Dairy Farm 2.0

A shift from traditional to artificial dairy production

‘Research Plan’

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PROBLEM STATEMENT

Global

Global population is growing and the demand for ASF is disproportionately increasing

Dairy crisis: environmental crisis

GHG emissions (methane, CO_2)

soil and ground water pollution due to cattle manure

Local: **The Netherlands**

the demand for housing is increasing due to the demographic growth

more than 1/4 of the surface employed for livestock practices

the surface of the Netherlands is shrinking due to the rising in the sea level

GHG emissions

land use

RESEARCH PAPER

- 85%/ 97%

- 97%

CULTURED-MILK TECHNOLOGY

HOW CULTURED/COW-LESS MILK TECHNOLOGY MIGHT BE DISRUPTIVE FOR THE BUILT ENVIRONMENT?

QUALITATIVE INVESTIGATON

QUANTITATIVE INVESTIGATON

QUALITATIVE INVESTIGATON

the process

What is cultured-milk technology? How cultured/cow-less milk is produced?

building scale (architecture)

material circulation

functional programme

the harvest

What are the material, energy and water flows of a hypothetical cultured/cow-less milk farm?

building scale (energy and water supply systems)

resources required by a cultured-milk farm in terms of material inputs, water use, energy consumption and GHG emissions to get a certain amount of milk

spaces dimensioning

benefits of the technology

What are the potential environmental and societal benefits of cultured/cow-less milk technology?

What are the benefits of replacing conventional milk with cultured/cow-less milk production in the Netherlands?

context/ urban scale

how the intervention would benefit the environment and the population (sustainable principles of the design)

TECHNICAL FEASIBILITY

RESEARCH FRAMEWORK

2 ZERO HUNGER

'End hunger, achieve food security and improved nutrition and promote sustainable agriculture'

SDG-2, un.org

How to make our food chains more environmentally sustainable and resilient?

production-oriented philosophy: sustainable intensification

new technologies for food production: post-animal agriculture

consumption-oriented philosophy: switching to a vegan diet

building a **personal theoretical position** through the exploration of the sustainable alternatives for ASF production

site choice: Noorder-IJpolder

urban analysis

contextual-specific design

exploration of architectural typologies (shift in the paradigm of the idea of farm)

inspiration

sustainability

social:

public functions

relationship people-nature

environmental: DESIGN IN AND FOR THE CONTEXT

physical integration with nature

technological integration by using the natural resources available on the site

CONCEPT

DAIRY FARM 2.0

DESIGN

1. Introduction

Key words: intensive livestock practices, cow-less milk farm, human farm, conventional dairy farm, GHG emissions, land use, water use, energy consumption

Problem Statement:

Global:

The consumption of meat and dairy is forecasted to globally increase by 70% within 2050, accompanied by a demographic growth of 2 billions people (FAO, 2017). Although this is just a prediction, the huge disproportion between the data turns into a wake-up call for our food security and environmental sustainability and resilience. Raising animals for food production ranks as the highest contributor of GHG emissions in the sector called 'agriculture, forestry and other land use' with 7 billion tons/year, corresponding to the 15% of the global annual emissions (Bill Gates, 2021) and with the 27% of the global water footprint (Hoekstra, 2012). Moreover, considering that approximately the 60% of the planet's ice-free land is employed for livestock practices between arable land to grow animal's feed and grassland (FAO, 2017), is immediately understandable how the actual animal source food (ASF) production system won't be suitable anymore to satisfy the future overall demand. Therefore innovative and more sustainable alternatives should be introduced and experimented in order to build more resilient food chains and to achieve the 'Zero Hunger Sustainable Development Goal', aiming to reach food security by 2030 (sustainable development.un.org)

Local:

The Netherlands are world-wide known as a dairy country. Livestock practices involve more than 1/4 of the entire surface of the country with the highest density of milking cows (1.6 millions) in Europe (ZuivelNL, 2018). Looking at the actual consumption patterns of dairy products of the Dutch population with an average of two glasses of drinking milk for a total of 1 kg of dairy products pro capite (FAO,2013) and considering the foreseen demographic growth of 2 millions people within 2060 (Central Bureau voor de Statistiek, 2020), it's evident how the actual dairy system would become more and more intensive to satisfy the population demand, at the expense of the environment. The Netherlands is already living an environmental dairy crisis, started in 2018 when the release of phosphate and nitrogen in the soil, due to the amount of manure produced by cattle, exceeded the ceiling set by the European Union (The Guardian, 2018 and Science, 2019). This caused the pollution of ground water and the eutrophication (uncontrolled growth of algae) of the water bodies with the consequent loss in aquatic biodiversity. Moreover land availability is becoming a main concern: on the one hand people are demanding for new affordable houses while on the other hand one third of the Netherlands lies already below the sea level and its surface is gradually shrinking due to the rising in the sea level as a consequence of the global warming. Then, how would be possible to build a sustainable and resilient dairy system for the Netherlands to satisfy the increasing population demand and likewise reducing the environmental impact in terms of land use and GHG emissions?

Post-animal agriculture technology might be a potential solution to overcome the current dairy crisis and satisfy the demand for dairy products in the Netherlands, ensuring an environmental and social sustainable dairy production system. Cow-less or cultured milk technology is a fermentation-based cellular agriculture process that involves genetically engineered microflora to obtain casein and whey, the proteins that constitute milk. This "out-of-body udder system" (Linda Qiu, 2014) operates on a cellular level churning out milk proteins without the need to grow the entire cow. Although this technology is relatively new and still at a lab-scale experimentation, the LCA study released by PerfectDay start-up (9th Feb 2021) gives hope: cultured/cowless milk technology process reduces GHG emissions by between 85% and 97% in comparison with traditional milk production process, it requires the 91% less of land and the final product is also potentially

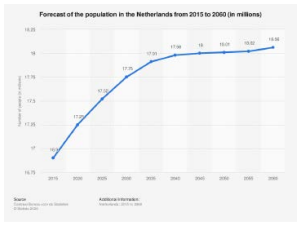
healthier than traditional milk due to the possibility to handle its composition in terms of amount of proteins, fats and sugars and avoiding antibiotics (highly employed in intensive dairy farm practices). Thus, cultured milk technology might be highly disruptive for the agriculture sector.

2. Research framework & Methodology

2.1 Definition of a personal theoretical position

The definition of a **personal theoretical position** in relation to the problem statement has been essential to develop a coherent and critical architectural research. The research is founded on a previous exploration of the actual sustainable alternatives and philosophies aiming to mitigate the environmental impact of animal source food (ASF) production and make our food chains more resilient. If on the one hand principles of sustainable intensification, that means increasing ASF yields per unit of resource used or emissions produced, are argued by production-oriented philosophies (Van Zantem, 2018), on the other hand hard-core vegan movements might persuade to completely avoid ASF to tackle animals bad living conditions and slaughter while cut out carbon emissions. However, studies from De Vries (2015) and Herrero (2016) show that the production pathway can't be the solution because it *'does not account for the competition for natural resources (e.g., land, water, fossil phosphorus) between feed and food production*' (van Zantem,2018). Feeding more concentrates instead of roughage to cattle, in fact, can reduce footprints of beef but at the same time increase feed-food competition, favouring a transition from grass-based to concentrate-based feed systems. Likewise, revolutionise people's consumption patterns looks really unrealistic on a broad scale because of the higher price of the products and their tastes (Bill Gates, 2021). As Savina van der Straten argues, it's really difficult to compromise on taste and price of food for an environmental purpose because we don't see it as an issue strictly connected to our daily lives (Towards an animal-free food system, 2019). Moreover meat and dairy play a crucial role in human culture. Bill Gates in '*How to avoid a climate disaster*' emphasises how meat and dairy are part of festivals and celebrations all around the world and how food is listed as "country's Intangible Cultural Heritage of Humanity". To this regard I report the Unesco's manifesto: "*The gastronomic meal emphasises togetherness, the pleasure of taste, and the balance between human beings and the products of nature"* (Unesco website). So how can we shrink the environmental impact of ASF production while still enjoying meat and dairy products? My thesis is that we should come up with replacements of animals products that have reduced environmental footprint and might benefit the society as traditional ones, without compromising the taste.

The solution might come from post-animal agriculture technologies, an emergent field in which animal-based products are obtained through processes operating at the cellular level, opposing to the typical farm-based practices that operate the whole organism level (Stephens & Ellis, 2020).
Edwin Gardner defines 'second domestication' this potential shift in food production where micro-organisms take the place of macro-organisms. However, the domestication of micro-organisms is far from new: fermentation for making bread, cheese, yogurt, beer and other products is indeed an ancient process but nowadays technology allows to operate with an high degree of control and precision (De Grote Omdraaiing, 2021).



population

demand for dairy products

		Actual Dutch dairy production	SCENARIO 1 production-oriented phylosophy: sustainable intensification	SCENARIO 2 post-animal agriculture technologies	SCENARIO 3 consumption-oriented phylosophy: change people consumption patterns,veganism
consumption pro-capite of dairy products		1 kg	1 kg	1 kg	0
n. of cattle employed		1.6 millions	1.6 millions	0	0
natural resources employed	GHG emissions	1195 g CO2 (Sustainable Dairy Chain, 2016)	increasing ASF yields per unit of resource used or emission produced. The footprint concept, however, does not account for the competition for natural resources (e.g., land, water, fossil phosphorus) between feed and food production.	- 85%/ 97% GHG emissions, - 91% land use, - 65% energy consumption, - 98% water use (LCA PérfectDay, 2021) (in comparison to conventional milk production)	environmentally-friendly alternative
	water use	1020 L (Mekonnen&Hoekstra, 2010)			
	electricity use	5 MJ (Thomassen, 2008)			
	land use	1.3 mq (Thomassen, 2008)			
money		0,85 euros 1 L of milk	↓ large-scale production, cheaper	↑ Currently, cultured milk costs about twice the price of ordinary milk. However, once in full scale production, it is likely that the price will rapidly fall and become cheaper than cow derived milk.	↑ more expensive than cow milk (around 2 euros)
		NOT environmentally sustainable	NOT environmentally sustainable	- environmentally sustainable - cheaper after scale-up	unrealistic to modify people's consumption patterns on a broad scale

The proposed thematic research aims to position cultured milk technology as a potential solution of the abovementioned societal issue for the dairy sector in the Netherlands and investigates the environmental and societal advantages of partly replacing conventional dairy farms with cultured-milk refineries. From an architectural perspective, shifting from conventional agricultural practices to artificial food production processes would mean replacing the traditional idea of farm (strictly interconnected with the biosphere) with the new concept of totally 'human farm', where bioreactors vessels hosting populations of micro-organisms would replace cattle breeding. This radical shift would deeply impact our built environment. On the one hand it will offer a large-scale nature restoration and regeneration of some areas actually employed for livestock while on the other hand it would cast doubts about the new relationship between technology and nature in the new concept of 'farm'. The design project 'Dairy Farm 2.0' will speculate about this new relationship combining a technical feasible and efficient design with public functions to connect people and nature.

The architectural research relates to a multiplicity of disciplines such as agriculture, biotechnology, genetical engineering, ecology and touches also principles of ethics and economy. The intersection of those different fields of knowledge provides the theoretical framework to design a feasible cultured-milk farm.

According to the structure of the Architectural Engineering Studio, the technical research is executed and concluded with a written academic paper whereby the qualitative and quantitative data are elaborated in preliminary conclusions.

2.2 Research questions and research methods

The main research question - **How cultured/cow-less milk technology might be disruptive for the built environment?**- addresses the thematic research to the architectural field and aims at speculating about the effects of synthetic food production on our built environment, on the landscape and our lives. The main focus is on the impact of cow-less/cultured milk technology on the environment in terms of land use, GHG emissions, water use and energy consumption and on the potential societal benefits that it might bring.

The investigation starts from an **understanding of the** scientific **process** of cow-less milk production to define the hypothetical inputs required by the 'human farm' and, on the whole, the material circulation into the milk refinery. Thus the sub-questions: **What is cultured/cow-less milk technology? How cultured/cow-less milk is produced?**

Methods: literary review of scientific papers and contacting the start-up PerfectDay. Qualitative investigation

Outputs: diagram of the scientific process with the various inputs necessary to produce artificial milk

Then the research explores the **potential environmental and societal benefits** of replacing conventional milk production with cow-less milk production and the hypothetical future scenario of replacing the 50% of the current milk production in the Netherlands is analysed. This scenario-based exploration is purely arbitrary and aims to understand the amount of resource savings (GHG emissions, land use, water use, energy consumption) in the specific context of the Netherlands.
Sub-questions: **What are the potential environmental and societal benefits of cultured/cow-less milk technology? What are the benefits of replacing conventional milk with cultured/ cow-less milk production in the Netherlands?**

Methods: study the anticipatory LCA released by PerfectDay, comparison between the data about the environmental impact of the current milk production system in the Netherlands in terms of GHG emissions, land use, water use and energy consumption and cultured-milk production, literary review of scientific papers. Qualitative and quantitative investigation

Outputs: resource savings data (GHG emissions, land use, water use and energy consumption) in the hypothesis of replacing the 50% of the current conventional milk production with cultured milk technology

Finally the research focuses on **the harvest** of artificial milk with a quantitative exploration of the inputs necessary to produce a defined amount of milk and the outputs of the process. The data are collected in a material flow analysis (MFA) diagram and are essential to inform the design of a cultured milk farm and study its technical feasibility. The MFA allows to estimate the number of machines and to dimensioning the spaces required by the refinery.
Sub-questions: **What are the material, energy and water flows of a hypothetical cultured/cow-less milk farm?**

Methods: literary review of scientific papers, collecting data, elaboration and data calculation. Quantitative investigation

Outputs: MFA diagram

Objective:
On the whole, the proposed project positions architecture, its role and potential impact in relation to the relatively new cultured milk technology. The overall design question -**'How the design of a cultured/cow-less milk farm can be achieved on water?**- addresses the thematic research towards the technical feasibility of the project, with the exploration of architecture on water as a new paradigm able to bring together sustainable, ethics and social considerations and to re-design the relationship technology-nature in the new idea of farm. The project will speculate about the new paradigm of 'totally human farm' and the new relationship nature-technology through the design of a cultured-milk farm on the Noorder-IJpolder.

3. Preliminary conclusions & Design strategies

Site: The Noorder-IJpolder

The Noorder-IJpolder is an extensive green area sited in the North of Amsterdam, in the area of the harbour. This former agricultural area has become a sand extraction pit for the construction of national roads and residential areas since 1860. What's really fascinating about the site is its hybrid nature: a very natural and green lung with two artificial lakes surrounded by the industrial

landscape of the Amsterdam harbour and its view on the North Sea Canal that makes it a unique spot. Currently the polder is pretty isolated, with a few pedestrian-only accesses and without public functions to attract the citizens. However the Noorder-IJpolder is part of the Haven-stad plan, a redevelopment project of the entire area of the harbour promoted by the municipality of Amsterdam. Within 2030 the polder is going to become the key area of the entire intervention and the second park for extension and importance of Amsterdam after Groote Park. The plan includes the creation of some public functions on the North bank to engage the community with leisure activities and water sports, while the south bank will provide a connection between the Achtersluis polder and Cornelis Douwes neighbourhoods. Moreover the Noorder-IJpolder will become an eco-park to educate people about sustainability and circularity principles with the installation of floating solar panels and wind turbines that would provide green energy to 7.000 homes within 2021.
The Noorder-IJpolder could be an interesting spot to develop the first 'cultured-milk farm' of the Netherlands and to introduce for the first time this innovative process that in a future would complement conventional milk production. Although this technology would easily adapt to every sites, the program of the design is aligned with the educational purpose of the park and the 'hybrid' nature of the area would offer also some points of reflections regarding the new relationship between technology and nature.

The programme

The programme concept is founded on three key points:

1. The design of a cow-less milk production pole on the Noorder-IJpolder that guarantees the daily amount of drinking milk to the community of the Haven-stad and to the Achtersluis polder neighbourhood inhabitants (roughly 200.000 people).
2. Design an educational and social hub to engage the community, promoting the public acceptance and the democratisation of this new technology and help people to build a new food culture.

The functional programme is divided into four themes:
- Research: research labs and a library
- Building a new food culture: conference room/auditorium, café/restaurant, food market for dairy and local products, workshops, community kitchen, milk distributor machines
- Technology democratisation: visitors path in the production area
- Interaction with nature: outdoor spaces to interact with water/nature, an observation tower that becomes a landmark of the site and allows people to enjoy the view of the North Sea Canal.

3. Design in an for the context: integrating nature and technology through an architecture on water to create a nature inclusive building.

Physical integration:
- enhance the physical interaction with nature and water through an architecture on water and define a new relationship between nature and technology.
- developing nature further: the structure will be nature inclusive and will benefit the local biodiversity.

Technological integration:
- Explore the energy supply possibilities of a structure on water starting from the natural resources available on the Noorder-IJpolder site.

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