935.52	- 1,751.75	- 1,585.31	- 1,434.57	- 1,298.07	- 1,174.47	- 1,062.58	- 961.28	- 869.58
CAPEX_Non-Heating																					
Building																					
Material	42,069.34	- 2,103.47	- 2,103.47	- 2,103.47	- 2,103.47	- 2,103.47	- 2,103.47	- 2,103.47	- 2,103.47	- 2,103.47	- 2,103.47	- 2,103.47	- 2,103.47	- 2,103.47	- 2,103.47	- 2,103.47	- 2,103.47	- 2,103.47	- 2,103.47	- 2,103.47	- 2,103.47
Labour	37,362.98	- 1,868.15	- 1,868.15	- 1,868.15	- 1,868.15	- 1,868.15	- 1,868.15	- 1,868.15	- 1,868.15	- 1,868.15	- 1,868.15	- 1,868.15	- 1,868.15	- 1,868.15	- 1,868.15	- 1,868.15	- 1,868.15	- 1,868.15	- 1,868.15	- 1,868.15	- 1,868.15
Total:	**79,432.33**	3,971.62	3,971.62	3,971.62	3,971.62	3,971.62	3,971.62	3,971.62	3,971.62	3,971.62	3,971.62	3,971.62	3,971.62	3,971.62	3,971.62	3,971.62	3,971.62	3,971.62	3,971.62	3,971.62	3,971.62
Aquaponics																					
Aquaculture system	8,825.00	- 441.25	- 441.25	- 441.25	- 441.25	- 441.25	- 441.25	- 441.25	- 441.25	- 441.25	- 441.25	- 441.25	- 441.25	- 441.25	- 441.25	- 441.25	- 441.25	- 441.25	- 441.25	- 441.25	- 441.25
NFT system 1: Horizontal	11,477.08	- 573.85	- 573.85	- 573.85	- 573.85	- 573.85	- 573.85	- 573.85	- 573.85	- 573.85	- 573.85	- 573.85	- 573.85	- 573.85	- 573.85	- 573.85	- 573.85	- 573.85	- 573.85	- 573.85	- 573.85
NFT system 2: Vertical	22,820.83	- 1,141.04	- 1,141.04	- 1,141.04	- 1,141.04	- 1,141.04	- 1,141.04	- 1,141.04	- 1,141.04	- 1,141.04	- 1,141.04	- 1,141.04	- 1,141.04	- 1,141.04	- 1,141.04	- 1,141.04	- 1,141.04	- 1,141.04	- 1,141.04	- 1,141.04	- 1,141.04
Growing lights	20,630.16	- 1,031.51	- 1,031.51	- 1,031.51	- 1,031.51	- 1,031.51	- 1,031.51	- 1,031.51	- 1,031.51	- 1,031.51	- 1,031.51	- 1,031.51	- 1,031.51	- 1,031.51	- 1,031.51	- 1,031.51	- 1,031.51	- 1,031.51	- 1,031.51	- 1,031.51	- 1,031.51
Water	138.19	- 6.91	- 6.91	- 6.91	- 6.91	- 6.91	- 6.91	- 6.91	- 6.91	- 6.91	- 6.91	- 6.91	- 6.91	- 6.91	- 6.91	- 6.91	- 6.91	- 6.91	- 6.91	- 6.91	- 6.91
Total:	**63,891.27**	3,194.56	3,194.56	3,194.56	3,194.56	3,194.56	3,194.56	3,194.56	3,194.56	3,194.56	3,194.56	3,194.56	3,194.56	3,194.56	3,194.56	3,194.56	3,194.56	3,194.56	3,194.56	3,194.56	3,194.56
Soil-based cultivation																					
Growing beds	1,031.25	- 51.56	- 51.56	- 51.56	- 51.56	- 51.56	- 51.56	- 51.56	- 51.56	- 51.56	- 51.56	- 51.56	- 51.56	- 51.56	- 51.56	- 51.56	- 51.56	- 51.56	- 51.56	- 51.56	- 51.56
Soil	2,062.50	- 103.13	- 103.13	- 103.13	- 103.13	- 103.13	- 103.13	- 103.13	- 103.13	- 103.13	- 103.13	- 103.13	- 103.13	- 103.13	- 103.13	- 103.13	- 103.13	- 103.13	- 103.13	- 103.13	- 103.13
Total:	**3,093.75**	154.69	154.69	154.69	154.69	154.69	154.69	154.69	154.69	154.69	154.69	154.69	154.69	154.69	154.69	154.69	154.69	154.69	154.69	154.69	154.69
	54,682.80	**- 6,536.49**	**- 5,836.15**	**- 5,210.85**	**- 4,652.54**	**- 4,154.06**	**- 3,708.98**	**- 3,311.59**	**- 2,956.78**	**- 2,639.98**	**- 2,357.12**	**- 2,104.57**	**- 1,879.08**	**- 1,677.75**	**- 1,497.99**	**- 1,337.50**	**- 1,194.19**	**- 1,066.24**	**- 952.00**	**- 850.00**	**- 758.93**
OPEX_Non-Heating																					
Electricity	Grow lights	- 1,859.83	- 1,945.48	- 2,031.13	- 2,116.78	- 2,202.43	- 2,288.08	- 2,373.73	- 2,459.38	- 2,545.03	- 2,630.68	- 2,716.33	- 2,801.98	- 2,887.63	- 2,973.28	- 3,058.93	- 3,144.58	- 3,230.23	- 3,315.88	- 3,401.53	- 3,487.18
	Pumps	- 265.16	- 277.37	- 289.58	- 301.79	- 314.00	- 326.22	- 338.43	- 350.64	- 362.85	- 375.06	- 387.27	- 399.48	- 411.70	- 423.91	- 436.12	- 448.33	- 460.54	- 472.75	- 484.96	- 497.17
Labor		- 2,290.00	- 2,290.00	- 2,290.00	- 2,290.00	- 2,290.00	- 2,290.00	- 2,290.00	- 2,290.00	- 2,290.00	- 2,290.00	- 2,290.00	- 2,290.00	- 2,290.00	- 2,290.00	- 2,290.00	- 2,290.00	- 2,290.00	- 2,290.00	- 2,290.00	- 2,290.00
Fish feed		- 3,019.50	- 3,019.50	- 3,019.50	- 3,019.50	- 3,019.50	- 3,019.50	- 3,019.50	- 3,019.50	- 3,019.50	- 3,019.50	- 3,019.50	- 3,019.50	- 3,019.50	- 3,019.50	- 3,019.50	- 3,019.50	- 3,019.50	- 3,019.50	- 3,019.50	- 3,019.50
Maintenance	Building	- 897.20	- 897.20	- 897.20	- 897.20	- 897.20	- 897.20	- 897.20	- 897.20	- 897.20	- 897.20	- 897.20	- 897.20	- 897.20	- 897.20	- 897.20	- 897.20	- 897.20	- 897.20	- 897.20	- 897.20
	Aquaponics	- 1,300.00	- 1,300.00	- 1,300.00	- 1,300.00	- 1,300.00	- 1,300.00	- 1,300.00	- 1,300.00	- 1,300.00	- 1,300.00	- 1,300.00	- 1,300.00	- 1,300.00	- 1,300.00	- 1,300.00	- 1,300.00	- 1,300.00	- 1,300.00	- 1,300.00	- 1,300.00
	76,343.93	**- 8,599.72**	**- 7,756.34**	**- 6,994.96**	**- 6,307.69**	**- 5,687.39**	**- 5,127.61**	**- 4,622.49**	**- 4,166.75**	**- 3,755.60**	**- 3,384.72**	**- 3,050.21**	**- 2,748.52**	**- 2,476.46**	**- 2,231.15**	**- 2,009.98**	**- 1,810.59**	**- 1,630.85**	**- 1,468.84**	**- 1,322.83**	**- 1,191.24**
NPC Total	**-183,677.79**	- 20,900.92	- 18,815.39	- 16,937.29	- 15,246.06	- 13,723.19	- 12,351.98	- 11,117.37	- 10,005.82	- 9,005.10	- 8,104.19	- 7,293.18	- 6,563.13	- 5,905.97	- 5,314.45	- 4,782.04	- 4,302.85	- 3,871.57	- 3,483.42	- 3,134.11	- 2,819.75
AG yield																					
Fish [CAD/kg]	8.8	2,200.00	2,200.00	2,200.00	2,200.00	2,200.00	2,200.00	2,200.00	2,200.00	2,200.00	2,200.00	2,200.00	2,200.00	2,200.00	2,200.00	2,200.00	2,200.00	2,200.00	2,200.00	2,200.00	2,200.00
Basil: NFT [CAD/kg]	7.5	14,850.00	14,850.00	14,850.00	14,850.00	14,850.00	14,850.00	14,850.00	14,850.00	14,850.00	14,850.00	14,850.00	14,850.00	14,850.00	14,850.00	14,850.00	14,850.00	14,850.00	14,850.00	14,850.00	14,850.00
Lettuce: Soil [CAD/kg]	5	4,950.00	4,950.00	4,950.00	4,950.00	4,950.00	4,950.00	4,950.00	4,950.00	4,950.00	4,950.00	4,950.00	4,950.00	4,950.00	4,950.00	4,950.00	4,950.00	4,950.00	4,950.00	4,950.00	4,950.00
Savings																					
Carbon offsets (Renewables)		1,944.87	2,210.08	2,475.29	2,740.50	3,005.71	3,041.07	3,076.43	3,111.79	3,147.15	3,182.51	3,217.87	3,253.24	3,288.60	3,323.96	3,359.32	3,394.68	3,430.04	3,465.40	3,500.76	3,536.13
Biomass waste [CAD/t]	85	42.08	42.08	42.08	42.08	42.08	42.08	42.08	42.08	42.08	42.08	42.08	42.08	42.08	42.08	42.08	42.08	42.08	42.08	42.08	42.08
	185,782.79	**21,416.92**	**19,333.67**	**17,450.98**	**15,749.78**	**14,212.79**	**12,707.91**	**11,362.34**	**10,159.23**	**9,083.49**	**8,121.64**	**7,261.63**	**6,492.68**	**5,805.14**	**5,190.39**	**4,640.74**	**4,149.29**	**3,709.87**	**3,316.98**	**2,965.70**	**2,651.61**
NPV Total	**2,105.00**	516.00	518.28	513.69	503.72	489.60	355.93	244.97	153.41	78.39	17.45	- 31.55	- 70.45	- 100.83	- 124.06	- 141.30	- 153.56	- 161.69	- 166.44	- 168.41	- 168.14
Cumulative		3,560.55	6,698.16	9,462.59	11,897.78	14,042.55	15,801.82	17,233.58	18,387.80	19,307.53	20,029.77	20,586.27	21,004.27	21,307.04	21,514.49	21,643.56	21,708.67	21,722.05	21,694.02	21,633.32	21,547.26

Discount rate 12 [%]

Hybrid 2: GSHP & Biomass

304 [m2] 6000 [l]

Lifespan	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Years	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**	**2036**	**2037**	**2038**	**2039**	**2040**	**2041**	**2042**	**2043**	**2044**	**2045**
Electricity rates [CAD/kWh]	0.104	0.160	0.167	0.175	0.182	0.189	0.197	0.204	0.212	0.219	0.226	0.234	0.241	0.248	0.256	0.263	0.271	0.278	0.285	0.293	0.300
Wood chip: Alberta waste rec	95	97	99	101	103	105	107	109	111	114	116	118	120	123	125	128	130	133	136	138	141
Carbon offset price [CAD/t]	95	110	125	140	155	170	172	174	176	178	180	182	184	186	188	190	192	194	196	198	200
CAPEX_Heating																					
Hydronic radiant heating	12,792.51	-639.63	-639.63	-639.63	-639.63	-639.63	-639.63	-639.63	-639.63	-639.63	-639.63	-639.63	-639.63	-639.63	-639.63	-639.63	-639.63	-639.63	-639.63	-639.63	-639.63
Biomass boiler	8,600.00	-430.00	-430.00	-430.00	-430.00	-430.00	-430.00	-430.00	-430.00	-430.00	-430.00	-430.00	-430.00	-430.00	-430.00	-430.00	-430.00	-430.00	-430.00	-430.00	-430.00
Ground loop installation	9,372.27	-468.61	-468.61	-468.61	-468.61	-468.61	-468.61	-468.61	-468.61	-468.61	-468.61	-468.61	-468.61	-468.61	-468.61	-468.61	-468.61	-468.61	-468.61	-468.61	-468.61
Heat pump	14,527.00	-726.35	-726.35	-726.35	-726.35	-726.35	-726.35	-726.35	-726.35	-726.35	-726.35	-726.35	-726.35	-726.35	-726.35	-726.35	-726.35	-726.35	-726.35	-726.35	-726.35
Total:	**45,291.78**	2,264.59	2,264.59	2,264.59	2,264.59	2,264.59	2,264.59	2,264.59	2,264.59	2,264.59	2,264.59	2,264.59	2,264.59	2,264.59	2,264.59	2,264.59	2,264.59	2,264.59	2,264.59	2,264.59	2,264.59
	16,915.22	**-2,021.95**	**-1,805.32**	**-1,611.89**	**-1,439.19**	**-1,284.99**	**-1,147.31**	**-1,024.38**	**-914.63**	**-816.63**	**-729.14**	**-651.02**	**-581.26**	**-518.99**	**-463.38**	**-413.73**	**-369.40**	**-329.82**	**-294.49**	**-262.93**	**-234.76**
OPEX_Heating																					
Fuel (Wood chip)		-1,577.74	-1,609.29	-1,641.48	-1,674.31	-1,707.79	-1,741.95	-1,776.79	-1,812.32	-1,848.57	-1,885.54	-1,923.25	-1,961.72	-2,000.95	-2,040.97	-2,081.79	-2,123.43	-2,165.90	-2,209.21	-2,253.40	-2,298.47
CoE		-2,068.79	-2,164.06	-2,259.33	-2,354.61	-2,449.88	-2,545.15	-2,640.43	-2,735.70	-2,830.97	-2,926.25	-3,021.52	-3,116.79	-3,212.06	-3,307.34	-3,402.61	-3,497.88	-3,593.16	-3,688.43	-3,783.70	-3,878.98
Maintenance		-307.73	-307.73	-307.73	-307.73	-307.73	-307.73	-307.73	-307.73	-307.73	-307.73	-307.73	-307.73	-307.73	-307.73	-307.73	-307.73	-307.73	-307.73	-307.73	-307.73
Transport		-814.11	-814.11	-814.11	-814.11	-814.11	-814.11	-814.11	-814.11	-814.11	-814.11	-814.11	-814.11	-814.11	-814.11	-814.11	-814.11	-814.11	-814.11	-814.11	-814.11
Labour		-265.94	-265.94	-265.94	-265.94	-265.94	-265.94	-265.94	-265.94	-265.94	-265.94	-265.94	-265.94	-265.94	-265.94	-265.94	-265.94	-265.94	-265.94	-265.94	-265.94
Total:		5,034.30	5,161.13	5,288.59	5,416.69	5,545.45	5,674.88	5,804.99	5,935.80	6,067.32	6,199.57	6,332.55	6,466.29	6,600.80	6,736.09	6,872.18	7,009.09	7,146.83	7,285.42	7,424.88	7,565.22
Net emissions impact (Gas)	[t CO2e]	6.76	6.76	6.76	6.76	6.76	6.76	6.76	6.76	6.76	6.76	6.76	6.76	6.76	6.76	6.76	6.76	6.76	6.76	6.76	6.76
Net emissions impact (RE)	[t CO2e]	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45
	43,449.81	**-4,494.92**	**-4,114.42**	**-3,764.32**	**-3,442.41**	**-3,146.64**	**-2,875.07**	**-2,625.88**	**-2,397.37**	**-2,187.94**	**-1,996.09**	**-1,820.46**	**-1,659.74**	**-1,512.73**	**-1,378.34**	**-1,255.52**	**-1,143.33**	**-1,040.90**	**-947.39**	**-862.08**	**-784.26**
NPC Heating	**-60,365.03**	-6,516.87	-5,919.74	-5,376.20	-4,881.59	-4,431.63	-4,022.38	-3,650.27	-3,312.00	-3,004.57	-2,725.23	-2,471.47	-2,241.00	-2,031.72	-1,841.72	-1,669.25	-1,512.74	-1,370.72	-1,241.88	-1,125.01	-1,019.02
CAPEX_Non-Heating																					
Building																					
Material	48,687.79	-2,434.39	-2,434.39	-2,434.39	-2,434.39	-2,434.39	-2,434.39	-2,434.39	-2,434.39	-2,434.39	-2,434.39	-2,434.39	-2,434.39	-2,434.39	-2,434.39	-2,434.39	-2,434.39	-2,434.39	-2,434.39	-2,434.39	-2,434.39
Labour	43,396.53	-2,169.83	-2,169.83	-2,169.83	-2,169.83	-2,169.83	-2,169.83	-2,169.83	-2,169.83	-2,169.83	-2,169.83	-2,169.83	-2,169.83	-2,169.83	-2,169.83	-2,169.83	-2,169.83	-2,169.83	-2,169.83	-2,169.83	-2,169.83
Total:	**92,084.32**	4,604.22	4,604.22	4,604.22	4,604.22	4,604.22	4,604.22	4,604.22	4,604.22	4,604.22	4,604.22	4,604.22	4,604.22	4,604.22	4,604.22	4,604.22	4,604.22	4,604.22	4,604.22	4,604.22	4,604.22
Aquaponics																					
Aquaculture system	10,590.00	-529.50	-529.50	-529.50	-529.50	-529.50	-529.50	-529.50	-529.50	-529.50	-529.50	-529.50	-529.50	-529.50	-529.50	-529.50	-529.50	-529.50	-529.50	-529.50	-529.50
NFT system 1: Horizontal	13,772.50	-688.63	-688.63	-688.63	-688.63	-688.63	-688.63	-688.63	-688.63	-688.63	-688.63	-688.63	-688.63	-688.63	-688.63	-688.63	-688.63	-688.63	-688.63	-688.63	-688.63
NFT system 2: Vertical	27,385.00	-1,369.25	-1,369.25	-1,369.25	-1,369.25	-1,369.25	-1,369.25	-1,369.25	-1,369.25	-1,369.25	-1,369.25	-1,369.25	-1,369.25	-1,369.25	-1,369.25	-1,369.25	-1,369.25	-1,369.25	-1,369.25	-1,369.25	-1,369.25
Growing lights	24,756.19	-1,237.81	-1,237.81	-1,237.81	-1,237.81	-1,237.81	-1,237.81	-1,237.81	-1,237.81	-1,237.81	-1,237.81	-1,237.81	-1,237.81	-1,237.81	-1,237.81	-1,237.81	-1,237.81	-1,237.81	-1,237.81	-1,237.81	-1,237.81
Water	165.83	-8.29	-8.29	-8.29	-8.29	-8.29	-8.29	-8.29	-8.29	-8.29	-8.29	-8.29	-8.29	-8.29	-8.29	-8.29	-8.29	-8.29	-8.29	-8.29	-8.29
Total:	**76,669.52**	3,833.48	3,833.48	3,833.48	3,833.48	3,833.48	3,833.48	3,833.48	3,833.48	3,833.48	3,833.48	3,833.48	3,833.48	3,833.48	3,833.48	3,833.48	3,833.48	3,833.48	3,833.48	3,833.48	3,833.48
Soil-based cultivation																					
Growing beds	1,237.50	-61.88	-61.88	-61.88	-61.88	-61.88	-61.88	-61.88	-61.88	-61.88	-61.88	-61.88	-61.88	-61.88	-61.88	-61.88	-61.88	-61.88	-61.88	-61.88	-61.88
Soil	2,475.00	-123.75	-123.75	-123.75	-123.75	-123.75	-123.75	-123.75	-123.75	-123.75	-123.75	-123.75	-123.75	-123.75	-123.75	-123.75	-123.75	-123.75	-123.75	-123.75	-123.75
Total:	**3,712.50**	185.63	185.63	185.63	185.63	185.63	185.63	185.63	185.63	185.63	185.63	185.63	185.63	185.63	185.63	185.63	185.63	185.63	185.63	185.63	185.63
	64,411.38	**-7,699.39**	**-6,874.46**	**-6,137.91**	**-5,480.27**	**-4,893.10**	**-4,368.84**	**-3,900.75**	**-3,482.81**	**-3,109.65**	**-2,776.48**	**-2,479.00**	**-2,213.39**	**-1,976.24**	**-1,764.50**	**-1,575.45**	**-1,406.65**	**-1,255.94**	**-1,121.37**	**-1,001.23**	**-893.95**
OPEX_Non-Heating																					
Electricity – Grow lights		-2,231.80	-2,334.58	-2,437.36	-2,540.14	-2,642.92	-2,745.70	-2,848.48	-2,951.26	-3,054.04	-3,156.82	-3,259.60	-3,362.38	-3,465.16	-3,567.94	-3,670.72	-3,773.50	-3,876.28	-3,979.06	-4,081.84	-4,184.62
Pumps		-318.19	-332.85	-347.50	-362.15	-376.81	-391.46	-406.11	-420.77	-435.42	-450.07	-464.73	-479.38	-494.03	-508.69	-523.34	-538.00	-552.65	-567.30	-581.96	-596.61
Labor		-2,748.00	-2,748.00	-2,748.00	-2,748.00	-2,748.00	-2,748.00	-2,748.00	-2,748.00	-2,748.00	-2,748.00	-2,748.00	-2,748.00	-2,748.00	-2,748.00	-2,748.00	-2,748.00	-2,748.00	-2,748.00	-2,748.00	-2,748.00
Fish feed		-3,623.40	-3,623.40	-3,623.40	-3,623.40	-3,623.40	-3,623.40	-3,623.40	-3,623.40	-3,623.40	-3,623.40	-3,623.40	-3,623.40	-3,623.40	-3,623.40	-3,623.40	-3,623.40	-3,623.40	-3,623.40	-3,623.40	-3,623.40
Maintenance – Building		-1,050.03	-1,050.03	-1,050.03	-1,050.03	-1,050.03	-1,050.03	-1,050.03	-1,050.03	-1,050.03	-1,050.03	-1,050.03	-1,050.03	-1,050.03	-1,050.03	-1,050.03	-1,050.03	-1,050.03	-1,050.03	-1,050.03	-1,050.03
Aquaponics		-1,560.00	-1,560.00	-1,560.00	-1,560.00	-1,560.00	-1,560.00	-1,560.00	-1,560.00	-1,560.00	-1,560.00	-1,560.00	-1,560.00	-1,560.00	-1,560.00	-1,560.00	-1,560.00	-1,560.00	-1,560.00	-1,560.00	-1,560.00
	91,414.01	**-10,295.91**	**-9,286.40**	**-8,375.01**	**-7,552.32**	**-6,809.78**	**-6,139.65**	**-5,534.96**	**-4,989.35**	**-4,497.13**	**-4,053.10**	**-3,652.60**	**-3,291.39**	**-2,965.66**	**-2,671.94**	**-2,407.11**	**-2,168.36**	**-1,953.14**	**-1,759.15**	**-1,584.30**	**-1,426.73**
NPC Total	**-216,190.42**	-24,512.17	-22,080.59	-19,889.12	-17,914.19	-16,134.51	-14,530.88	-13,085.98	-11,784.17	-10,611.35	-9,554.81	-8,603.07	-7,745.78	-6,973.62	-6,278.16	-5,651.81	-5,087.75	-4,579.80	-4,122.40	-3,710.54	-3,339.71
AG yield																					
Fish [CAD/kg]	8.8	2,640.00	2,640.00	2,640.00	2,640.00	2,640.00	2,640.00	2,640.00	2,640.00	2,640.00	2,640.00	2,640.00	2,640.00	2,640.00	2,640.00	2,640.00	2,640.00	2,640.00	2,640.00	2,640.00	2,640.00
Basil: NFT [CAD/kg]	7.5	17,820.00	17,820.00	17,820.00	17,820.00	17,820.00	17,820.00	17,820.00	17,820.00	17,820.00	17,820.00	17,820.00	17,820.00	17,820.00	17,820.00	17,820.00	17,820.00	17,820.00	17,820.00	17,820.00	17,820.00
Lettuce: Soil [CAD/kg]	5	5,940.00	5,940.00	5,940.00	5,940.00	5,940.00	5,940.00	5,940.00	5,940.00	5,940.00	5,940.00	5,940.00	5,940.00	5,940.00	5,940.00	5,940.00	5,940.00	5,940.00	5,940.00	5,940.00	5,940.00
Savings																					
Carbon offsets (Renewables)		2,220.60	2,523.41	2,826.22	3,129.03	3,431.83	3,472.21	3,512.58	3,552.96	3,593.33	3,633.71	3,674.08	3,714.46	3,754.83	3,795.20	3,835.58	3,875.95	3,916.33	3,956.70	3,997.08	4,037.45
Biomass waste [CAD/t]	85	50.50	50.50	50.50	50.50	50.50	50.50	50.50	50.50	50.50	50.50	50.50	50.50	50.50	50.50	50.50	50.50	50.50	50.50	50.50	50.50
	221,708.38	**25,599.20**	**23,097.82**	**20,838.59**	**18,798.32**	**16,956.04**	**15,159.78**	**13,553.78**	**12,117.89**	**10,834.11**	**9,686.31**	**8,660.10**	**7,742.59**	**6,922.28**	**6,188.87**	**5,533.15**	**4,946.90**	**4,422.76**	**3,954.14**	**3,535.17**	**3,160.59**
NPV Total	**5,517.97**	1,087.02	1,017.23	949.47	884.13	821.53	628.90	467.80	333.73	222.75	131.50	57.03	-3.19	-51.33	-89.29	-118.66	-140.85	-157.04	-168.26	-175.37	-179.12
Cumulative		3,560.55	6,698.16	9,462.59	11,897.78	14,042.55	15,801.82	17,233.58	18,387.80	19,307.53	20,029.77	20,586.27	21,004.27	21,307.04	21,514.49	21,643.56	21,708.67	21,722.05	21,694.02	21,633.32	21,547.26

Discount rate 12 [%]

Hybrid 2: GSHP & Biomass

348 [m2] 7000 [l]

Lifespan	0	1	2	3	4	5
Years	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
Electricity rates [CAD/kWh]	0.104	0.160	0.167	0.175	0.182	0.189
Wood chip: Alberta waste rec	95	97	99	101	103	105
Carbon offset price [CAD/t]	95	110	125	140	155	170
CAPEX_Heating						
Hydronic radiant heating	14,654.50	-732.73	-732.73	-732.73	-732.73	-732.73
Biomass boiler	10,300.00	-515.00	-515.00	-515.00	-515.00	-515.00
Ground loop installation	8,352.45	-417.62	-417.62	-417.62	-417.62	-417.62
Heat pump	13,660.00	-683.00	-683.00	-683.00	-683.00	-683.00
Total:	**46,966.95**	2,348.35	2,348.35	2,348.35	2,348.35	2,348.35
	17,540.85	**-2,096.74**	**-1,872.09**	**-1,671.51**	**-1,492.42**	**-1,332.52**
OPEX_Heating						
Fuel (Wood chip)		-2,064.01	-2,105.29	-2,147.40	-2,190.34	-2,234.15
CoE		-1,739.83	-1,819.96	-1,900.08	-1,980.20	-2,060.33
Maintenance		-464.20	-464.20	-464.20	-464.20	-464.20
Transport		-1,065.02	-1,065.02	-1,065.02	-1,065.02	-1,065.02
Labour		-347.91	-347.91	-347.91	-347.91	-347.91
Total:		5,680.97	5,802.37	5,924.60	6,047.67	6,171.60
Net emissions impact (Gas)	[t CO2e]	5.88	5.88	5.88	5.88	5.88
Net emissions impact (RE)	[t CO2e]	0.58	0.58	0.58	0.58	0.58
	48,080.27	**-5,072.29**	**-4,625.62**	**-4,217.01**	**-3,843.41**	**-3,501.93**
NPC Heating	**-65,621.12**	-7,169.03	-6,497.70	-5,888.52	-5,335.82	-4,834.45
CAPEX_Non-Heating						
Building						
Material	52,233.67	-2,611.68	-2,611.68	-2,611.68	-2,611.68	-2,611.68
Labour	49,430.08	-2,471.50	-2,471.50	-2,471.50	-2,471.50	-2,471.50
Total:	**101,663.75**	5,083.19	5,083.19	5,083.19	5,083.19	5,083.19
Aquaponics						
Aquaculture system	12,355.00	-617.75	-617.75	-617.75	-617.75	-617.75
NFT system 1: Horizontal	16,067.92	-803.40	-803.40	-803.40	-803.40	-803.40
NFT system 2: Vertical	31,949.17	-1,597.46	-1,597.46	-1,597.46	-1,597.46	-1,597.46
Growing lights	28,882.22	-1,444.11	-1,444.11	-1,444.11	-1,444.11	-1,444.11
Water	193.47	-9.67	-9.67	-9.67	-9.67	-9.67
Total:	**89,447.77**	4,472.39	4,472.39	4,472.39	4,472.39	4,472.39
Soil-based cultivation						
Growing beds	1,443.75	-72.19	-72.19	-72.19	-72.19	-72.19
Soil	2,887.50	-144.38	-144.38	-144.38	-144.38	-144.38
Total:	**4,331.25**	216.56	216.56	216.56	216.56	216.56
	72,992.44	**-8,725.12**	**-7,790.29**	**-6,955.62**	**-6,210.37**	**-5,544.97**
OPEX_Non-Heating						
Electricity Grow lights		-2,603.76	-2,723.67	-2,843.58	-2,963.49	-3,083.40
Pumps		-371.22	-388.32	-405.42	-422.51	-439.61
Labor		-3,206.00	-3,206.00	-3,206.00	-3,206.00	-3,206.00
Fish feed		-4,227.30	-4,227.30	-4,227.30	-4,227.30	-4,227.30
Maintenance Building		-1,202.87	-1,202.87	-1,202.87	-1,202.87	-1,202.87
Aquaponics		-1,820.00	-1,820.00	-1,820.00	-1,820.00	-1,820.00
	106,484.08	**-11,992.10**	**-10,816.46**	**-9,755.07**	**-8,796.95**	**-7,932.16**
NPC Total	**-245,097.64**	-27,886.26	-25,104.45	-22,599.20	-20,343.15	-18,311.59
AG yield						
Fish [CAD/kg]	8.8	3,080.00	3,080.00	3,080.00	3,080.00	3,080.00
Basil: NFT [CAD/kg]	7.5	20,790.00	20,790.00	20,790.00	20,790.00	20,790.00
Lettuce: Soil [CAD/kg]	5	6,930.00	6,930.00	6,930.00	6,930.00	6,930.00
Savings						
Carbon offsets (Renewables)		2,481.94	2,820.38	3,158.83	3,497.28	3,835.72
Biomass waste [CAD/t]	85	58.92	58.92	58.92	58.92	58.92
	257,477.56	**29,768.62**	**26,848.93**	**24,213.16**	**21,833.98**	**19,686.67**
NPV Total	**12,379.92**	1,882.36	1,744.48	1,613.96	1,490.84	1,375.08
Cumulative		3,560.55	6,698.16	9,462.59	11,897.78	14,042.55

Lifespan	6	7	8	9	10
Years	**2031**	**2032**	**2033**	**2034**	**2035**
Electricity rates [CAD/kWh]	0.197	0.204	0.212	0.219	0.226
Wood chip: Alberta waste rec	107	109	111	114	116
Carbon offset price [CAD/t]	172	174	176	178	180
CAPEX_Heating					
Hydronic radiant heating	-732.73	-732.73	-732.73	-732.73	-732.73
Biomass boiler	-515.00	-515.00	-515.00	-515.00	-515.00
Ground loop installation	-417.62	-417.62	-417.62	-417.62	-417.62
Heat pump	-683.00	-683.00	-683.00	-683.00	-683.00
Total:	2,348.35	2,348.35	2,348.35	2,348.35	2,348.35
	-1,189.75	**-1,062.27**	**-948.46**	**-846.84**	**-756.11**
OPEX_Heating					
Fuel (Wood chip)	-2,278.83	-2,324.41	-2,370.90	-2,418.32	-2,466.68
CoE	-2,140.45	-2,220.58	-2,300.70	-2,380.82	-2,460.95
Maintenance	-464.20	-464.20	-464.20	-464.20	-464.20
Transport	-1,065.02	-1,065.02	-1,065.02	-1,065.02	-1,065.02
Labour	-347.91	-347.91	-347.91	-347.91	-347.91
Total:	6,296.41	6,422.11	6,548.72	6,676.27	6,804.76
Net emissions impact (Gas)	5.88	5.88	5.88	5.88	5.88
Net emissions impact (RE)	0.58	0.58	0.58	0.58	0.58
	-3,189.96	**-2,905.04**	**-2,644.92**	**-2,407.53**	**-2,190.95**
NPC Heating	-4,379.70	-3,967.31	-3,593.38	-3,254.37	-2,947.05
CAPEX_Non-Heating					
Building					
Material	-2,611.68	-2,611.68	-2,611.68	-2,611.68	-2,611.68
Labour	-2,471.50	-2,471.50	-2,471.50	-2,471.50	-2,471.50
Total:	5,083.19	5,083.19	5,083.19	5,083.19	5,083.19
Aquaponics					
Aquaculture system	-617.75	-617.75	-617.75	-617.75	-617.75
NFT system 1: Horizontal	-803.40	-803.40	-803.40	-803.40	-803.40
NFT system 2: Vertical	-1,597.46	-1,597.46	-1,597.46	-1,597.46	-1,597.46
Growing lights	-1,444.11	-1,444.11	-1,444.11	-1,444.11	-1,444.11
Water	-9.67	-9.67	-9.67	-9.67	-9.67
Total:	4,472.39	4,472.39	4,472.39	4,472.39	4,472.39
Soil-based cultivation					
Growing beds	-72.19	-72.19	-72.19	-72.19	-72.19
Soil	-144.38	-144.38	-144.38	-144.38	-144.38
Total:	216.56	216.56	216.56	216.56	216.56
	-4,950.87	**-4,420.42**	**-3,946.80**	**-3,523.93**	**-3,146.37**
OPEX_Non-Heating					
Electricity Grow lights	-3,203.31	-3,323.22	-3,443.13	-3,563.04	-3,682.95
Pumps	-456.70	-473.80	-490.89	-507.99	-525.09
Labor	-3,206.00	-3,206.00	-3,206.00	-3,206.00	-3,206.00
Fish feed	-4,227.30	-4,227.30	-4,227.30	-4,227.30	-4,227.30
Maintenance Building	-1,202.87	-1,202.87	-1,202.87	-1,202.87	-1,202.87
Aquaponics	-1,820.00	-1,820.00	-1,820.00	-1,820.00	-1,820.00
	-7,151.70	**-6,447.42**	**-5,811.96**	**-5,238.65**	**-4,721.48**
NPC Total	-16,482.27	-14,835.15	-13,352.14	-12,016.95	-10,814.90
AG yield					
Fish [CAD/kg]	3,080.00	3,080.00	3,080.00	3,080.00	3,080.00
Basil: NFT [CAD/kg]	20,790.00	20,790.00	20,790.00	20,790.00	20,790.00
Lettuce: Soil [CAD/kg]	6,930.00	6,930.00	6,930.00	6,930.00	6,930.00
Savings					
Carbon offsets (Renewables)	3,880.85	3,925.97	3,971.10	4,016.23	4,061.35
Biomass waste [CAD/t]	58.92	58.92	58.92	58.92	58.92
	17,600.25	**15,734.92**	**14,067.26**	**12,576.33**	**11,243.39**
NPV Total	1,117.97	899.77	715.12	559.37	428.49
Cumulative	15,801.82	17,233.58	18,387.80	19,307.53	20,029.77

Lifespan	11	12	13	14	15
Years	**2036**	**2037**	**2038**	**2039**	**2040**
Electricity rates [CAD/kWh]	0.234	0.241	0.248	0.256	0.263
Wood chip: Alberta waste rec	118	120	123	125	128
Carbon offset price [CAD/t]	182	184	186	188	190
CAPEX_Heating					
Hydronic radiant heating	-732.73	-732.73	-732.73	-732.73	-732.73
Biomass boiler	-515.00	-515.00	-515.00	-515.00	-515.00
Ground loop installation	-417.62	-417.62	-417.62	-417.62	-417.62
Heat pump	-683.00	-683.00	-683.00	-683.00	-683.00
Total:	2,348.35	2,348.35	2,348.35	2,348.35	2,348.35
	-675.09	**-602.76**	**-538.18**	**-480.52**	**-429.03**
OPEX_Heating					
Fuel (Wood chip)	-2,516.02	-2,566.34	-2,617.66	-2,670.02	-2,723.42
CoE	-2,541.07	-2,621.20	-2,701.32	-2,781.44	-2,861.57
Maintenance	-464.20	-464.20	-464.20	-464.20	-464.20
Transport	-1,065.02	-1,065.02	-1,065.02	-1,065.02	-1,065.02
Labour	-347.91	-347.91	-347.91	-347.91	-347.91
Total:	6,934.21	7,064.66	7,196.11	7,328.59	7,462.11
Net emissions impact (Gas)	5.88	5.88	5.88	5.88	5.88
Net emissions impact (RE)	0.58	0.58	0.58	0.58	0.58
	-1,993.42	**-1,813.32**	**-1,649.16**	**-1,499.57**	**-1,363.30**
NPC Heating	-2,668.51	-2,416.08	-2,187.34	-1,980.09	-1,792.33
CAPEX_Non-Heating					
Building					
Material	-2,611.68	-2,611.68	-2,611.68	-2,611.68	-2,611.68
Labour	-2,471.50	-2,471.50	-2,471.50	-2,471.50	-2,471.50
Total:	5,083.19	5,083.19	5,083.19	5,083.19	5,083.19
Aquaponics					
Aquaculture system	-617.75	-617.75	-617.75	-617.75	-617.75
NFT system 1: Horizontal	-803.40	-803.40	-803.40	-803.40	-803.40
NFT system 2: Vertical	-1,597.46	-1,597.46	-1,597.46	-1,597.46	-1,597.46
Growing lights	-1,444.11	-1,444.11	-1,444.11	-1,444.11	-1,444.11
Water	-9.67	-9.67	-9.67	-9.67	-9.67
Total:	4,472.39	4,472.39	4,472.39	4,472.39	4,472.39
Soil-based cultivation					
Growing beds	-72.19	-72.19	-72.19	-72.19	-72.19
Soil	-144.38	-144.38	-144.38	-144.38	-144.38
Total:	216.56	216.56	216.56	216.56	216.56
	-2,809.26	**-2,508.26**	**-2,239.52**	**-1,999.57**	**-1,785.33**
OPEX_Non-Heating					
Electricity Grow lights	-3,802.86	-3,922.77	-4,042.68	-4,162.59	-4,282.50
Pumps	-542.18	-559.28	-576.37	-593.47	-610.57
Labor	-3,206.00	-3,206.00	-3,206.00	-3,206.00	-3,206.00
Fish feed	-4,227.30	-4,227.30	-4,227.30	-4,227.30	-4,227.30
Maintenance Building	-1,202.87	-1,202.87	-1,202.87	-1,202.87	-1,202.87
Aquaponics	-1,820.00	-1,820.00	-1,820.00	-1,820.00	-1,820.00
	-4,255.00	**-3,834.27**	**-3,454.85**	**-3,112.72**	**-2,804.25**
NPC Total	-9,732.77	-8,758.62	-7,881.72	-7,092.39	-6,381.92
AG yield					
Fish [CAD/kg]	3,080.00	3,080.00	3,080.00	3,080.00	3,080.00
Basil: NFT [CAD/kg]	20,790.00	20,790.00	20,790.00	20,790.00	20,790.00
Lettuce: Soil [CAD/kg]	6,930.00	6,930.00	6,930.00	6,930.00	6,930.00
Savings					
Carbon offsets (Renewables)	4,106.48	4,151.61	4,196.73	4,241.86	4,286.98
Biomass waste [CAD/t]	58.92	58.92	58.92	58.92	58.92
	10,051.72	**8,986.33**	**8,033.85**	**7,182.31**	**6,421.02**
NPV Total	318.95	227.71	152.13	89.92	39.11
Cumulative	20,586.27	21,004.27	21,307.04	21,514.49	21,643.56

Lifespan	16	17	18	19	20
Years	**2041**	**2042**	**2043**	**2044**	**2045**
Electricity rates [CAD/kWh]	0.271	0.278	0.285	0.293	0.300
Wood chip: Alberta waste rec	130	133	136	138	141
Carbon offset price [CAD/t]	192	194	196	198	200
CAPEX_Heating					
Hydronic radiant heating	-732.73	-732.73	-732.73	-732.73	-732.73
Biomass boiler	-515.00	-515.00	-515.00	-515.00	-515.00
Ground loop installation	-417.62	-417.62	-417.62	-417.62	-417.62
Heat pump	-683.00	-683.00	-683.00	-683.00	-683.00
Total:	2,348.35	2,348.35	2,348.35	2,348.35	2,348.35
	-383.07	**-342.02**	**-305.38**	**-272.66**	**-243.45**
OPEX_Heating					
Fuel (Wood chip)	-2,777.89	-2,833.44	-2,890.11	-2,947.92	-3,006.87
CoE	-2,941.69	-3,021.81	-3,101.94	-3,182.06	-3,262.19
Maintenance	-464.20	-464.20	-464.20	-464.20	-464.20
Transport	-1,065.02	-1,065.02	-1,065.02	-1,065.02	-1,065.02
Labour	-347.91	-347.91	-347.91	-347.91	-347.91
Total:	7,596.70	7,732.38	7,869.18	8,007.10	8,146.18
Net emissions impact (Gas)	5.88	5.88	5.88	5.88	5.88
Net emissions impact (RE)	0.58	0.58	0.58	0.58	0.58
	-1,239.19	**-1,126.18**	**-1,023.30**	**-929.68**	**-844.49**
NPC Heating	-1,622.25	-1,468.20	-1,328.68	-1,202.34	-1,087.93
CAPEX_Non-Heating					
Building					
Material	-2,611.68	-2,611.68	-2,611.68	-2,611.68	-2,611.68
Labour	-2,471.50	-2,471.50	-2,471.50	-2,471.50	-2,471.50
Total:	5,083.19	5,083.19	5,083.19	5,083.19	5,083.19
Aquaponics					
Aquaculture system	-617.75	-617.75	-617.75	-617.75	-617.75
NFT system 1: Horizontal	-803.40	-803.40	-803.40	-803.40	-803.40
NFT system 2: Vertical	-1,597.46	-1,597.46	-1,597.46	-1,597.46	-1,597.46
Growing lights	-1,444.11	-1,444.11	-1,444.11	-1,444.11	-1,444.11
Water	-9.67	-9.67	-9.67	-9.67	-9.67
Total:	4,472.39	4,472.39	4,472.39	4,472.39	4,472.39
Soil-based cultivation					
Growing beds	-72.19	-72.19	-72.19	-72.19	-72.19
Soil	-144.38	-144.38	-144.38	-144.38	-144.38
Total:	216.56	216.56	216.56	216.56	216.56
	-1,594.05	**-1,423.26**	**-1,270.76**	**-1,134.61**	**-1,013.05**
OPEX_Non-Heating					
Electricity Grow lights	-4,402.41	-4,522.32	-4,642.23	-4,762.14	-4,882.06
Pumps	-627.66	-644.76	-661.85	-678.95	-696.04
Labor	-3,206.00	-3,206.00	-3,206.00	-3,206.00	-3,206.00
Fish feed	-4,227.30	-4,227.30	-4,227.30	-4,227.30	-4,227.30
Maintenance Building	-1,202.87	-1,202.87	-1,202.87	-1,202.87	-1,202.87
Aquaponics	-1,820.00	-1,820.00	-1,820.00	-1,820.00	-1,820.00
	-2,526.14	**-2,275.44**	**-2,049.46**	**-1,845.78**	**-1,662.22**
NPC Total	-5,742.44	-5,166.90	-4,648.90	-4,182.73	-3,763.20
AG yield					
Fish [CAD/kg]	3,080.00	3,080.00	3,080.00	3,080.00	3,080.00
Basil: NFT [CAD/kg]	20,790.00	20,790.00	20,790.00	20,790.00	20,790.00
Lettuce: Soil [CAD/kg]	6,930.00	6,930.00	6,930.00	6,930.00	6,930.00
Savings					
Carbon offsets (Renewables)	4,332.11	4,377.24	4,422.36	4,467.49	4,512.61
Biomass waste [CAD/t]	58.92	58.92	58.92	58.92	58.92
	5,740.42	**5,131.95**	**4,587.96**	**4,101.64**	**3,666.85**
NPV Total	-2.02	-34.95	-60.94	-81.09	-96.35
Cumulative	21,708.67	21,722.05	21,694.02	21,633.32	21,547.26

Discount rate 12 [%]

Hybrid 2: GSHP & Biomass

392 [m2] 8000 [l]

Lifespan	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Years	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**	**2036**	**2037**	**2038**	**2039**	**2040**	**2041**	**2042**	**2043**	**2044**	**2045**
Electricity rates [CAD/kWh]	0.104	0.160	0.167	0.175	0.182	0.189	0.197	0.204	0.212	0.219	0.226	0.234	0.241	0.248	0.256	0.263	0.271	0.278	0.285	0.293	0.300
Wood chip: Alberta waste rec	95	97	99	101	103	105	107	109	111	114	116	118	120	123	125	128	130	133	136	138	141
Carbon offset price [CAD/t]	95	110	125	140	155	170	172	174	176	178	180	182	184	186	188	190	192	194	196	198	200
CAPEX_Heating																					
Hydronic radiant heating	16,516.50	-825.82	-825.82	-825.82	-825.82	-825.82	-825.82	-825.82	-825.82	-825.82	-825.82	-825.82	-825.82	-825.82	-825.82	-825.82	-825.82	-825.82	-825.82	-825.82	-825.82
Biomass boiler	10,300.00	-515.00	-515.00	-515.00	-515.00	-515.00	-515.00	-515.00	-515.00	-515.00	-515.00	-515.00	-515.00	-515.00	-515.00	-515.00	-515.00	-515.00	-515.00	-515.00	-515.00
Ground loop installation	11,300.93	-565.05	-565.05	-565.05	-565.05	-565.05	-565.05	-565.05	-565.05	-565.05	-565.05	-565.05	-565.05	-565.05	-565.05	-565.05	-565.05	-565.05	-565.05	-565.05	-565.05
Heat pump	18,383.00	-919.15	-919.15	-919.15	-919.15	-919.15	-919.15	-919.15	-919.15	-919.15	-919.15	-919.15	-919.15	-919.15	-919.15	-919.15	-919.15	-919.15	-919.15	-919.15	-919.15
Total:	**56,500.43**	2,825.02	2,825.02	2,825.02	2,825.02	2,825.02	2,825.02	2,825.02	2,825.02	2,825.02	2,825.02	2,825.02	2,825.02	2,825.02	2,825.02	2,825.02	2,825.02	2,825.02	2,825.02	2,825.02	2,825.02
	21,101.34	**-2,522.34**	**-2,252.09**	**-2,010.79**	**-1,795.35**	**-1,602.99**	**-1,431.24**	**-1,277.90**	**-1,140.98**	**-1,018.73**	**-909.58**	**-812.13**	**-725.11**	**-647.42**	**-578.06**	**-516.12**	**-460.82**	**-411.45**	**-367.36**	**-328.00**	**-292.86**
OPEX_Heating																					
Fuel (Wood chip)		-1,962.40	-2,001.65	-2,041.68	-2,082.52	-2,124.17	-2,166.65	-2,209.98	-2,254.18	-2,299.27	-2,345.25	-2,392.16	-2,440.00	-2,488.80	-2,538.58	-2,589.35	-2,641.14	-2,693.96	-2,747.84	-2,802.79	-2,858.85
CoE		-2,573.17	-2,691.68	-2,810.18	-2,928.68	-3,047.18	-3,165.68	-3,284.18	-3,402.68	-3,521.19	-3,639.69	-3,758.19	-3,876.69	-3,995.19	-4,113.69	-4,232.19	-4,350.70	-4,469.20	-4,587.70	-4,706.20	-4,824.70
Maintenance		-382.76	-382.76	-382.76	-382.76	-382.76	-382.76	-382.76	-382.76	-382.76	-382.76	-382.76	-382.76	-382.76	-382.76	-382.76	-382.76	-382.76	-382.76	-382.76	-382.76
Transport		-1,012.59	-1,012.59	-1,012.59	-1,012.59	-1,012.59	-1,012.59	-1,012.59	-1,012.59	-1,012.59	-1,012.59	-1,012.59	-1,012.59	-1,012.59	-1,012.59	-1,012.59	-1,012.59	-1,012.59	-1,012.59	-1,012.59	-1,012.59
Labour		-330.78	-330.78	-330.78	-330.78	-330.78	-330.78	-330.78	-330.78	-330.78	-330.78	-330.78	-330.78	-330.78	-330.78	-330.78	-330.78	-330.78	-330.78	-330.78	-330.78
Total:		6,261.71	6,419.46	6,577.99	6,737.33	6,897.48	7,058.46	7,220.30	7,383.00	7,546.58	7,711.07	7,876.48	8,042.82	8,210.12	8,378.40	8,547.67	8,717.96	8,889.29	9,061.67	9,235.13	9,409.68
Net emissions impact (Gas)	[t CO2e]	8.41	8.41	8.41	8.41	8.41	8.41	8.41	8.41	8.41	8.41	8.41	8.41	8.41	8.41	8.41	8.41	8.41	8.41	8.41	8.41
Net emissions impact (RE)	[t CO2e]	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56
	54,043.22	**-5,590.81**	**-5,117.55**	**-4,682.08**	**-4,281.69**	**-3,913.81**	**-3,576.04**	**-3,266.10**	**-2,981.87**	**-2,721.37**	**-2,482.76**	**-2,264.30**	**-2,064.39**	**-1,881.55**	**-1,714.39**	**-1,561.63**	**-1,422.09**	**-1,294.67**	**-1,178.38**	**-1,072.26**	**-975.47**
NPC Heating	**-75,144.55**	-8,113.15	-7,369.64	-6,692.88	-6,077.05	-5,516.81	-5,007.28	-4,543.99	-4,122.85	-3,740.10	-3,392.34	-3,076.43	-2,789.50	-2,528.97	-2,292.44	-2,077.75	-1,882.91	-1,706.12	-1,545.74	-1,400.26	-1,268.33
CAPEX_Non-Heating																					
Building																					
Material	58,484.42	-2,924.22	-2,924.22	-2,924.22	-2,924.22	-2,924.22	-2,924.22	-2,924.22	-2,924.22	-2,924.22	-2,924.22	-2,924.22	-2,924.22	-2,924.22	-2,924.22	-2,924.22	-2,924.22	-2,924.22	-2,924.22	-2,924.22	-2,924.22
Labour	55,463.63	-2,773.18	-2,773.18	-2,773.18	-2,773.18	-2,773.18	-2,773.18	-2,773.18	-2,773.18	-2,773.18	-2,773.18	-2,773.18	-2,773.18	-2,773.18	-2,773.18	-2,773.18	-2,773.18	-2,773.18	-2,773.18	-2,773.18	-2,773.18
Total:	**113,948.05**	5,697.40	5,697.40	5,697.40	5,697.40	5,697.40	5,697.40	5,697.40	5,697.40	5,697.40	5,697.40	5,697.40	5,697.40	5,697.40	5,697.40	5,697.40	5,697.40	5,697.40	5,697.40	5,697.40	5,697.40
Aquaponics																					
Aquaculture system	14,120.00	-706.00	-706.00	-706.00	-706.00	-706.00	-706.00	-706.00	-706.00	-706.00	-706.00	-706.00	-706.00	-706.00	-706.00	-706.00	-706.00	-706.00	-706.00	-706.00	-706.00
NFT system 1: Horizontal	18,363.33	-918.17	-918.17	-918.17	-918.17	-918.17	-918.17	-918.17	-918.17	-918.17	-918.17	-918.17	-918.17	-918.17	-918.17	-918.17	-918.17	-918.17	-918.17	-918.17	-918.17
NFT system 2: Vertical	36,513.33	-1,825.67	-1,825.67	-1,825.67	-1,825.67	-1,825.67	-1,825.67	-1,825.67	-1,825.67	-1,825.67	-1,825.67	-1,825.67	-1,825.67	-1,825.67	-1,825.67	-1,825.67	-1,825.67	-1,825.67	-1,825.67	-1,825.67	-1,825.67
Growing lights	33,008.25	-1,650.41	-1,650.41	-1,650.41	-1,650.41	-1,650.41	-1,650.41	-1,650.41	-1,650.41	-1,650.41	-1,650.41	-1,650.41	-1,650.41	-1,650.41	-1,650.41	-1,650.41	-1,650.41	-1,650.41	-1,650.41	-1,650.41	-1,650.41
Water	221.11	-11.06	-11.06	-11.06	-11.06	-11.06	-11.06	-11.06	-11.06	-11.06	-11.06	-11.06	-11.06	-11.06	-11.06	-11.06	-11.06	-11.06	-11.06	-11.06	-11.06
Total:	**102,226.03**	5,111.30	5,111.30	5,111.30	5,111.30	5,111.30	5,111.30	5,111.30	5,111.30	5,111.30	5,111.30	5,111.30	5,111.30	5,111.30	5,111.30	5,111.30	5,111.30	5,111.30	5,111.30	5,111.30	5,111.30
Soil-based cultivation																					
Growing beds	1,650.00	-82.50	-82.50	-82.50	-82.50	-82.50	-82.50	-82.50	-82.50	-82.50	-82.50	-82.50	-82.50	-82.50	-82.50	-82.50	-82.50	-82.50	-82.50	-82.50	-82.50
Soil	3,300.00	-165.00	-165.00	-165.00	-165.00	-165.00	-165.00	-165.00	-165.00	-165.00	-165.00	-165.00	-165.00	-165.00	-165.00	-165.00	-165.00	-165.00	-165.00	-165.00	-165.00
Total:	**4,950.00**	247.50	247.50	247.50	247.50	247.50	247.50	247.50	247.50	247.50	247.50	247.50	247.50	247.50	247.50	247.50	247.50	247.50	247.50	247.50	247.50
	82,583.69	**-9,871.61**	**-8,813.94**	**-7,869.59**	**-7,026.42**	**-6,273.59**	**-5,601.42**	**-5,001.27**	**-4,465.42**	**-3,986.98**	**-3,559.80**	**-3,178.39**	**-2,837.85**	**-2,533.80**	**-2,262.32**	**-2,019.93**	**-1,803.51**	**-1,610.27**	**-1,437.74**	**-1,283.70**	**-1,146.16**
OPEX_Non-Heating																					
Electricity – Grow lights		-2,975.73	-3,112.77	-3,249.81	-3,386.85	-3,523.89	-3,660.93	-3,797.97	-3,935.01	-4,072.05	-4,209.09	-4,346.13	-4,483.17	-4,620.21	-4,757.25	-4,894.29	-5,031.33	-5,168.37	-5,305.41	-5,442.45	-5,579.49
Pumps		-424.26	-443.79	-463.33	-482.87	-502.41	-521.95	-541.48	-561.02	-580.56	-600.10	-619.64	-639.17	-658.71	-678.25	-697.79	-717.33	-736.86	-756.40	-775.94	-795.48
Labor		-3,664.00	-3,664.00	-3,664.00	-3,664.00	-3,664.00	-3,664.00	-3,664.00	-3,664.00	-3,664.00	-3,664.00	-3,664.00	-3,664.00	-3,664.00	-3,664.00	-3,664.00	-3,664.00	-3,664.00	-3,664.00	-3,664.00	-3,664.00
Fish feed		-4,831.20	-4,831.20	-4,831.20	-4,831.20	-4,831.20	-4,831.20	-4,831.20	-4,831.20	-4,831.20	-4,831.20	-4,831.20	-4,831.20	-4,831.20	-4,831.20	-4,831.20	-4,831.20	-4,831.20	-4,831.20	-4,831.20	-4,831.20
Maintenance – Building		-1,355.71	-1,355.71	-1,355.71	-1,355.71	-1,355.71	-1,355.71	-1,355.71	-1,355.71	-1,355.71	-1,355.71	-1,355.71	-1,355.71	-1,355.71	-1,355.71	-1,355.71	-1,355.71	-1,355.71	-1,355.71	-1,355.71	-1,355.71
Aquaponics		-2,080.00	-2,080.00	-2,080.00	-2,080.00	-2,080.00	-2,080.00	-2,080.00	-2,080.00	-2,080.00	-2,080.00	-2,080.00	-2,080.00	-2,080.00	-2,080.00	-2,080.00	-2,080.00	-2,080.00	-2,080.00	-2,080.00	-2,080.00
	121,554.16	**-13,688.29**	**-12,346.51**	**-11,135.12**	**-10,041.58**	**-9,054.55**	**-8,163.74**	**-7,359.88**	**-6,634.56**	**-5,980.18**	**-5,389.86**	**-4,857.39**	**-4,377.14**	**-3,944.05**	**-3,553.51**	**-3,201.38**	**-2,883.92**	**-2,597.73**	**-2,339.77**	**-2,107.26**	**-1,897.71**
NPC Total	**-279,282.40**	-31,673.06	-28,530.09	-25,697.59	-23,145.04	-20,844.94	-18,772.44	-16,905.14	-15,222.83	-13,707.26	-12,342.00	-11,112.21	-10,004.50	-9,006.82	-8,108.27	-7,299.06	-6,570.34	-5,914.13	-5,323.25	-4,791.22	-4,312.20
AG yield																					
Fish [CAD/kg]	8.8	3,520.00	3,520.00	3,520.00	3,520.00	3,520.00	3,520.00	3,520.00	3,520.00	3,520.00	3,520.00	3,520.00	3,520.00	3,520.00	3,520.00	3,520.00	3,520.00	3,520.00	3,520.00	3,520.00	3,520.00
Basil: NFT [CAD/kg]	7.5	23,760.00	23,760.00	23,760.00	23,760.00	23,760.00	23,760.00	23,760.00	23,760.00	23,760.00	23,760.00	23,760.00	23,760.00	23,760.00	23,760.00	23,760.00	23,760.00	23,760.00	23,760.00	23,760.00	23,760.00
Lettuce: Soil [CAD/kg]	5	7,920.00	7,920.00	7,920.00	7,920.00	7,920.00	7,920.00	7,920.00	7,920.00	7,920.00	7,920.00	7,920.00	7,920.00	7,920.00	7,920.00	7,920.00	7,920.00	7,920.00	7,920.00	7,920.00	7,920.00
Savings																					
Carbon offsets (Renewables)		2,762.00	3,138.63	3,515.27	3,891.91	4,268.54	4,318.76	4,368.98	4,419.20	4,469.41	4,519.63	4,569.85	4,620.07	4,670.29	4,720.51	4,770.72	4,820.94	4,871.16	4,921.38	4,971.60	5,021.81
Biomass waste [CAD/t]	85	67.33	67.33	67.33	67.33	67.33	67.33	67.33	67.33	67.33	67.33	67.33	67.33	67.33	67.33	67.33	67.33	67.33	67.33	67.33	67.33
	293,450.22	**33,954.76**	**30,617.00**	**27,604.69**	**24,886.40**	**22,433.72**	**20,055.55**	**17,929.45**	**16,028.72**	**14,329.47**	**12,810.34**	**11,452.24**	**10,238.10**	**9,152.67**	**8,182.30**	**7,314.80**	**6,539.27**	**5,845.94**	**5,226.12**	**4,672.01**	**4,176.65**
NPV Total	**14,167.82**	2,281.70	2,086.91	1,907.10	1,741.36	1,588.78	1,283.11	1,024.31	805.90	622.21	468.33	340.03	233.60	145.86	74.03	15.74	-31.07	-68.18	-97.13	-119.21	-135.56
Cumulative		3,560.55	6,698.16	9,462.59	11,897.78	14,042.55	15,801.82	17,233.58	18,387.80	19,307.53	20,029.77	20,586.27	21,004.27	21,307.04	21,514.49	21,643.56	21,708.67	21,722.05	21,694.02	21,633.32	21,547.26

Discount rate 12 [%]

Hybrid 2: GSHP & Biomass

436 [m2] 9000 [l]

Lifespan	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Years	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**	**2036**	**2037**	**2038**	**2039**	**2040**	**2041**	**2042**	**2043**	**2044**	**2045**
Electricity rates [CAD/kWh]	0.104	0.160	0.167	0.175	0.182	0.189	0.197	0.204	0.212	0.219	0.226	0.234	0.241	0.248	0.256	0.263	0.271	0.278	0.285	0.293	0.300
Wood chip: Alberta waste rec	95	97	99	101	103	105	107	109	111	114	116	118	120	123	125	128	130	133	136	138	141
Carbon offset price [CAD/t]	95	110	125	140	155	170	172	174	176	178	180	182	184	186	188	190	192	194	196	198	200
CAPEX_Heating																					
Hydronic radiant heating	18,378.49	-918.92	-918.92	-918.92	-918.92	-918.92	-918.92	-918.92	-918.92	-918.92	-918.92	-918.92	-918.92	-918.92	-918.92	-918.92	-918.92	-918.92	-918.92	-918.92	-918.92
Biomass boiler	10,300.00	-515.00	-515.00	-515.00	-515.00	-515.00	-515.00	-515.00	-515.00	-515.00	-515.00	-515.00	-515.00	-515.00	-515.00	-515.00	-515.00	-515.00	-515.00	-515.00	-515.00
Ground loop installation	12,265.26	-613.26	-613.26	-613.26	-613.26	-613.26	-613.26	-613.26	-613.26	-613.26	-613.26	-613.26	-613.26	-613.26	-613.26	-613.26	-613.26	-613.26	-613.26	-613.26	-613.26
Heat pump	18,383.00	-919.15	-919.15	-919.15	-919.15	-919.15	-919.15	-919.15	-919.15	-919.15	-919.15	-919.15	-919.15	-919.15	-919.15	-919.15	-919.15	-919.15	-919.15	-919.15	-919.15
Total:	**59,326.75**	2,966.34	2,966.34	2,966.34	2,966.34	2,966.34	2,966.34	2,966.34	2,966.34	2,966.34	2,966.34	2,966.34	2,966.34	2,966.34	2,966.34	2,966.34	2,966.34	2,966.34	2,966.34	2,966.34	2,966.34
	22,156.89	**-2,648.52**	**-2,364.75**	**-2,111.38**	**-1,885.16**	**-1,683.18**	**-1,502.84**	**-1,341.82**	**-1,198.05**	**-1,069.69**	**-955.08**	**-852.75**	**-761.38**	**-679.81**	**-606.97**	**-541.94**	**-483.87**	**-432.03**	**-385.74**	**-344.41**	**-307.51**
OPEX_Heating																					
Fuel (Wood chip)		-2,156.66	-2,199.79	-2,243.79	-2,288.66	-2,334.44	-2,381.13	-2,428.75	-2,477.32	-2,526.87	-2,577.41	-2,628.95	-2,681.53	-2,735.16	-2,789.87	-2,845.67	-2,902.58	-2,960.63	-3,019.84	-3,080.24	-3,141.84
CoE		-2,827.89	-2,958.12	-3,088.35	-3,218.58	-3,348.82	-3,479.05	-3,609.28	-3,739.51	-3,869.74	-3,999.98	-4,130.21	-4,260.44	-4,390.67	-4,520.90	-4,651.13	-4,781.37	-4,911.60	-5,041.83	-5,172.06	-5,302.29
Maintenance		-420.65	-420.65	-420.65	-420.65	-420.65	-420.65	-420.65	-420.65	-420.65	-420.65	-420.65	-420.65	-420.65	-420.65	-420.65	-420.65	-420.65	-420.65	-420.65	-420.65
Transport		-1,112.83	-1,112.83	-1,112.83	-1,112.83	-1,112.83	-1,112.83	-1,112.83	-1,112.83	-1,112.83	-1,112.83	-1,112.83	-1,112.83	-1,112.83	-1,112.83	-1,112.83	-1,112.83	-1,112.83	-1,112.83	-1,112.83	-1,112.83
Labour		-363.52	-363.52	-363.52	-363.52	-363.52	-363.52	-363.52	-363.52	-363.52	-363.52	-363.52	-363.52	-363.52	-363.52	-363.52	-363.52	-363.52	-363.52	-363.52	-363.52
Total:		6,881.55	7,054.91	7,229.14	7,404.25	7,580.25	7,757.17	7,935.03	8,113.83	8,293.61	8,474.38	8,656.16	8,838.97	9,022.83	9,207.77	9,393.80	9,580.94	9,769.23	9,958.67	10,149.30	10,341.14
Net emissions impact (Gas) [t CO2e]		9.24	9.24	9.24	9.24	9.24	9.24	9.24	9.24	9.24	9.24	9.24	9.24	9.24	9.24	9.24	9.24	9.24	9.24	9.24	9.24
Net emissions impact (RE) [t CO2e]		0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61
	59,392.89	**-6,144.24**	**-5,624.13**	**-5,145.56**	**-4,705.53**	**-4,301.24**	**-3,930.03**	**-3,589.40**	**-3,277.04**	**-2,990.76**	**-2,728.52**	**-2,488.44**	**-2,268.74**	**-2,067.80**	**-1,884.09**	**-1,716.21**	**-1,562.86**	**-1,422.83**	**-1,295.02**	**-1,178.40**	**-1,072.03**
NPC Heating	**-81,549.78**	-8,792.75	-7,988.88	-7,256.94	-6,590.69	-5,984.42	-5,432.86	-4,931.22	-4,475.10	-4,060.45	-3,683.61	-3,341.19	-3,030.13	-2,747.61	-2,491.06	-2,258.15	-2,046.73	-1,854.86	-1,680.76	-1,522.81	-1,379.54
CAPEX_Non-Heating																					
Building																					
Material	60,927.23	-3,046.36	-3,046.36	-3,046.36	-3,046.36	-3,046.36	-3,046.36	-3,046.36	-3,046.36	-3,046.36	-3,046.36	-3,046.36	-3,046.36	-3,046.36	-3,046.36	-3,046.36	-3,046.36	-3,046.36	-3,046.36	-3,046.36	-3,046.36
Labour	61,497.18	-3,074.86	-3,074.86	-3,074.86	-3,074.86	-3,074.86	-3,074.86	-3,074.86	-3,074.86	-3,074.86	-3,074.86	-3,074.86	-3,074.86	-3,074.86	-3,074.86	-3,074.86	-3,074.86	-3,074.86	-3,074.86	-3,074.86	-3,074.86
Total:	**122,424.40**	6,121.22	6,121.22	6,121.22	6,121.22	6,121.22	6,121.22	6,121.22	6,121.22	6,121.22	6,121.22	6,121.22	6,121.22	6,121.22	6,121.22	6,121.22	6,121.22	6,121.22	6,121.22	6,121.22	6,121.22
Aquaponics																					
Aquaculture system	15,885.00	-794.25	-794.25	-794.25	-794.25	-794.25	-794.25	-794.25	-794.25	-794.25	-794.25	-794.25	-794.25	-794.25	-794.25	-794.25	-794.25	-794.25	-794.25	-794.25	-794.25
NFT system 1: Horizontal	20,658.75	-1,032.94	-1,032.94	-1,032.94	-1,032.94	-1,032.94	-1,032.94	-1,032.94	-1,032.94	-1,032.94	-1,032.94	-1,032.94	-1,032.94	-1,032.94	-1,032.94	-1,032.94	-1,032.94	-1,032.94	-1,032.94	-1,032.94	-1,032.94
NFT system 2: Vertical	41,077.50	-2,053.88	-2,053.88	-2,053.88	-2,053.88	-2,053.88	-2,053.88	-2,053.88	-2,053.88	-2,053.88	-2,053.88	-2,053.88	-2,053.88	-2,053.88	-2,053.88	-2,053.88	-2,053.88	-2,053.88	-2,053.88	-2,053.88	-2,053.88
Growing lights	37,134.28	-1,856.71	-1,856.71	-1,856.71	-1,856.71	-1,856.71	-1,856.71	-1,856.71	-1,856.71	-1,856.71	-1,856.71	-1,856.71	-1,856.71	-1,856.71	-1,856.71	-1,856.71	-1,856.71	-1,856.71	-1,856.71	-1,856.71	-1,856.71
Water	248.74	-12.44	-12.44	-12.44	-12.44	-12.44	-12.44	-12.44	-12.44	-12.44	-12.44	-12.44	-12.44	-12.44	-12.44	-12.44	-12.44	-12.44	-12.44	-12.44	-12.44
Total:	**115,004.28**	5,750.21	5,750.21	5,750.21	5,750.21	5,750.21	5,750.21	5,750.21	5,750.21	5,750.21	5,750.21	5,750.21	5,750.21	5,750.21	5,750.21	5,750.21	5,750.21	5,750.21	5,750.21	5,750.21	5,750.21
Soil-based cultivation																					
Growing beds	1,856.25	-92.81	-92.81	-92.81	-92.81	-92.81	-92.81	-92.81	-92.81	-92.81	-92.81	-92.81	-92.81	-92.81	-92.81	-92.81	-92.81	-92.81	-92.81	-92.81	-92.81
Soil	3,712.50	-185.63	-185.63	-185.63	-185.63	-185.63	-185.63	-185.63	-185.63	-185.63	-185.63	-185.63	-185.63	-185.63	-185.63	-185.63	-185.63	-185.63	-185.63	-185.63	-185.63
Total:	**5,568.75**	278.44	278.44	278.44	278.44	278.44	278.44	278.44	278.44	278.44	278.44	278.44	278.44	278.44	278.44	278.44	278.44	278.44	278.44	278.44	278.44
	90,752.78	**-10,848.10**	**-9,685.80**	**-8,648.04**	**-7,721.46**	**-6,894.16**	**-6,155.50**	**-5,495.98**	**-4,907.13**	**-4,381.37**	**-3,911.93**	**-3,492.80**	**-3,118.57**	**-2,784.44**	**-2,486.10**	**-2,219.74**	**-1,981.91**	**-1,769.56**	**-1,579.96**	**-1,410.68**	**-1,259.54**
OPEX_Non-Heating																					
Electricity: Grow lights		-3,347.69	-3,501.87	-3,656.04	-3,810.21	-3,964.38	-4,118.55	-4,272.72	-4,426.89	-4,581.06	-4,735.23	-4,889.40	-5,043.57	-5,197.74	-5,351.91	-5,506.08	-5,660.25	-5,814.42	-5,968.59	-6,122.76	-6,276.93
Pumps		-477.29	-499.27	-521.25	-543.23	-565.21	-587.19	-609.17	-631.15	-653.13	-675.11	-697.09	-719.07	-741.05	-763.03	-785.01	-806.99	-828.97	-850.95	-872.93	-894.91
Labor		-4,122.00	-4,122.00	-4,122.00	-4,122.00	-4,122.00	-4,122.00	-4,122.00	-4,122.00	-4,122.00	-4,122.00	-4,122.00	-4,122.00	-4,122.00	-4,122.00	-4,122.00	-4,122.00	-4,122.00	-4,122.00	-4,122.00	-4,122.00
Fish feed		-5,435.10	-5,435.10	-5,435.10	-5,435.10	-5,435.10	-5,435.10	-5,435.10	-5,435.10	-5,435.10	-5,435.10	-5,435.10	-5,435.10	-5,435.10	-5,435.10	-5,435.10	-5,435.10	-5,435.10	-5,435.10	-5,435.10	-5,435.10
Maintenance: Building		-1,508.54	-1,508.54	-1,508.54	-1,508.54	-1,508.54	-1,508.54	-1,508.54	-1,508.54	-1,508.54	-1,508.54	-1,508.54	-1,508.54	-1,508.54	-1,508.54	-1,508.54	-1,508.54	-1,508.54	-1,508.54	-1,508.54	-1,508.54
Aquaponics		-2,340.00	-2,340.00	-2,340.00	-2,340.00	-2,340.00	-2,340.00	-2,340.00	-2,340.00	-2,340.00	-2,340.00	-2,340.00	-2,340.00	-2,340.00	-2,340.00	-2,340.00	-2,340.00	-2,340.00	-2,340.00	-2,340.00	-2,340.00
	136,624.23	**-15,384.49**	**-13,876.57**	**-12,515.18**	**-11,286.21**	**-10,176.93**	**-9,175.79**	**-8,272.35**	**-7,457.17**	**-6,721.71**	**-6,058.24**	**-5,459.78**	**-4,920.02**	**-4,433.24**	**-3,994.30**	**-3,598.52**	**-3,241.70**	**-2,920.03**	**-2,630.07**	**-2,368.73**	**-2,133.20**
NPC Total	**-308,926.79**	-35,025.34	-31,551.26	-28,420.16	-25,598.37	-23,055.51	-20,764.15	-18,699.56	-16,839.39	-15,163.52	-13,653.78	-12,293.77	-11,068.72	-9,965.29	-8,971.47	-8,076.41	-7,270.34	-6,544.45	-5,890.80	-5,302.23	-4,772.28
AG yield																					
Fish [CAD/kg]	8.8	3,960.00	3,960.00	3,960.00	3,960.00	3,960.00	3,960.00	3,960.00	3,960.00	3,960.00	3,960.00	3,960.00	3,960.00	3,960.00	3,960.00	3,960.00	3,960.00	3,960.00	3,960.00	3,960.00	3,960.00
Basil: NFT [CAD/kg]	7.5	26,730.00	26,730.00	26,730.00	26,730.00	26,730.00	26,730.00	26,730.00	26,730.00	26,730.00	26,730.00	26,730.00	26,730.00	26,730.00	26,730.00	26,730.00	26,730.00	26,730.00	26,730.00	26,730.00	26,730.00
Lettuce: Soil [CAD/kg]	5	8,910.00	8,910.00	8,910.00	8,910.00	8,910.00	8,910.00	8,910.00	8,910.00	8,910.00	8,910.00	8,910.00	8,910.00	8,910.00	8,910.00	8,910.00	8,910.00	8,910.00	8,910.00	8,910.00	8,910.00
Savings																					
Carbon offsets (Renewables)		3,035.40	3,449.32	3,863.24	4,277.16	4,691.08	4,746.27	4,801.46	4,856.65	4,911.84	4,967.03	5,022.22	5,077.40	5,132.59	5,187.78	5,242.97	5,298.16	5,353.35	5,408.54	5,463.73	5,518.92
Biomass waste [CAD/t]	85	75.75	75.75	75.75	75.75	75.75	75.75	75.75	75.75	75.75	75.75	75.75	75.75	75.75	75.75	75.75	75.75	75.75	75.75	75.75	75.75
	329,350.57	**38,134.96**	**34,379.04**	**30,990.19**	**27,932.87**	**25,174.93**	**22,505.58**	**20,119.23**	**17,985.89**	**16,078.73**	**14,373.78**	**12,849.60**	**11,487.02**	**10,268.92**	**9,179.97**	**8,206.48**	**7,336.22**	**6,558.23**	**5,862.74**	**5,241.00**	**4,685.19**
NPV Total	**20,423.78**	3,109.62	2,827.79	2,570.04	2,334.50	2,119.42	1,741.42	1,419.67	1,146.49	915.21	720.00	555.83	418.30	303.63	208.50	130.08	65.88	13.78	-28.06	-61.23	-87.10
Cumulative		3,560.55	6,698.16	9,462.59	11,897.78	14,042.55	15,801.82	17,233.58	18,387.80	19,307.53	20,029.77	20,586.27	21,004.27	21,307.04	21,514.49	21,643.56	21,708.67	21,722.05	21,694.02	21,633.32	21,547.26

Discount rate 12 [%]

Hybrid 2: GSHP & Biomass

481 [m2] 10000 [l]

Lifespan	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Years	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**	**2036**	**2037**	**2038**	**2039**	**2040**	**2041**	**2042**	**2043**	**2044**	**2045**
Electricity rates [CAD/kWh]	0.104	0.160	0.167	0.175	0.182	0.189	0.197	0.204	0.212	0.219	0.226	0.234	0.241	0.248	0.256	0.263	0.271	0.278	0.285	0.293	0.300
Wood chip: Alberta waste rec	95	97	99	101	103	105	107	109	111	114	116	118	120	123	125	128	130	133	136	138	141
Carbon offset price [CAD/t]	95	110	125	140	155	170	172	174	176	178	180	182	184	186	188	190	192	194	196	198	200
CAPEX_Heating																					
Hydronic radiant heating	20,240.49	-1,012.02	-1,012.02	-1,012.02	-1,012.02	-1,012.02	-1,012.02	-1,012.02	-1,012.02	-1,012.02	-1,012.02	-1,012.02	-1,012.02	-1,012.02	-1,012.02	-1,012.02	-1,012.02	-1,012.02	-1,012.02	-1,012.02	-1,012.02
Biomass boiler	8,600.00	-430.00	-430.00	-430.00	-430.00	-430.00	-430.00	-430.00	-430.00	-430.00	-430.00	-430.00	-430.00	-430.00	-430.00	-430.00	-430.00	-430.00	-430.00	-430.00	-430.00
Ground loop installation	18,919.10	-945.96	-945.96	-945.96	-945.96	-945.96	-945.96	-945.96	-945.96	-945.96	-945.96	-945.96	-945.96	-945.96	-945.96	-945.96	-945.96	-945.96	-945.96	-945.96	-945.96
Heat pump	39,972.00	-1,998.60	-1,998.60	-1,998.60	-1,998.60	-1,998.60	-1,998.60	-1,998.60	-1,998.60	-1,998.60	-1,998.60	-1,998.60	-1,998.60	-1,998.60	-1,998.60	-1,998.60	-1,998.60	-1,998.60	-1,998.60	-1,998.60	-1,998.60
Total:	**87,731.59**	4,386.58	4,386.58	4,386.58	4,386.58	4,386.58	4,386.58	4,386.58	4,386.58	4,386.58	4,386.58	4,386.58	4,386.58	4,386.58	4,386.58	4,386.58	4,386.58	4,386.58	4,386.58	4,386.58	4,386.58
	32,765.31	**-3,916.59**	**-3,496.95**	**-3,122.28**	**-2,787.75**	**-2,489.06**	**-2,222.38**	**-1,984.27**	**-1,771.67**	**-1,581.84**	**-1,412.36**	**-1,261.04**	**-1,125.93**	**-1,005.29**	**-897.58**	**-801.41**	**-715.55**	**-638.88**	**-570.43**	**-509.31**	**-454.74**
OPEX_Heating																					
Fuel (Wood chip)		-1,573.74	-1,605.21	-1,637.32	-1,670.06	-1,703.46	-1,737.53	-1,772.28	-1,807.73	-1,843.88	-1,880.76	-1,918.38	-1,956.74	-1,995.88	-2,035.80	-2,076.51	-2,118.04	-2,160.40	-2,203.61	-2,247.68	-2,292.64
CoE		-3,850.26	-4,027.58	-4,204.89	-4,382.21	-4,559.52	-4,736.84	-4,914.15	-5,091.47	-5,268.78	-5,446.10	-5,623.41	-5,800.73	-5,978.04	-6,155.36	-6,332.67	-6,509.99	-6,687.30	-6,864.62	-7,041.93	-7,219.25
Maintenance		-142.51	-142.51	-142.51	-142.51	-142.51	-142.51	-142.51	-142.51	-142.51	-142.51	-142.51	-142.51	-142.51	-142.51	-142.51	-142.51	-142.51	-142.51	-142.51	-142.51
Transport		-812.04	-812.04	-812.04	-812.04	-812.04	-812.04	-812.04	-812.04	-812.04	-812.04	-812.04	-812.04	-812.04	-812.04	-812.04	-812.04	-812.04	-812.04	-812.04	-812.04
Labour		-265.27	-265.27	-265.27	-265.27	-265.27	-265.27	-265.27	-265.27	-265.27	-265.27	-265.27	-265.27	-265.27	-265.27	-265.27	-265.27	-265.27	-265.27	-265.27	-265.27
Total:		6,643.82	6,852.61	7,062.03	7,272.09	7,482.81	7,694.19	7,906.26	8,119.02	8,332.49	8,546.68	8,761.61	8,977.29	9,193.74	9,410.97	9,629.00	9,847.85	10,067.53	10,288.05	10,509.44	10,731.70
Net emissions impact (Gas)	[t CO2e]	12.22	12.22	12.22	12.22	12.22	12.22	12.22	12.22	12.22	12.22	12.22	12.22	12.22	12.22	12.22	12.22	12.22	12.22	12.22	12.22
Net emissions impact (RE)	[t CO2e]	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47
	59,157.26	**-5,931.98**	**-5,462.86**	**-5,026.61**	**-4,621.55**	**-4,245.95**	**-3,898.12**	**-3,576.39**	**-3,279.14**	**-3,004.78**	**-2,751.80**	**-2,518.75**	**-2,304.25**	**-2,106.97**	**-1,925.67**	**-1,759.18**	**-1,606.40**	**-1,466.28**	**-1,337.85**	**-1,220.22**	**-1,112.52**
NPC Heating	**-91,922.57**	-9,848.57	-8,959.81	-8,148.89	-7,409.30	-6,735.01	-6,120.49	-5,560.66	-5,050.80	-4,586.62	-4,164.16	-3,779.79	-3,430.17	-3,112.26	-2,823.25	-2,560.59	-2,321.94	-2,105.16	-1,908.28	-1,729.53	-1,567.26
CAPEX_Non-Heating																					
Building																					
Material	69,137.60	-3,456.88	-3,456.88	-3,456.88	-3,456.88	-3,456.88	-3,456.88	-3,456.88	-3,456.88	-3,456.88	-3,456.88	-3,456.88	-3,456.88	-3,456.88	-3,456.88	-3,456.88	-3,456.88	-3,456.88	-3,456.88	-3,456.88	-3,456.88
Labour	69,801.60	-3,490.08	-3,490.08	-3,490.08	-3,490.08	-3,490.08	-3,490.08	-3,490.08	-3,490.08	-3,490.08	-3,490.08	-3,490.08	-3,490.08	-3,490.08	-3,490.08	-3,490.08	-3,490.08	-3,490.08	-3,490.08	-3,490.08	-3,490.08
Total:	**138,939.19**	6,946.96	6,946.96	6,946.96	6,946.96	6,946.96	6,946.96	6,946.96	6,946.96	6,946.96	6,946.96	6,946.96	6,946.96	6,946.96	6,946.96	6,946.96	6,946.96	6,946.96	6,946.96	6,946.96	6,946.96
Aquaponics																					
Aquaculture system	17,650.00	-882.50	-882.50	-882.50	-882.50	-882.50	-882.50	-882.50	-882.50	-882.50	-882.50	-882.50	-882.50	-882.50	-882.50	-882.50	-882.50	-882.50	-882.50	-882.50	-882.50
NFT system 1: Horizontal	22,954.17	-1,147.71	-1,147.71	-1,147.71	-1,147.71	-1,147.71	-1,147.71	-1,147.71	-1,147.71	-1,147.71	-1,147.71	-1,147.71	-1,147.71	-1,147.71	-1,147.71	-1,147.71	-1,147.71	-1,147.71	-1,147.71	-1,147.71	-1,147.71
NFT system 2: Vertical	45,641.67	-2,282.08	-2,282.08	-2,282.08	-2,282.08	-2,282.08	-2,282.08	-2,282.08	-2,282.08	-2,282.08	-2,282.08	-2,282.08	-2,282.08	-2,282.08	-2,282.08	-2,282.08	-2,282.08	-2,282.08	-2,282.08	-2,282.08	-2,282.08
Growing lights	41,260.32	-2,063.02	-2,063.02	-2,063.02	-2,063.02	-2,063.02	-2,063.02	-2,063.02	-2,063.02	-2,063.02	-2,063.02	-2,063.02	-2,063.02	-2,063.02	-2,063.02	-2,063.02	-2,063.02	-2,063.02	-2,063.02	-2,063.02	-2,063.02
Water	276.38	-13.82	-13.82	-13.82	-13.82	-13.82	-13.82	-13.82	-13.82	-13.82	-13.82	-13.82	-13.82	-13.82	-13.82	-13.82	-13.82	-13.82	-13.82	-13.82	-13.82
Total:	**127,782.53**	6,389.13	6,389.13	6,389.13	6,389.13	6,389.13	6,389.13	6,389.13	6,389.13	6,389.13	6,389.13	6,389.13	6,389.13	6,389.13	6,389.13	6,389.13	6,389.13	6,389.13	6,389.13	6,389.13	6,389.13
Soil-based cultivation																					
Growing beds	2,062.50	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13	-103.13
Soil	4,125.00	-206.25	-206.25	-206.25	-206.25	-206.25	-206.25	-206.25	-206.25	-206.25	-206.25	-206.25	-206.25	-206.25	-206.25	-206.25	-206.25	-206.25	-206.25	-206.25	-206.25
Total:	**6,187.50**	309.38	309.38	309.38	309.38	309.38	309.38	309.38	309.38	309.38	309.38	309.38	309.38	309.38	309.38	309.38	309.38	309.38	309.38	309.38	309.38
	101,924.00	**-12,183.45**	**-10,878.08**	**-9,712.57**	**-8,671.94**	**-7,742.80**	**-6,913.22**	**-6,172.51**	**-5,511.17**	**-4,920.69**	**-4,393.47**	**-3,922.74**	**-3,502.45**	**-3,127.19**	**-2,792.13**	**-2,492.97**	**-2,225.87**	**-1,987.38**	**-1,774.45**	**-1,584.33**	**-1,414.58**
OPEX_Non-Heating																					
Electricity	Grow lights	-3,719.66	-3,890.96	-4,062.26	-4,233.56	-4,404.86	-4,576.16	-4,747.46	-4,918.76	-5,090.06	-5,261.36	-5,432.66	-5,603.96	-5,775.26	-5,946.56	-6,117.86	-6,289.16	-6,460.46	-6,631.76	-6,803.06	-6,974.36
	Pumps	-530.32	-554.74	-579.16	-603.59	-628.01	-652.43	-676.85	-701.28	-725.70	-750.12	-774.55	-798.97	-823.39	-847.81	-872.24	-896.66	-921.08	-945.50	-969.93	-994.35
Labor		-4,580.00	-4,580.00	-4,580.00	-4,580.00	-4,580.00	-4,580.00	-4,580.00	-4,580.00	-4,580.00	-4,580.00	-4,580.00	-4,580.00	-4,580.00	-4,580.00	-4,580.00	-4,580.00	-4,580.00	-4,580.00	-4,580.00	-4,580.00
Fish feed		-6,039.00	-6,039.00	-6,039.00	-6,039.00	-6,039.00	-6,039.00	-6,039.00	-6,039.00	-6,039.00	-6,039.00	-6,039.00	-6,039.00	-6,039.00	-6,039.00	-6,039.00	-6,039.00	-6,039.00	-6,039.00	-6,039.00	-6,039.00
Maintenance	Building	-1,661.38	-1,661.38	-1,661.38	-1,661.38	-1,661.38	-1,661.38	-1,661.38	-1,661.38	-1,661.38	-1,661.38	-1,661.38	-1,661.38	-1,661.38	-1,661.38	-1,661.38	-1,661.38	-1,661.38	-1,661.38	-1,661.38	-1,661.38
	Aquaponics	-2,600.00	-2,600.00	-2,600.00	-2,600.00	-2,600.00	-2,600.00	-2,600.00	-2,600.00	-2,600.00	-2,600.00	-2,600.00	-2,600.00	-2,600.00	-2,600.00	-2,600.00	-2,600.00	-2,600.00	-2,600.00	-2,600.00	-2,600.00
	151,694.31	**-17,080.68**	**-15,406.63**	**-13,895.23**	**-12,530.84**	**-11,299.31**	**-10,187.83**	**-9,184.81**	**-8,279.77**	**-7,463.24**	**-6,726.62**	**-6,062.18**	**-5,462.90**	**-4,922.44**	**-4,435.08**	**-3,995.65**	**-3,599.48**	**-3,242.32**	**-2,920.38**	**-2,630.21**	**-2,368.69**
NPC Total	**-345,540.88**	-39,112.70	-35,244.53	-31,756.70	-28,612.08	-25,777.12	-23,221.54	-20,917.98	-18,841.75	-16,970.55	-15,284.26	-13,764.71	-12,395.52	-11,161.89	-10,050.47	-9,049.22	-8,147.29	-7,334.87	-6,603.12	-5,944.07	-5,350.54
AG yield																					
Fish [CAD/kg]	8.8	4,400.00	4,400.00	4,400.00	4,400.00	4,400.00	4,400.00	4,400.00	4,400.00	4,400.00	4,400.00	4,400.00	4,400.00	4,400.00	4,400.00	4,400.00	4,400.00	4,400.00	4,400.00	4,400.00	4,400.00
Basil: NFT [CAD/kg]	7.5	29,700.00	29,700.00	29,700.00	29,700.00	29,700.00	29,700.00	29,700.00	29,700.00	29,700.00	29,700.00	29,700.00	29,700.00	29,700.00	29,700.00	29,700.00	29,700.00	29,700.00	29,700.00	29,700.00	29,700.00
Lettuce: Soil [CAD/kg]	5	9,900.00	9,900.00	9,900.00	9,900.00	9,900.00	9,900.00	9,900.00	9,900.00	9,900.00	9,900.00	9,900.00	9,900.00	9,900.00	9,900.00	9,900.00	9,900.00	9,900.00	9,900.00	9,900.00	9,900.00
Savings																					
Carbon offsets (Renewables)		3,344.91	3,801.03	4,257.15	4,713.28	5,169.40	5,230.22	5,291.03	5,351.85	5,412.67	5,473.48	5,534.30	5,595.12	5,655.93	5,716.75	5,777.57	5,838.38	5,899.20	5,960.02	6,020.83	6,081.65
Biomass waste [CAD/t]	85	84.17	84.17	84.17	84.17	84.17	84.17	84.17	84.17	84.17	84.17	84.17	84.17	84.17	84.17	84.17	84.17	84.17	84.17	84.17	84.17
	365,643.27	**42,347.39**	**38,173.79**	**34,408.40**	**31,011.66**	**27,947.80**	**24,984.20**	**22,334.83**	**19,966.38**	**17,849.05**	**15,956.24**	**14,264.12**	**12,751.43**	**11,399.15**	**10,190.25**	**9,109.55**	**8,143.45**	**7,279.79**	**6,507.72**	**5,817.53**	**5,200.53**
NPV Total	**20,102.39**	3,234.69	2,929.26	2,651.70	2,399.58	2,170.67	1,762.66	1,416.85	1,124.63	878.51	671.98	499.41	355.92	237.26	139.79	60.33	-3.84	-55.07	-95.39	-126.54	-150.01
Cumulative		3,560.55	6,698.16	9,462.59	11,897.78	14,042.55	15,801.82	17,233.58	18,387.80	19,307.53	20,029.77	20,586.27	21,004.27	21,307.04	21,514.49	21,643.56	21,708.67	21,722.05	21,694.02	21,633.32	21,547.26

Discount rate 12 [%]

Hybrid 2: GSHP & Biomass

525 [m2] 11000 [l]

Lifespan	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Years	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**	**2036**	**2037**	**2038**	**2039**	**2040**	**2041**	**2042**	**2043**	**2044**	**2045**
Electricity rates [CAD/kWh]	0.104	0.160	0.167	0.175	0.182	0.189	0.197	0.204	0.212	0.219	0.226	0.234	0.241	0.248	0.256	0.263	0.271	0.278	0.285	0.293	0.300
Wood chip: Alberta waste rec	95	97	99	101	103	105	107	109	111	114	116	118	120	123	125	128	130	133	136	138	141
Carbon offset price [CAD/t]	95	110	125	140	155	170	172	174	176	178	180	182	184	186	188	190	192	194	196	198	200
CAPEX_Heating																					
Hydronic radiant heating	22,102.48	-1,105.12	-1,105.12	-1,105.12	-1,105.12	-1,105.12	-1,105.12	-1,105.12	-1,105.12	-1,105.12	-1,105.12	-1,105.12	-1,105.12	-1,105.12	-1,105.12	-1,105.12	-1,105.12	-1,105.12	-1,105.12	-1,105.12	-1,105.12
Biomass boiler	10,300.00	-515.00	-515.00	-515.00	-515.00	-515.00	-515.00	-515.00	-515.00	-515.00	-515.00	-515.00	-515.00	-515.00	-515.00	-515.00	-515.00	-515.00	-515.00	-515.00	-515.00
Ground loop installation	17,389.84	-869.49	-869.49	-869.49	-869.49	-869.49	-869.49	-869.49	-869.49	-869.49	-869.49	-869.49	-869.49	-869.49	-869.49	-869.49	-869.49	-869.49	-869.49	-869.49	-869.49
Heat pump	39,972.00	-1,998.60	-1,998.60	-1,998.60	-1,998.60	-1,998.60	-1,998.60	-1,998.60	-1,998.60	-1,998.60	-1,998.60	-1,998.60	-1,998.60	-1,998.60	-1,998.60	-1,998.60	-1,998.60	-1,998.60	-1,998.60	-1,998.60	-1,998.60
Total:	**89,764.32**	4,488.22	4,488.22	4,488.22	4,488.22	4,488.22	4,488.22	4,488.22	4,488.22	4,488.22	4,488.22	4,488.22	4,488.22	4,488.22	4,488.22	4,488.22	4,488.22	4,488.22	4,488.22	4,488.22	4,488.22
	33,524.48	**-4,007.34**	**-3,577.98**	**-3,194.62**	**-2,852.34**	**-2,546.73**	**-2,273.87**	**-2,030.24**	**-1,812.72**	**-1,618.50**	**-1,445.09**	**-1,290.25**	**-1,152.01**	**-1,028.58**	**-918.38**	**-819.98**	**-732.13**	**-653.68**	**-583.65**	**-521.11**	**-465.28**
OPEX_Heating																					
Fuel (Wood chip)		-2,134.74	-2,177.43	-2,220.98	-2,265.40	-2,310.71	-2,356.92	-2,404.06	-2,452.14	-2,501.18	-2,551.21	-2,602.23	-2,654.28	-2,707.36	-2,761.51	-2,816.74	-2,873.07	-2,930.53	-2,989.14	-3,048.93	-3,109.91
CoE		-3,481.86	-3,642.21	-3,802.56	-3,962.91	-4,123.26	-4,283.61	-4,443.95	-4,604.30	-4,764.65	-4,925.00	-5,085.35	-5,245.70	-5,406.05	-5,566.40	-5,726.74	-5,887.09	-6,047.44	-6,207.79	-6,368.14	-6,528.49
Maintenance		-327.15	-327.15	-327.15	-327.15	-327.15	-327.15	-327.15	-327.15	-327.15	-327.15	-327.15	-327.15	-327.15	-327.15	-327.15	-327.15	-327.15	-327.15	-327.15	-327.15
Transport		-1,101.51	-1,101.51	-1,101.51	-1,101.51	-1,101.51	-1,101.51	-1,101.51	-1,101.51	-1,101.51	-1,101.51	-1,101.51	-1,101.51	-1,101.51	-1,101.51	-1,101.51	-1,101.51	-1,101.51	-1,101.51	-1,101.51	-1,101.51
Labour		-359.83	-359.83	-359.83	-359.83	-359.83	-359.83	-359.83	-359.83	-359.83	-359.83	-359.83	-359.83	-359.83	-359.83	-359.83	-359.83	-359.83	-359.83	-359.83	-359.83
Total:		7,405.09	7,608.13	7,812.03	8,016.80	8,222.45	8,429.02	8,636.51	8,844.94	9,054.33	9,264.70	9,476.07	9,688.47	9,901.90	10,116.40	10,331.98	10,548.66	10,766.47	10,985.43	11,205.56	11,426.89
Net emissions impact (Gas) [t CO2e]		11.24	11.24	11.24	11.24	11.24	11.24	11.24	11.24	11.24	11.24	11.24	11.24	11.24	11.24	11.24	11.24	11.24	11.24	11.24	11.24
Net emissions impact (RE) [t CO2e]		0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61
	64,636.04	**-6,611.69**	**-6,065.16**	**-5,560.45**	**-5,094.82**	**-4,665.64**	**-4,270.40**	**-3,906.72**	**-3,572.32**	**-3,265.08**	**-2,982.99**	**-2,724.14**	**-2,486.79**	**-2,269.26**	**-2,070.02**	**-1,887.61**	**-1,720.71**	**-1,568.08**	**-1,428.54**	**-1,301.04**	**-1,184.59**
NPC Heating	**-98,160.52**	-10,619.02	-9,643.13	-8,755.07	-7,947.16	-7,212.38	-6,544.27	-5,936.96	-5,385.04	-4,883.58	-4,428.07	-4,014.40	-3,638.80	-3,297.84	-2,988.39	-2,707.59	-2,452.84	-2,221.76	-2,012.19	-1,822.15	-1,649.87
CAPEX_Non-Heating																					
Building																					
Material	70,527.84	-3,526.39	-3,526.39	-3,526.39	-3,526.39	-3,526.39	-3,526.39	-3,526.39	-3,526.39	-3,526.39	-3,526.39	-3,526.39	-3,526.39	-3,526.39	-3,526.39	-3,526.39	-3,526.39	-3,526.39	-3,526.39	-3,526.39	-3,526.39
Labour	76,036.14	-3,801.81	-3,801.81	-3,801.81	-3,801.81	-3,801.81	-3,801.81	-3,801.81	-3,801.81	-3,801.81	-3,801.81	-3,801.81	-3,801.81	-3,801.81	-3,801.81	-3,801.81	-3,801.81	-3,801.81	-3,801.81	-3,801.81	-3,801.81
Total:	**146,563.98**	7,328.20	7,328.20	7,328.20	7,328.20	7,328.20	7,328.20	7,328.20	7,328.20	7,328.20	7,328.20	7,328.20	7,328.20	7,328.20	7,328.20	7,328.20	7,328.20	7,328.20	7,328.20	7,328.20	7,328.20
Aquaponics																					
Aquaculture system	19,415.00	-970.75	-970.75	-970.75	-970.75	-970.75	-970.75	-970.75	-970.75	-970.75	-970.75	-970.75	-970.75	-970.75	-970.75	-970.75	-970.75	-970.75	-970.75	-970.75	-970.75
NFT system 1: Horizontal	25,249.58	-1,262.48	-1,262.48	-1,262.48	-1,262.48	-1,262.48	-1,262.48	-1,262.48	-1,262.48	-1,262.48	-1,262.48	-1,262.48	-1,262.48	-1,262.48	-1,262.48	-1,262.48	-1,262.48	-1,262.48	-1,262.48	-1,262.48	-1,262.48
NFT system 2: Vertical	50,205.83	-2,510.29	-2,510.29	-2,510.29	-2,510.29	-2,510.29	-2,510.29	-2,510.29	-2,510.29	-2,510.29	-2,510.29	-2,510.29	-2,510.29	-2,510.29	-2,510.29	-2,510.29	-2,510.29	-2,510.29	-2,510.29	-2,510.29	-2,510.29
Growing lights	45,386.35	-2,269.32	-2,269.32	-2,269.32	-2,269.32	-2,269.32	-2,269.32	-2,269.32	-2,269.32	-2,269.32	-2,269.32	-2,269.32	-2,269.32	-2,269.32	-2,269.32	-2,269.32	-2,269.32	-2,269.32	-2,269.32	-2,269.32	-2,269.32
Water	304.02	-15.20	-15.20	-15.20	-15.20	-15.20	-15.20	-15.20	-15.20	-15.20	-15.20	-15.20	-15.20	-15.20	-15.20	-15.20	-15.20	-15.20	-15.20	-15.20	-15.20
Total:	**140,560.78**	7,028.04	7,028.04	7,028.04	7,028.04	7,028.04	7,028.04	7,028.04	7,028.04	7,028.04	7,028.04	7,028.04	7,028.04	7,028.04	7,028.04	7,028.04	7,028.04	7,028.04	7,028.04	7,028.04	7,028.04
Soil-based cultivation																					
Growing beds	2,268.75	-113.44	-113.44	-113.44	-113.44	-113.44	-113.44	-113.44	-113.44	-113.44	-113.44	-113.44	-113.44	-113.44	-113.44	-113.44	-113.44	-113.44	-113.44	-113.44	-113.44
Soil	4,537.50	-226.88	-226.88	-226.88	-226.88	-226.88	-226.88	-226.88	-226.88	-226.88	-226.88	-226.88	-226.88	-226.88	-226.88	-226.88	-226.88	-226.88	-226.88	-226.88	-226.88
Total:	**6,806.25**	340.31	340.31	340.31	340.31	340.31	340.31	340.31	340.31	340.31	340.31	340.31	340.31	340.31	340.31	340.31	340.31	340.31	340.31	340.31	340.31
	109,775.06	**-13,121.92**	**-11,716.00**	**-10,460.71**	**-9,339.92**	**-8,339.22**	**-7,445.73**	**-6,647.97**	**-5,935.69**	**-5,299.72**	**-4,731.90**	**-4,224.91**	**-3,772.24**	**-3,368.07**	**-3,007.21**	**-2,685.00**	**-2,397.33**	**-2,140.47**	**-1,911.13**	**-1,706.37**	**-1,523.54**
OPEX_Non-Heating																					
Electricity: Grow lights		-4,091.63	-4,280.06	-4,468.49	-4,656.92	-4,845.35	-5,033.78	-5,222.21	-5,410.64	-5,599.07	-5,787.50	-5,975.93	-6,164.36	-6,352.79	-6,541.22	-6,729.65	-6,918.08	-7,106.51	-7,294.94	-7,483.37	-7,671.80
Pumps		-583.35	-610.22	-637.08	-663.95	-690.81	-717.68	-744.54	-771.41	-798.27	-825.14	-852.00	-878.86	-905.73	-932.59	-959.46	-986.32	-1,013.19	-1,040.05	-1,066.92	-1,093.78
Labor		-5,038.00	-5,038.00	-5,038.00	-5,038.00	-5,038.00	-5,038.00	-5,038.00	-5,038.00	-5,038.00	-5,038.00	-5,038.00	-5,038.00	-5,038.00	-5,038.00	-5,038.00	-5,038.00	-5,038.00	-5,038.00	-5,038.00	-5,038.00
Fish feed		-6,642.90	-6,642.90	-6,642.90	-6,642.90	-6,642.90	-6,642.90	-6,642.90	-6,642.90	-6,642.90	-6,642.90	-6,642.90	-6,642.90	-6,642.90	-6,642.90	-6,642.90	-6,642.90	-6,642.90	-6,642.90	-6,642.90	-6,642.90
Maintenance: Building		-1,814.21	-1,814.21	-1,814.21	-1,814.21	-1,814.21	-1,814.21	-1,814.21	-1,814.21	-1,814.21	-1,814.21	-1,814.21	-1,814.21	-1,814.21	-1,814.21	-1,814.21	-1,814.21	-1,814.21	-1,814.21	-1,814.21	-1,814.21
Aquaponics		-2,860.00	-2,860.00	-2,860.00	-2,860.00	-2,860.00	-2,860.00	-2,860.00	-2,860.00	-2,860.00	-2,860.00	-2,860.00	-2,860.00	-2,860.00	-2,860.00	-2,860.00	-2,860.00	-2,860.00	-2,860.00	-2,860.00	-2,860.00
	166,764.38	**-18,776.87**	**-16,936.69**	**-15,275.29**	**-13,775.48**	**-12,421.70**	**-11,199.87**	**-10,097.28**	**-9,102.38**	**-8,204.76**	**-7,395.00**	**-6,664.57**	**-6,005.77**	**-5,411.64**	**-4,875.87**	**-4,392.79**	**-3,957.25**	**-3,564.62**	**-3,210.69**	**-2,891.69**	**-2,604.18**
NPC Total	**-374,699.96**	-42,517.81	-38,295.83	-34,491.08	-31,062.56	-27,973.29	-25,189.88	-22,682.21	-20,423.11	-18,388.06	-16,554.97	-14,903.88	-13,416.81	-12,077.55	-10,871.47	-9,785.39	-8,807.42	-7,926.85	-7,134.01	-6,420.21	-5,777.59
AG yield																					
Fish [CAD/kg]	8.8	4,840.00	4,840.00	4,840.00	4,840.00	4,840.00	4,840.00	4,840.00	4,840.00	4,840.00	4,840.00	4,840.00	4,840.00	4,840.00	4,840.00	4,840.00	4,840.00	4,840.00	4,840.00	4,840.00	4,840.00
Basil: NFT [CAD/kg]	7.5	32,670.00	32,670.00	32,670.00	32,670.00	32,670.00	32,670.00	32,670.00	32,670.00	32,670.00	32,670.00	32,670.00	32,670.00	32,670.00	32,670.00	32,670.00	32,670.00	32,670.00	32,670.00	32,670.00	32,670.00
Lettuce: Soil [CAD/kg]	5	10,890.00	10,890.00	10,890.00	10,890.00	10,890.00	10,890.00	10,890.00	10,890.00	10,890.00	10,890.00	10,890.00	10,890.00	10,890.00	10,890.00	10,890.00	10,890.00	10,890.00	10,890.00	10,890.00	10,890.00
Savings																					
Carbon offsets (Renewables)		3,617.98	4,111.34	4,604.70	5,098.06	5,591.42	5,657.20	5,722.98	5,788.77	5,854.55	5,920.33	5,986.11	6,051.89	6,117.67	6,183.45	6,249.24	6,315.02	6,380.80	6,446.58	6,512.36	6,578.14
Biomass waste [CAD/t]	85	92.58	92.58	92.58	92.58	92.58	92.58	92.58	92.58	92.58	92.58	92.58	92.58	92.58	92.58	92.58	92.58	92.58	92.58	92.58	92.58
	401,539.98	**46,527.29**	**41,935.53**	**37,793.60**	**34,057.82**	**30,688.72**	**27,433.97**	**24,524.37**	**21,923.33**	**19,598.12**	**17,519.50**	**15,661.32**	**14,000.21**	**12,515.26**	**11,187.80**	**10,001.13**	**8,940.31**	**7,992.00**	**7,144.27**	**6,386.45**	**5,709.00**
NPV Total	**26,840.02**	4,009.48	3,639.70	3,302.52	2,995.26	2,715.43	2,244.09	1,842.16	1,500.22	1,210.06	964.53	757.45	583.40	437.71	316.33	215.74	132.89	65.15	10.25	-33.76	-68.59
Cumulative		3,560.55	6,698.16	9,462.59	11,897.78	14,042.55	15,801.82	17,233.58	18,387.80	19,307.53	20,029.77	20,586.27	21,004.27	21,307.04	21,514.49	21,643.56	21,708.67	21,722.05	21,694.02	21,633.32	21,547.26