A Blended Government-Private Sector Perspective Analysis for Optimizing Subsidies to Promote Renewable Energy Deployment in Indonesia

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Summary

The global shift towards renewable energy has witnessed substantial growth, with installed capacity nearly doubling from 2015 to 2023 and with only positive expectations of growth. A key issue in the transition is in developing emerging economies, and in particular the ASEAN region is interesting due to its high availability of renewable resources and its current heavy reliance on fossil fuels. Indonesia alone contributes to almost 50% of the region's total energy supply and with its mainly coal-based electrical grid, there is a need to transition towards more sustainable energy. The government has set a goal of achieving a 30% share of renewable energy in the Total Primary Energy Supply by 2030; however institutional barriers limit new entrants. And despite new regulations being released, current renewable energy projects are not yet profitable at market rates of equity. Therefore, this thesis sets out to identify the optimal subsidy policy that can be implemented to promote the development of large-scale renewable energy in Indonesia.

In order to address this question, this thesis focused on using a novel optimization technique that aimed to maximize the change in equity NPV (Net Present Value) relative to subsidy costs along three different scenarios. The goal of using the unitless ratio results in a metric that can be baselined and compared with different scenarios resulting in a deeper understanding of optimal subsidy policy. The equity NPV was calculated using a detailed discounted cash flow analysis resulting in accurate estimations of subsidy needs per MWh over time. In addition, the maximization problem was solved by using subsidy policy parameters, such as initial value and annual decay rate, to optimize a long-term policy that can sustain growth.

The results revealed that the optimized policies are in fact path independent implying that the transition is mainly dictated by the quantity of resources the government is willing to mobilize to address this goal. The results also indicate that investors can capture 100% of the subsidy value awarded implying a balance between both the government and private sector. The results also showed how different technologies have different policy needs, with solar PV initially relying on capital subsidies to be then replaced by production-oriented subsidies, whereas, wind, geothermal, biomass, and hydropower require more capital subsidies relative to production subsidies. The impact of capital and financing costs emerges as crucial, underscoring the role of CAPEX in eliminating subsidy needs and the challenge of achieving financing parity with fossil fuels. Model limitations include a predetermined growth path, static cost decline assumptions, investor dynamics oversight, and a narrow policy scope, highlighting the need for refinement in future research for more accurate subsidy requirement assessments.

The main findings highlighted the government's ability to maximize subsidy effectiveness by optimizing the ratio between equity NPV change and total subsidy amount. Recommendations for the government included addressing policy uncertainty, reducing capital costs, and phasing out fossil subsidies. Private-sector recommendations emphasized improved deal structures, strategic area consideration, and leveraging local content laws. The thesis proposed model enhancements, such as policy adaptability, carbon market inclusion, and aligning scenario design with policy design, to navigate uncertainties in the energy transition effectively. The primary focus for future research should center around introducing more policy flexibility, including carbon pricing schemes, and congruent pathway-policy interactions.

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Chapter 1. Introduction

In recent years, there has been a push towards renewable energy technologies. From 2015 to 2023, global installed renewable energy capacity has grown by almost 100% (IEA, 2022c). Moreover, the same IEA report anticipates that renewables will account anywhere between 43% to 49% of global electricity production. This is only possible via a global effort, and with the ASAEN region growing at a rapid pace, it has become a region of interest given its currently high reliance on fossil energy, such as coal (ACE, 2022). Indonesia specifically accounts for almost 50% of the region's total energy supply making it an especially important country and can be used as a case study for how to influence the energy transition in neighbouring countries. This thesis report will focus on the use of subsidies to promote the energy transition in Indonesia.

1.1. Context on the Indonesian Energy System

Indonesia has seen steady growth in its electricity consumption, almost doubling in the period of 2010 to 2020 in which electricity consumption grew from 147 TWh to 243 TWh. To supply this electricity, Indonesia has a total installed capacity of 73 GW as of 2020. In 2022, coal accounted for 25% of final energy consumption (Adi et al., 2022). Natural gas and oil account for an additional 38% of total capacity, with coal in particular behaving as the base load for the country. Renewable generation accounts for the remaining production (IEA, 2022d; KEN, 2022). In terms of owners, Perusahaan Listrik Negara (PLN), the state electricity company, operates 43 GW of the total installed capacity followed by 20 GW being operated by IPPs. Price caps on coal have historically caused prices to be cheaper as per Minister of Energy and Mineral Resources (MEMR) Reg 3, 2020.

Renewable resources are currently highly underutilized, as it is expected that Indonesia can support around 400 to 800 GW of renewable energy installations with solar and wind being the largest contributors to potential. If 100% of viable area is used, the technical potential of solar and wind becomes a factor of 10 larger as reported by(Langer et al., 2021). It is also likely that the known technical potentials also increase as technology matures, resulting in more efficient conversion of light to electricity or finding better ways to harness tidal energy. In terms of utilization, renewable resources are highly underutilized with geothermal being only 9% utilized and on the low end, only 0.1% of solar resources are currently utilized. From the generation perspective, Vidinopoulos et al. (2020) estimates that Indonesia has the technical potential to produce 26,225 TWh annually with most of that potential coming from solar. And with demand only expected to grow in the coming decades by 3% to 6% until 2030 reaching total demand anywhere from 433 TWh to 702 TWh at which point the demand rate will continue to grow at higher rates (KEN, 2022; Pambudi et al., 2023). Given that the government of Indonesia has explicitly stated goals to reach a 30% renewable energy in Total Primary Energy Supply (TEPS) by 2030, massive efforts are needed to transition from a mainly fossil powered grid to a more renewable one. To better utilize the renewable energy resources, forecasts by National Energy Council expect that installed renewable energy capacity will reach between 27 and 52 GW. Optimistic scenarios predict reaching 25% renewable energy share whereas realistic scenarios place it closer 14% (KEN, 2022). Non-governmental sources indicate that reaching net-zero could also be possible. For example, IEA (2022a) presents net-zero scenarios where renewable energy share of electricity reaches 90% by 2050. Reaching this goal requires both the public and private sectors to work together.

IPPs face the problem of having to work with the context of Indonesia's Energy Law (2007) and essentially only have 1 buyer: PLN (Saladin Islami & Aditya, 2020). This results in the government holding a major stake in the power industry via PLN, the state electricity company, is the key stakeholder responsible for power generation and distribution. PLN controls the majority of the country's generation capacity and is the sole distributor (Widya Yudha & Tjahjono, 2019). Independent Power Producers (IPPs) are as the name implies independent power producers. They function by securing permits from the PLN to connect to the grid or permits for establishing microgrids given the difficult geography of the country. IPPs also sell all of their power to the PLN with guidelines provided by PR 211/2022. The Ministry of Finance supports renewable energy development to achieve greenhouse gas emission reduction targets, increase energy security, and promote regional development. This translates to the Ministry of Finance being the key source of public investment in the energy sector (Saladin Islami & Aditya, 2020). Given that Indonesia is primarily an island nation, local governments also have heavy influence on the success of projects. Regional governments are also capable of setting local targets and developing local projects; however, for large sources of fundings, the regional government must engage in conversation with the Ministry of Finance. Finally, all parties in the energy sector receive regulations and laws from the National Energy Board. The key goal of the National Energy Board is to establish longer term goals and policies to encourage further utilization of renewable energy. Another aspect of the energy market in Indonesia are the barriers due to PLN being such a large share of the market. IPPs are faced with economic and institutional barriers. According to an article by Sambodo et al. (2022) key barriers hindering the development of RET are governance, lack of investors, and lack of infrastructure. The governance issue and lack of investors are due to unclear subsidies, particularly the large disparity of feed-in-tariffs. In order to reach the target, more independent investors are needed to provide capital.

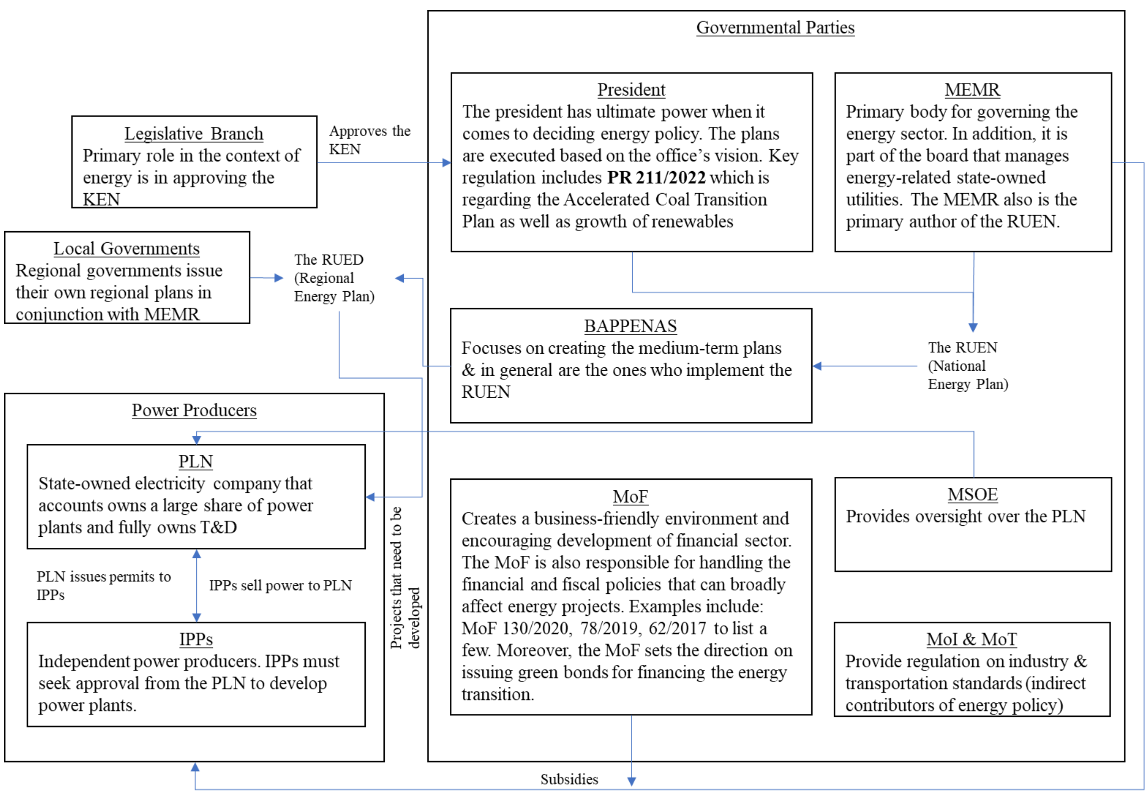

Figure 1.1 Stakeholders in the Indonesian Energy System

1.2. Context on Energy Investment & Subsidies in Indonesia

Investments in the Indonesian energy market have proven to have a positive impact as for every 1% increase in electricity investment has been roughly equated to a long-term 0.72% increase in economic growth. This mutual benefit shows that the government has a vested interest in promoting the industry via subsidies. According to Foreign Direct Investment (FDI) data as cited by OECD (2021), general FDI into Indonesia doubled over the period of 2013 to 2016, reaching 30 billion USD. FDI in the energy sector; however, saw a decline from 7 billion USD to 5 USD billion in 2016. However, with the new plans to transition to low-carbon energy, the government of Indonesia has set new investment goals. The 2025 renewables investment target is 72.5 billion USD and expected to grow to 255.9 billion USD. Energy investments have seen steady increase in the years following 2016, reaching around 12 billion USD in 2019. Investment in Indonesia currently comes from 3 major sources. 40% of power investments are sourced from development finance institutes (DFIs), such as the World Bank, and export credit agencies (ECAs), such as the Asian Development Bank. Another 25% of investments were driven by public spending; however, almost all the ~3 billion USD invested in energy from 2016 to 2019 went towards fossil fuel power. The remaining 30% was sourced from private investors. Private investment accounted for almost half of all investment into renewables during the same period.

This is a positive directional indicator highlighting the government's dedication towards the energy transition. The government also established the Indonesian Infrastructure Finance (IIF) to behave as a catalyst to encourage private investment in infrastructure which also includes regulations regarding the issuance of green bonds (IIF, 2020). The IIF also has access to long-term funding to award to projects that meet targets in line with the UN Sustainable Development Goals. In more recent analyses, it was noted that investment into renewable energy only reached 74% of its 2021 target (2.04 billion USD) and this was only coupled with sub-par performance along planned transition routes. Moreover, a modification made to RUPTL modified growth rates in the renewables sector to be 1.8% between 2025 and 2030, a steep decline in the 8% growth from 2020 to 2025. The Indonesian government stated that this was likely due to the impacts of COVID-19; however, private investors will be the key drivers in the transition indicating the need to design future policies in such a way as to encourage investors to build renewable plants in Indonesia.

Focusing in on the private sector specifically, Indonesian renewable energy plants have had mixed financial success. Langer, Kwee, et al. (2023) identified LCOE ranges for solar between 73 and 155 USD/ MWh and identified capital cost reductions as a major cost factor. Fathoni et al. (2014) also found that at discount rates of 10-14% and capital grants, the LCOE of solar would reach 55-65 USD/ MWh. And more interestingly, the LCOEs calculated in the papers are in fact greater than those offered by PR Regulation 112/2022 of 69.5 USD/ MWh. The trend for difficult investment is also seen in other technologies, with those on wind reporting LCOEs of 58 to 244 USD/MWh (Langer, Zaaijer, et al., 2023), with LCOEs of 82 USD/ MWh being achievable at wind speeds greater than 8 m/s (Fauzy et al., 2021). Pristiandaru & Pambudi (2019) also explain that under current regulations, wind is not a worthwhile investment. Geothermal obtains returns in the range of 8 to 11%; however, it is still not usually competitive (Putera et al., 2019; Sahdarani et al., 2020). Biomass incineration has been shown to need tariffs between 60 and 91 USD/ MWh to yield positive returns (Sudibyo et al., 2017; You et al., 2017); whereas gasification has LCOEs exceed 200 USD/ MWh (Sriwannawit et al., 2016). Finally, case studies on hydropower have seen LCOE of 56 USD/ MWh at a discount rate of 11% to returns of 19.5% at an FIT of 95 USD/MWh (Nashrulloh et al., 2021; Windarta et al., 2020). Overall, studies on investigating renewable energy project profitability have seen that about 40% of proposed projects are profitable under current conditions (Halimatussadiah et al., 2020).

On the subsidy side, energy subsidies in Indonesia can be sub-divided into 2 major categories: fossil fuel subsidies and renewable energy subsidies (ADB, 2019; Sen et al., 2020). And unsurprisingly, the 2 categories are competing for the same limited funds. To begin, the Indonesian government first began subsidizing fossil fuels in 1977 encompassing 7 different types of fuels. The next major decision involved narrowing the scope to only encompassing 5 types of fossil fuels. By 2004, Indonesia had become a net importer of oil and the following year, the government raised gasoline prices by 80% and removed subsidies from the industrial sector. In the same year, only 3 petroleum fuels now qualified for subsidies and the subsidy budget was increased to 8 billion USD. From the period between 2007 and 2017, electricity subsidies began to increase. It was first increased in 2010 by 10% and once again in 2013, electricity tariffs were increased by 15% by 450VA and 900VA were excluded. By 2017, electricity subsidies were only available to low-income households. Despite the reductions in electricity and fossil fuels subsidies, regulatory decisions made in 2021 ensure that coal producers are required to sell a portion of their production for domestic energy generation. Moreover, the government also fixes the price of coal at 70 USD per ton making it a cheap and accessible form of energy in the market. On the renewable energy side of the story, the key regulation is PR 211/2022 that sets ceiling prices based on LCOE on energy prices based on the technology and geographic area. This new regulation is aimed to aid the accelerated phase out of coal but seeing as it is a new regulation as of the writing of this document, that still awaits to be checked. On more current trends, the Indonesian government spent ~17 billion USD in 2020, representing approximately 1% of its GDP in 2020. Moreover, 94% of the subsidies went towards supporting fossil fuel production and consumption. Less than 1% went towards renewable energy further cementing investor doubts in the government's dedication to its own transition goals (Suharsono et al., 2022).

1.3. Research Question & Gap

For the purposes of meeting future demands, the government will need to implement a series of policies with measurable financial impacts on the market. The key gap is in understanding how the Indonesian government can support growth and how much is needed to fund the growth in the renewable energy sector. Therefore, this thesis sets out to answer the key question:

How can the government of Indonesia maximize the dollar effectiveness of a subsidy policy to provide the maximum benefit to private-sector investors?

To address this question, the thesis will need to answer the following questions first.

1. What is a likely transition pathway for the energy sector from 2025 to 2050 in Indonesia?
2. How can we value subsidies and investments in the future?
3. What does a good subsidy policy look like and how can it be modelled?
4. Which policies are effective at which point in time?

This thesis is divided into 5 main chapters. Chapter 2 provides the literature review detailing realistic transition pathways, the different subsidy structures in use, and the different methods of evaluating projects and how costs are expected to decline. Chapter 3 details the model development including how project valuations are calculated, how to identify the optimized subsidy-to-NPV ratio and summarizes the key inputs to the model. Chapter 4 details the results of the model in Chapter 3 and identifying key metrics such as subsidy awarded per MW installed and subsidy awarded per MWh generated among others. Chapter 5 focuses on a discussing how different needs appear at different times along with identifying where the model may benefit from an additional review. Chapter 6 focuses on generating specific policy recommendations and providing insights on the success and shortcomings of the model.

Chapter 2. Literature Review and Theoretical Background

This chapter details the literature used for the development of the model and a theoretical background into the topic. Both the literature and theoretical background are linked and best explained in tandem as real-world examples also provide an insight into how literature approaches the topic. Research primarily focused on 4 key elements: long-term scenarios for the Indonesian energy system, methods for evaluating energy investments, design and quantification of "good" subsidy policies, and methods for optimizing subsidy policy.

2.1. Long-term Energy Projections for the Power Sector in Indonesia

The future of the energy system in Indonesia heavily depends on the government's commitment to its renewable energy goals along. Long term scenario design methods such as LEAP and TIMES were primarily used for designing the scenarios and typically relied on assumptions such as population growth, per capita energy consumption, technological behavior, and financial parameters (Kanugrahan & Hakam, 2023).

Long-term scenario design into 2050 has followed 3 broad themes: Business-as-Usual (BAU), government plans (GP), and net-zero emissions by 2060 at the latest. BAU forecasts across literature reviewed shared two key assumptions. First, it assumed that no additional government policies would affect the development of the renewable energy grid. Examples of this include setting emission caps or offering additional subsidies. Second, it assumed that development would occur in a cost optimal method under the scenario assumptions. GP forecasts across literature primarily focused on identifying cost optimal pathways that meet the RUEN renewable technology shares of 23% by 2025 and 31% by 2050 under current government regulations. In these scenarios, the renewable energy share has been able to exceed the targets by minimizing costs as seen in (Dewi et al., 2022). Finally, NZE forecasts across literature typically focused on becoming completely net zero by 2060 at the latest. Some sources, such as IEA (2022b), found pathways that could meet net zero emissions by 2050. NZE scenarios were designed to meet the targets at the lowest possible cost but did not address the needed policies to drive the accelerated transition.

Table 2.1 Literature Reviewed for Long Term Forecasting of the Indonesian Power System

Source	Method	Period	Average Growth Rate
(Dewi et al., 2022)	AIM/ end-use	2020-2050	5.5-7%
(Kanugrahan & Hakam, 2023)	LEAP	2020-2050	6-13%
(Ordonez et al., 2022)	LEAP	2020-2040	9%
(Reyseliani & Purwanto, 2021)	TIMES	2020-2050	5-7%
(IEA, 2022a)	GEC-M	2020-2050	5-9%
(IRENA, 2022)	REMap	2020-2050	6-10%
(Suharyati et al., 2022)	LEAP	2020-2050	5-9%

The key findings from BAU related research indicated that coal and other fossil fuels will remain the dominant energy source until 2050 (Dewi et al., 2022). Ordonez et al. (2022) justifies the dominance of coal and other fossil fuels is due to higher financing costs for renewable energy. This is evident when comparing the Baseline and Combined Policies scenarios presented in the paper which shows that declining financing costs until parity leads to a much higher renewable share (30% vs 70% by 2040). The author noted the need for consistent policy to drive down risk in order to aid in the transition.

In the more ambitious scenarios, growth rates were much higher due to the increased demand for electricity driven by switches to the electric vehicles and higher carbon prices (Dewi et al., 2022; IEA, 2022b). Once again, the primary resource is solar PV in these studies accounting for ~40% to 45% of total installed capacity between the different sources.

2.2. Financial Modelling of Energy Projects

In order for power plants to be built, capital must be mobilized. Capital refers to cash that is being used in a productive manner. For these large projects to occur, investors typically also take on loans from banks to lower the upfront costs (Langer, Kwee, et al., 2023). The act of combining debt and equity financing is also referred to as project financing. The reason this is attractive is because lenders receive interest as payment for providing capital which is usually lower than the cost of equity (Damodaran, 2007). This is mainly due to the lower risk of losing on the investment due to having the rights to collect interest regardless of revenue. Lenders are typically the first ones to be paid in the event of a bankruptcy according to international principles of debt seniority. Providers of equity receive dividends as payment for providing the initial capital. The cost of equity is a function of how risky a project is perceived to be. A bankable project is one in which all parties agree to provide initial capital with a minimum acceptable rate of return (MARR) (Langer, Kwee, et al., 2023).

For large infrastructure projects that require large capital investments and that payback over a large period of time, there is a need for knowing how to appropriately value and is typically done using DCFA. A DCFA is the most recognized method internationally and is in simple terms the sum of all annual cash flows multiplied by a discount factor over the lifetime of a project (Equation 2.1) (Herbohn & Harrison, 2002). This sum is called the Net Present Value (NPV) of a project and represents the value to the investor at the start date of the project. As seen in Equation 2.1, the value of NPV is dependent on 3 key elements: the annual cashflow (c_i), the lifetime of the project (T_{life}), and the discount rate (r_d). Positive NPVs indicate that the project has returns greater than the discount rate while negative NPVs indicate the project returns less than the discount rate. The rate at which the NPV is exactly equal to zero is known as the Internal Rate of Return (IRR). The cash flows of a project represent the earnings, in cash, the project generates at the end of each year and typically mirrors an income statement. The advantage of this method is that the investor is more certain of the actual monetary benefit relative to an investor and project specific discount rate, MARR. The key disadvantages of this method are that it is complex in construction and that long-term strategic value of investments is not properly included.

Equation 2.1 Calculation of NPV

$$NPV = \sum_{t=0}^{T_{life}} c_i \cdot \left(\frac{1}{1+r_d}\right)^t$$

2.3. Subsidy Theory, Design, Mechanisms & Quantification

Subsidies are policy instruments available to governments that can be used to encourage certain private sector decisions. Different institutions have defined what a subsidy policy is actually; however, for a policy decision to be considered a subsidy it must have 3 elements (IRENA, 2020; Jones et al., 2010; Kojima, 2017). First, the policy is enacted with a certain and definable goal in mind. Second, the policy must be accompanied by the deployment of financial resources. And third, the policy must be trackable both in terms of impact and cost to government.

Despite having a relatively simplistic definition, the process of designing a “good" subsidy policy is difficult. For example, over-subsidizing a technology can result in the desired goal but can become increasingly expensive for the government. This was seen in the development of the Spanish solar sector in which the government cycled through a number of smaller policy updates over 2014 to 2019 resulting a dramatic slowdown in the sector due to policy uncertainty (Mahalingam & Reiner, 2016). Similarly, under-subsidizing a technology can result in poor deployment; a problem seen in Indonesia's previous attempt to encourage RET development under MEMR 4/2020. While it was a step in the right direction, the prices stipulated were set too low necessitating the updated PR 211/2022 (OECD, 2021). There is also the issue of identifying when a policy should be reformed since an over-reliance on subsidies can also lead to a decrease in innovation (Gouchoe et al., 2002).

This resulted in the definition of 5 design principles for "good" subsidy policy design (IRENA, 2020; Jones et al., 2010; Kojima, 2017). First, there must be a clearly stated goal with an end-date for when those goals are met. Second, the policy should be stable over multiple years. Third, the financial resources dedicated must be sufficient to drive the desired behavior but not too high so as to cause market distortions. Fourth, the level of aid provided should be benchmarked and dependent on meeting specific criteria. And fifth, institutional barriers should be removed so as to facilitate the introduction of new entrants.

In the specific case of energy subsidies, (Harvey et al., 2018) provided three classifications: performance standards, economic signals, or R&D support (definitions in Table 2.2). Each category provides its own incentives and acts in a virtue loop as seen in Figure 2.1; however, the private sector is most responsive to economic signals and performance standards. In a broader sense, economic signals have traditionally been seen as the most effective for promoting additional capacity installations and therefore will be the primary focus of this thesis (Peters, 2012). In a practical setting, determining subsidy levels is often a difficult process with literature providing different guidance. Gouchoue et al. (2022) suggests that over-subsidization can actually be beneficial for a short period until an industry is able to support itself. Sen et al. (2020) argues that subsidy policy for developing countries should not just be production based but also offer capital incentives to lower the barrier to entry. Özdemir et al. (2020) argues that production-oriented subsidies are useful for meeting short-term policy targets but does concede that capacity subsidies result in a more stable investment landscape. An example of a “good” policy was seen in Denmark’s approach to wind in which the government first instituted subsidies to lower installation costs and as the market matured began to gradually phase out the capital-oriented subsidies and began introducing an FIT scheme (IRENA, 2013). The real-world success of a blended policy also demonstrates that models aiming to optimize subsidy policy should also look at blended policies.

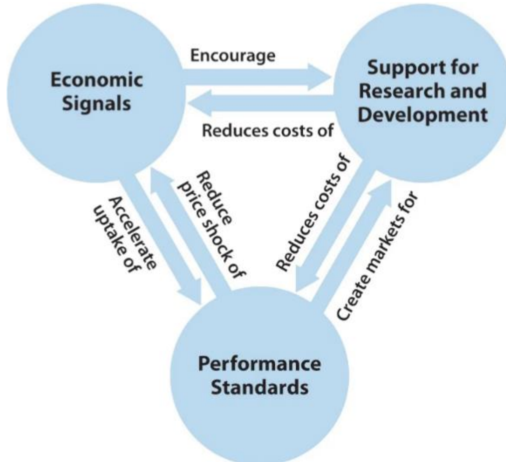

Figure 2.1 Diagram showing reinforcements and effects of different policies (Harvey et al., 2018)

There are two key elements of assessing the cost of a multi-year subsidy policy. The first is calculating the yearly costs incurred by the government. This is typically done using one of four methods listed by an OECD (2013) report. The one most used in literature aimed at optimizing subsidy policies is the TSE approach which measures the monetary value of all transfers to the subsidy recipients. This method is the simplest to calculate in the context of a model as all cash flows are known and it does not rely on additional assumptions such as a reference price seen in the PGA and P/CSE methods and does not aggregate subsidy costs to a societal level as in the GSSE method. The second element is in valuing the present value of a multi-year policy. None of the studies reviewed assigned a time-value of money to the government but did assign a time-value of money to investors. This results in a bias in evaluating total cost to the government and will tend to overestimate the actual subsidy requirement. In terms of aggregate costs, predictions estimate that total subsidy costs will drop to 0.2% of GDP in developing countries by 2050 (IRENA, 2020).

Overall, the concept of a "good" subsidy policy needs to be applied within the context of optimizing the monetary aspect of subsidy policy and within the context of Indonesia, this implies the use of both production and capacity-oriented subsidies due to its capital cost barriers. In addition, since policy uncertainty is another concern, this thesis will also focus on modelling optimal, long-term subsidy schemes.

Table 2.2 Energy Policy Design Principles (Harvey et al., 2018)

Performance Standards	*Economic Signals*	*Support for R&D*
• Create long-term standards certainty • Continuously improve • Goal-oriented • Prevent gaming the system	• Create long-term business certainty • Properly value externalities • Use price-finding mechanisms • Ensure liquidity of subsidies • Reward production	• Create long-term commitments to research success • Focus efforts to build critical mass • Ensure companies have access to STEM talent

2.4. Subsidy Optimization Methodologies

There is always a concern when implementing a subsidy policy that it turns out to be a failure, either due to the design of the policy itself or the amounts awarded. This has resulted in the creation of methods that aim to solve the issue of optimizing subsidy policies, and more specifically energy policy. There is a wide array of methods for calculating the optimal subsidy allotments with literature sources (Table 2.3) solving this issue using 4 key elements: theoretical framework, objective function, decision variable, and constraints. The specific set-up of each element is informed by the stated goal of the paper as seen in Figure 2.2.

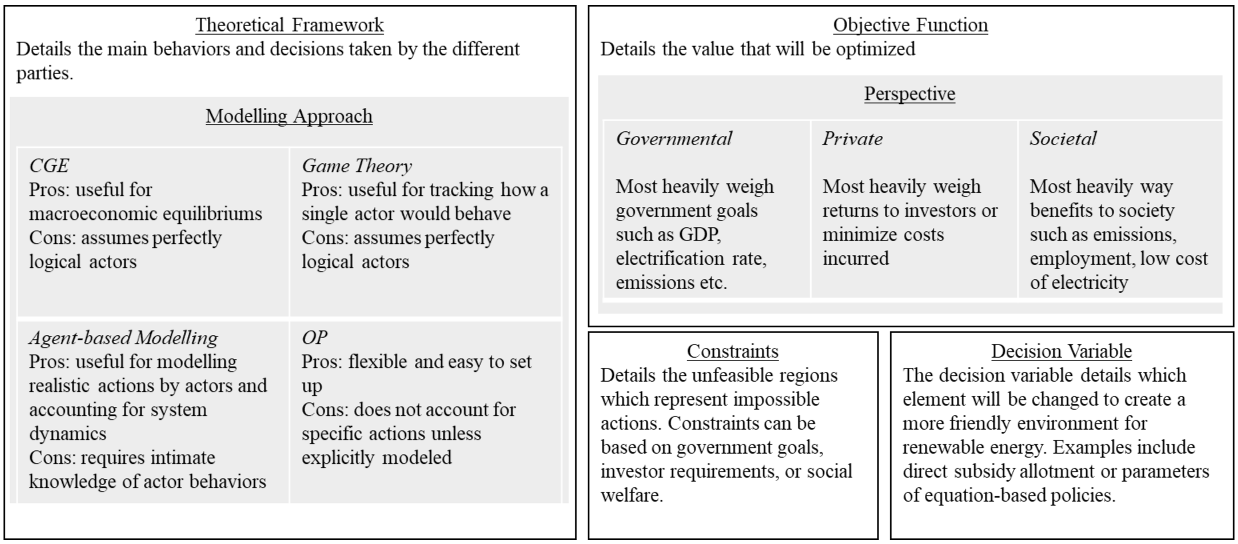

Figure 2.2 Explanation of the Key Elements of a Subsidy Optimizer

The *theoretical framework* refers to how the problem was solved and from which perspective. The solution methods found in literature include game theory, computer-generated equilibrium (CGE), agent-based approach, and objective programming (OP). The perspectives taken in literature have been either from the government, private, social, or a blend of perspectives.

The solution method refers to how the optimization problem was modelled as. As mentioned, literature broadly used one of four methods. Each method has its own advantages and disadvantages as seen in Figure 2.2.

Table 2.3 Summary of Subsidy Optimization Related Studies

Study	Methods	Objective Function	Decision Variable	Main contribution
(Antimiani et al., 2023)	CGE	Minimize emissions	Phase out of fossil subsidies, innovation funds & carbon tax	Understand the carbon tax required to encourage renewable and discourage fossil energies
(Liu et al., 2021)	Game theory	Minimize Net Present Costs & Nash Equilibrium	Subsidy allotment from government	Understanding investor decisions under different subsidy schemes
(Boomsma & Linnerud, 2015)	OP	Maximize RO Value	Electricity price, subsidy value, termination point	Identify the impact of uncertainty on subsidy schemes
(Rigter & Vidican, 2010)	OP	NPV + Subsidy = 0	Digression rate of FiT	Calculation of optimal FiT
(Batlle, 2011)	OP	Minimize total cost	Production of energy sources	An optimization scheme with policy considerations built-in as constraints
(Mir-Artigues & Del Río, 2014)	OP	Maximize profitability index	Annual tariff updating parameter, initial support level, annual tariff digression rate	Present a framework for analyzing different subsidy schemes in conjunction with each other
(Ritzenhofen & Spinler, 2013)	OP	Maximize RO value	Decision time horizon	Understanding the impact of time on investment decisions under pre-defined FiT regimes
(Kim & Lee, 2012)	OP	Maximize number of sign-ups to a FiT program	Value of subsidies awarded under FiT	Understanding the impact of different FiT policies on the market
(Schmidt et al., 2013)	OP	Maximize NPV	Binary decision variable indicating if a project occurs	Understanding if investments will happen under a particular FIT sche(Biondi & Moretto, 2015)gets
(Biondi & Moretto, 2015)	OP	Maximize RO value	Energy pricing and investment timing	Understanding the threshold between process and costs to maximize payoff
(Durand-Lasserve, 2015)	CGE	Maximize social welfare	Subsidies assignment by recipient	Understanding how different subsidy payoff structures influence different parties

(Y. Sun et al., 2021)	Multi-actor CGE	Actor 1: Maximize GDP Actor 2: Maximize NPV	Carbon tax rates & revenue recycling	Understanding how subsidies can be used to meet multiple targets
(X. Sun et al., 2019)	Agent-based	Best decision for each agent	RO value (producers) and LCOE (consumers)	Understanding how renewable energy may develop under real market decision making
(Schwenk-Nebbe et al., 2021)	Agent-based	Best decision for each agent	Emission allotments and carbon price	Understanding how competition and cooperation may influence competing markets in the energy transition
(Reichenbach & Requate, 2012)	Game theory	Maximize overall welfare (reaching Nash Equilibrium)	Subsidies and learning mechanisms (private and public)	Understanding how learning spillovers and subsidies impact renewable energy deployment
(Jeon et al., 2015)	Dynamic Agent-based	Best decision for each agent valued using RO	Subsidy allotment by policy type	An optimized balancing between R&D and economic policies
(Amiri-Pebdani et al., 2022)	Game theory	Nash equilibrium	Decision to tax or subsidize consumers	Understanding of how to back cast government actions based on desirable market conditions
(Marousi & Charitopoulos, 2023)	Game theory	Nash equilibrium	Decision to tax or subsidize consumers	Understanding of how cooperation vs competition in a market affect subsidy and taxation needs to meet government goals
(Zhang et al., 2017)	OP	RO Value + Subsidy = 0	Value of subsidies allotted and carbon trading	Comparing the changing subsidy requirements with and without carbon trading

Single perspective frameworks assume one fixed element while the others are flexible. For example, in Batlle (2011), the policy goals and subsidies awarded were fixed and the moving decision variable was on what type of capacity was to be installed. Battle (2011) modelled the problem from the perspective of the private sector as the goal with the objective of minimizing total present costs. This type of framework is useful when evaluating different schemes or pathways on specific actors; however, it is limited in that it offers little differentiation in the cost of subsidies compared to the cost of installations. Other research that aimed to design long-term subsidy policies primarily focused on using single perspective such aBoomsma & Linnerud (2015), and Boomsma & Linnerud (2015), solved this problem by using a time-dependent subsidy formula. Rigter & Vidican (2010) opted to optimize the formula parameters along a single pathway to minimize total subsidy costs while Boomsma & Linnerud (2015) assumed a fixed formula and maximized investor RO value. This illustrates that subsidy formulae can be applied in either perspective. However, a single perspective is limited as it does not account for inter-connections between the government and private sector.

Multi-perspective frameworks take the approach of trying to balance two or more perspectives at the same time. The studies that took this approach used game theory or agent-based approaches to model decisions made at each time step but was limited in its application of formulaic subsidy policy over multiple periods. For example, Liu et al. (2021), used a bi-level objective of first, minimizing subsidies and second, minimizing investment costs; however, it was only applied within a single year. Other studies such as Amiri-Pebdani et al. (2022) and in Marousi & Charitopoulos (2023) also used this approach but also only played the game in a single time-period. Other multi-perspective approaches that used agent-based models were able to map out realistic decisions but overall did not use formulaic subsidy policies.

While this is useful for determining optimal actions, it fails in addressing the issue of policy uncertainty. For example, in X. Sun et al. (2019), two agents were used to represent 1) renewable energy producers and 2) consumers. The agents then played for a set amount of time and at each time step, producers and consumers were both given the ability to make decisions such as entering the market, exiting the market, and purchasing (which represented the decision variables) and at what volume. The usefulness of this method is evident in that it can be played over a long period of time; however, it is limited since in practice governments establish policies that must be followed by the private sector rather than it being a negotiation on equal grounds. This results in a gap in identifying a model that accounts for the realities of the government establishing long-term policies and valuing the interests of the private sector at the same time.

This then leads to the next element of solving the optimum subsidy question: *the objective function*. In essence, the objective function is the value that is aimed to be optimized (either minimized or maximized) and is a function of the decision variable. Once again, the intended goal influences what the specific objective function should be. For example, Sun et al., 2021 proposed the goal of maximizing GDP under the introduction of a carbon tax. While this is useful for single-perspective models, the need for accounting other parties is also needed. For example, in Jeon et al. (2015), each agent sought out to seek the maximum of the value they were interested in, in this case GDP for the government and project NPV for investors. However, the shortcomings of this method were that the results produced once again assumed that both parties are on equal parity and that the optimal depended on the selected intent of the government. This implies that the objective function should be somewhere between these two extremes. Another issue in selecting the objective function comes about in identifying how to value projects. As discussed in sections 2.2 and 2.3. Current literature on subsidy allotments, have used metrics such as NPV, RO, and LCOE from the investor-side and have used an undiscounted TSE method for valuing subsidies as seen in Table 2.3. However, other metrics have also been used such as GDP, emissions, and net present cost. This is once again influenced by the goal of the analysis. For example, if the goal is to minimize emissions, then economics must be constrained, and similarly if the goal is to aid the private sector, then the subsidy scheme should be fixed. This then leads to the final element of subsidy optimization: the *constraints*.

Constraints represent values in which the solution cannot exist. In this case, constraints represent solutions that do not align with government goals, do not meet societal requirements, result in a poor investment landscape, or are physically unfeasible. Constraints based on government goals include limiting carbon emissions or limiting subsidy amounts paid out. Constraints based on societal goals include limiting the price of electricity to a certain amount or ensuring continuous power supply. Constraints based on the private sector goals include ensuring minimum investment thresholds or limiting costs. Constraints on physical limitations are based on the actual issues faced in installing new plants. An example of this kind of constraint is limiting the development of solar plants as total installed capacity reaches the technical potential. Overall, the different methods have both advantages and disadvantages that can be seen summarized in Figure 2.2.

Overall, five key gaps exist in the current literature in subsidy optimization. First, the studies reviewed aimed to only maximize benefit to private sector or minimize subsidy cost to government but did not aim for any efficiency requirements. Second, studies reviewed also failed to look at a subsidy policy as a multi-year effort and neglected discounting the total cost to government. Third, the existing literature only examined one energy scenario and therefore missed out on analysing the interconnection between pathway and policy. Fourth, to the author's knowledge, this level of DCFA has not been applied to look at the investor's returns. And fifth, this kind of subsidy optimization has never been applied to the case of Indonesia, to the author's knowledge. This thesis then in turn will contribute by addressing the gaps found in literature.

Chapter 3. Mathematical Model Development & Methodology

The key focus of this thesis is to identify the optimal subsidy structure for accelerating the energy transition. In order to solve this question, an optimizer was developed to solve for the "optimal" policy design. All parties have a vested interest in the deployment of renewable energy; however, since the focus is on large scale integration, only government and investor perspectives were considered. It is assumed that the government is interested in minimizing the cost of subsidies while designing a consistent and predictable subsidy policy. The government also only has 1 option: provide subsidies for the deployment of renewable energy capacity. It is also assumed that investors are interested in maximizing benefits and will invest in a project if it meets the minimum acceptable rate of return (MARR). Investors have the option to either invest or not invest.

More specifically, in the context of the Indonesian energy landscape and this project, four factors were considered development of this solution. First, the subsidy policy should be formulaic in nature due to the perceived higher risks in the country as discussed in Section 1.2. A formulaic and predictable subsidy, in theory, is also more effective as discussed in Section 2.3. Second, given the urgent need to transition, it is assumed that all new capacity goals are met in each year. This places a burden on the government to meet a minimum subsidy amount. This has the secondary effect of assuming that investors will only ever invest, effectively making their option to not invest irrelevant. Third, given that this is a long-term forecast, the model must have some method for valuing future projects and subsidies that is dependent on the state at the time. This also implies that the subsidy policy has an end date that can be determined, and it also suggests that project deficits in the future should also have a present value for assessing the needs. And fourth, the perspective taken is balanced between the government and private sector. This implies that the objective function being solved should account for the government need to reduce costs and the investor need to maximize benefits.

The model used will add to existing literature in four ways. First, the objective function will aim to maximize the change in project NPV relative to subsidy amounts. This represents a unitless measure of subsidy efficiency not used in literature to the author's knowledge. Second, this model will discount the cost of a multi-year policy using the government discount rate in addition to an optimizer (Jones et al., 2010). Third, this model will use three different scenarios to understand how subsidy policy can be tailored to different pathways. And fourth, a detailed DCFA will be used to assess the investor NPV as opposed to the standard project NPV typically used in literature. The aim of this is to capture a more accurate of private-sector investment needs.

This chapter details the overall process taken in developing the model while accounting for the four particularities of the model goal and perspective taken. The chapter is divided into 8 sections. First, an overall model scheme along with the solution strategy will be presented. Second, the transition pathways will be presented. The third section focuses on how costing parameters will change over time. The fourth section details how project valuations are made. The fifth section details how the value of subsidy policies will be calculated. Sixth, the objective function will be presented. And seventh, the method for validating the model will be presented.

3.1. Model Scheme

The four guiding principles were used in determining the necessary components and solution strategy for answering the question proposed. The model has five key elements: scenario design, forecasting future costs, valuing the projects and subsidies, designing the objective function, and the central algorithm to perform the calculations (Figure 3.1).

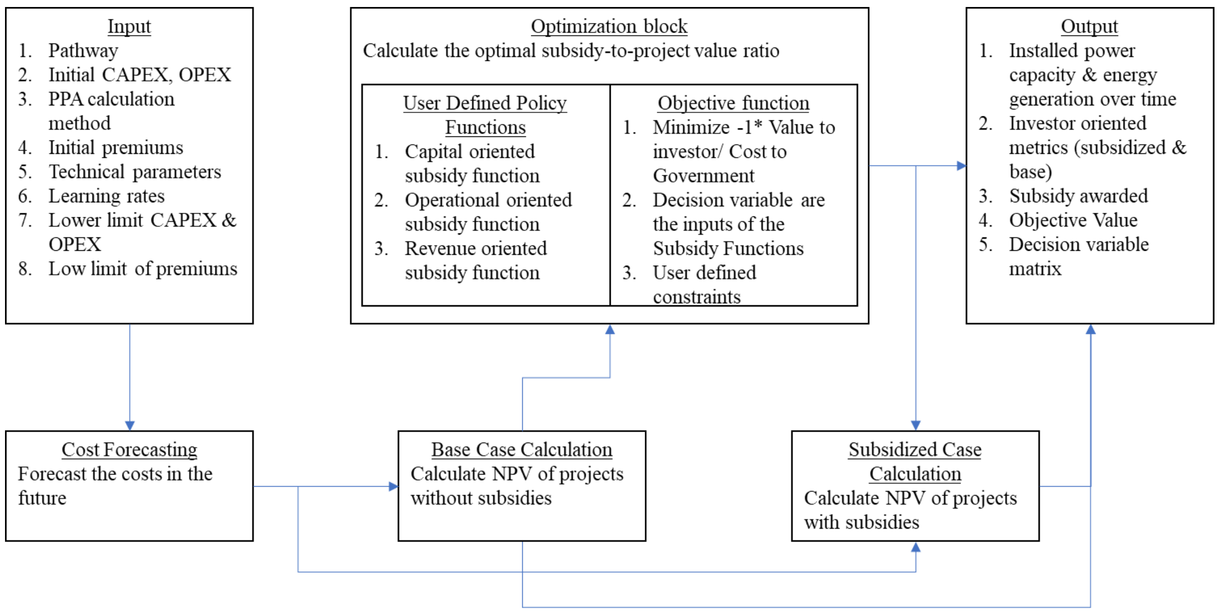

Figure 3.1 Model Algorithm with Key Elements

As seen in Figure 3.1, the key inputs into the model are the initial conditions, final conditions, the pathway, and forecasting parameters. With the inputs, first future costs are anticipated in the Forecast Costs and Forecast Rates blocks. Next is the Base Case Calculation block in which business cases are developed to determine the minimum subsidy requirements (i.e., the amount needed to ensure all investor-side NPVs to equal 0). The output of the block are the base case IRRs and NPVs and the minimum subsidy requirement. The next block is the Optimization block. In this block, the objective function is minimized. Within this block, the subsidy policy structures are determined. The output of this block is the objective function and the value of the subsidies awarded. Finally, the Subsidized Case Calculation block calculates the equity NPVs under the proposed subsidy scheme. The output of the algorithm is 3 tables: 1) summarizing the project values at different times, 2) the annual cash flows of the government, and 3) the results of the optimization.

This model was calculated assuming that all renewable energy technologies are solar PV, on shore wind power, large scale hydropower, large scale geothermal, and biomass.

3.2. Scenario Design

Following the second guiding principle that energy targets will be met, it was opted that the scenarios be user-defined. Following the trend seen in literature, 3 different scenarios were developed: BAU, GP, and NZE. Since the focus is on large-scale transformation, the following five technologies were investigated: utility scale solar, onshore wind, large-scale geothermal, large-scale hydropower, and biomass.

Since the goal is to find the optimized subsidy policy that maximizes benefit for the investor, it implies that the situation for this optimum occurs when the scenario without additional subsidies is also optimized. Given the scope of the project, the 3 scenarios were designed by using literature projections of cost-optimized scenarios (listed in Table 2.1). The data collected from literature can be found in Appendix A. Operating under the assumption of constant growth, the capacity growth rate was calculated as follows:

Equation 3.1 Calculation of Average Capacity Growth Rate as a Function of Time

$$r_g = \left(\frac{C_{t_1}}{C_{t_0}}\right)^{\frac{1}{t_1 - t_0}} - 1$$

Where C represents the capacity installed of a specific technology at a time, t_1 or t_0.

Using this equation, the growth rates for each period were computed based on the literature published values and computed using the actual installed capacity in 2022 as published in (Adi et al., 2022). The rates calculated were then filtered based on which scenario category it was in. This was done to ensure that only similar scenarios were compared resulting in three, distinct, and realistic scenarios. The average growth rate for each technology was computed as well as the total installed capacity growth rate.

Following the calculations of the capacity growth rates, forecasts were then made assuming exponential growth as seen in the equation below:

Equation 3.2 Calculating the Total Installed Capacity in a Year "t"

$$C_t = C_{t-1} \cdot \left(1 + r_g\right)$$

3.3. Costing, Pricing, and Interest Rate Parameters

In order to assess the subsidy requirements, the total costs and revenues need to be determined first. This section summarizes the costing parameters, pricing assumptions, and discount rate assumptions used in the project valuation module.

3.3.1. Costing

For the sake of simplicity, 3 cost parameters were used as input into the model: capital (CAPEX), variable operational (VC), and fixed operational costs (FOPEX). Costing parameters were sourced from Breyer et al. (2018), IESR (2023) and Ordonez et al. (2022). To reconcile the different costing assumptions, the average cost of the presented parameters was used.

All 3 sources also provided insights into long-term cost forecasts. The average cost reduction rate was calculated using the following equation:

Equation 3.3 Calculating the Average Rate of Cost Change

$$r_{cost} = \left(\frac{p_{t_1}}{p_{t_0}}\right)^{\frac{1}{t_1 - t_0}} - 1$$

Where r_{cost} represents the declination rate of the specific cost parameter, and p represents the cost in year t_1 and t_0.

The average of the calculated cost reduction rates was used in this model. The data can be found in Appendix B. Costs were forecasted using an exponential model as described in the equation below:

Equation 3.4 Calculating the Cost of a Parameter in a year, "t"

$$p_t = p_{t-1} \cdot (1 - r_{cost})$$

Where r_{cost} represents the declination rate of the specific cost parameter, and p represents the cost in year t_1 and t_0.

To assess the sensitivity of the subsidy requirement to cost, the same range as used in IESR, 2023 was applied to the initial cost averages calculated. Three cost declination rates were also used to assess the sensitivity of subsidy requirements to changes in cost. A -25%/+25% was used to determine the low and high cases based on the averages calculated. The following table summarizes the costs and declination rates used.

Table 3.1 Costing Parameters Used base on Breyer et al. (2018), IESR (2023) and Ordonez et al. (2022)

			Costs			***Declination Rate***		
Technology	**Cost**	**Unit**	**Low**	**Base**	**High**	**Low**	**Base**	**High**
PV single-axis	CAPEX	USD/ MW	750,230	833,589	1,250,383	-2.60%	-3.40%	-4.30%
	Fixed OPEX	USD/ MW	8,689	11,585	14,482	-2.50%	-3.30%	-4.10%
	Variable OPEX	USD/ MWh	-	-	-	0.00%	0.00%	0.00%
Wind onshore	CAPEX	USD/ MW	1,145,360	1,431,700	2,219,136	-1.00%	-1.30%	-1.60%
	Fixed OPEX	USD/ MW	22,209	44,419	51,082	-0.70%	-0.90%	-1.10%
	Variable OPEX	USD/ MWh	-	-	-	0.00%	0.00%	0.00%
Geothermal	CAPEX	USD/ MW	2,617,793	3,739,705	5,422,572	-0.80%	-1.10%	-1.40%
	Fixed OPEX	USD/ MW	25,238	33,651	42,064	-0.80%	-1.00%	-1.30%
	Variable OPEX	USD/ MWh	0.18	0.25	0.31	-0.70%	-0.90%	-1.10%
Biomass CHP	CAPEX	USD/ MW	1,180,929	1,816,814	2,089,336	-0.50%	-0.70%	-0.90%
	Fixed OPEX	USD/ MW	34,942	46,590	58,238	-0.60%	-0.80%	-1.00%
	Variable OPEX	USD/ MWh	22.5	30	37.5	-0.50%	-0.60%	-0.80%
Hydropower	CAPEX	USD/ MW	1,632,000	2,040,000	2,244,000	-0.20%	-0.20%	-0.30%
	Fixed OPEX	USD/ MW	27,981	37,308	46,635	-0.30%	-0.40%	-0.50%
	Variable OPEX	USD/ MWh	0.48	0.64	0.80	-0.30%	-0.40%	-0.50%

3.3.2. Pricing

Under the current Indonesian pricing model as described in PR 112/2022, companies bid for the right to develop, own, and operate power plants on a negotiated price. The rights to develop a new power plant will be given to the most competitive bidder as stated in PR 112/2022 (Presidential Regulation No. 112 of 2022 on Accelerated Development of Renewable Energy for Electricity Supply, 2022).

Since the goal is to identify the optimal subsidy policy, the ceiling prices were exclusively used to assess if additional subsidies are needed. This also implies that if the ceiling price is sufficiently high enough, then no subsidies are in fact needed and the existing bidding system is sufficient for promoting development. The following ceiling prices were used:

Table 3.2 Pricing Schemes Under PR 112/2022

Technology	*Tariff with Capital Subsidy, years 1-10*	*Tariff without Capital Subsidy, years 1-10*	*Multiplier for year 11 and onwards*
PV	56.3	69.5	0.6
Wind Onshore	56.3	95.4	0.6
Geothermal	76.5	76.5	0.85
Biomass	92.9	92.9	0.8
Hydropower	37.6	67.4	0.6

Given that the regulation does not directly outline the method for updating the ceiling prices, it is assumed that the ceiling prices will be updated in one of three ways. The first method is that the ceiling prices remain constant until 2050. This was done to give an indication into when regulations can be updated or need to be updated. The second method assumes a continual decrease in ceiling price to assess subsidy requirements as the sale price decreases. The third method assumes a continual increase in ceiling price to assess subsidy requirements if the sale price continues to escalate. The continual decrease rate was based on the BPP reduction between 2018 and 2022, resulting in a rate of -5.3%. The continual increase rate was based on the nominal change in the electricity tariff to consumers from 2013 to 2020, resulting in a rate of 3.8%. The data can be found in Appendix B.

3.3.3. Cost of Financing

The cost of financing refers to the costs of debt (CoD) and of equity (CoE). CoD and CoE are also the interest rate that is used to discount future cash flows. CoD can be thought of a sum of 2 terms as seen in Equation 3.5. The r_{BI} term is the sum of the global risk-free rate (the US treasury bill commonly), the country default spread, and the lender margin. Damodaran maintains a database of country spreads that is publicly available. A lender margin of 2% was assumed based on Anatolitis et al., (2023). The r_{tech} term represents the additional risk premium associated with investing in a particular technology. The CoE can also been seen as a sum (Equation 3.6). In this case, r_{C+E} represents the sum of the global risk-free rate, equity risk premium and country risk premium. This can also be the sum of the country risk-free rate (typically the government 10-year bond yield) and the equity risk premium. Damodaran maintains a database of equity risk premiums and can be found digitally. The 10-year bond yield of Indonesia as of 2023 is 6.5%. Rate related data can be found in Appendix B.

Equation 3.5 Formula for Calculating the Cost of Debt

$$r_i = r_{BI} + r_{tech} * (1 - r_{tax})$$

Equation 3.6 Formula for Calculating Cost of Equity

$$r_e = \mathrm{r}_{C+E} + r_{tech}$$

r_e is the cost of equity
r_{B+I} is the
r_{C+E} is the country & equity risk premium
r_{tech} is the technology risk premium
r_{tax} is the corporate tax rate

No direct values for technology premiums in Indonesia for all the technologies used in this paper. References were found for solar PV and wind risk premiums, and they served as the basis for scaling the risk to other technologies. Technology premiums were also assumed to be directly related to its market share as described in IRENA (2023). The relative risks of the different technologies were determined by comparing the standard deviation of index funds that track the performance of that technology globally. The index funds used are included in the NASDAQ OMX Green Economy Sector Index Family. No index was found for hydropower, so it was assumed to follow the index directly. Detailed calculations on the standard deviation calculations can be found in Appendix B. Given that technology premium data was available for wind and solar PV only, they were both used as bases. The difference in basing served as the basis for realistic technological premiums. The relative risk premiums were calculated as follows:

Equation 3.7 Calculation of Technology Risk Premiums

$$r_{tech} = \frac{\sigma_{tech}}{\sigma_{base}} \cdot r_{base}$$

Where σ represents the standard deviation of returns of a particular index

The base interest rate (CoD less technology premium) and the country and equity risk premium were assumed to be constant as they are more complex to model and may not necessarily be achieved during the deployment of additional renewable energy. The rates used are listed in the table below:

Table 3.3 Summary of Rates Used

<table>
<tr><th>Technology</th><th>Country & debt-risked premium[1]</th><th>Country & equity-risked premium[1]</th><th>Maturity Thresholds</th><th>Technology risk premium (%) [1]</th><th>CoD, year 0, (%)</th><th>CoE, year 0, (%)</th></tr>
<tr><td>Solar PV</td><td rowspan="5">5.5%</td><td rowspan="5">14.5%</td><td rowspan="5"><5%, <10% & >5%,10%</td><td>3, 2.1, 1.25</td><td>8</td><td>17.5</td></tr>
<tr><td>On shore wind</td><td>3.25, 2.4, 1.5</td><td>8.2</td><td>17.8</td></tr>
<tr><td>Hydropower</td><td>0.9, 0.8, 0.7</td><td>6.1</td><td>15.2</td></tr>
<tr><td>Geothermal</td><td>0.85, 0.8, 0.7</td><td>6.1</td><td>15.2</td></tr>
<tr><td>Biomass</td><td>0.9, 0.8, 0.7</td><td>6.1</td><td>15.2</td></tr>
</table>

3.4. Project Valuation & Metric Calculations

To properly assess the subsidy needs, projects need to be appropriately valued from the investor perspective. As explained in Section 2.2, a bankable project is defined by its ability to produce consistent and reliable returns while meeting certain criteria for all parties invested. In order to establish this criterion, a DCFA approach to calculating project value was selected because it is widely recognized and used in the real world for developing large scale projects. Moreover, the outcome of a DCFA provides an easily understandable value: NPV. As discussed in Section 2.2, a positive NPV indicates a favorable investment and following the assumptions made that 1) investors will only invest in a favorable project, and 2) the projects must occur, then the NPV can also serve to understand the funding gap between the current state and the subsidized state. The following table summarizes the input parameters used:

[1] Author calculations, see Appendix B, parameters for baselining: (IEA, 2023)

Table 3.4 Summary of General Input Parameters

Parameter	Value	Source/ Comments
Depreciation Rate (Straight-line)	6.25%	(Langer, Kwee, et al., 2023)
Tax Rate	16.25%	(PwC, 2019)
Inflation Rate	2%	Public inflation data
Government Rate	6.5%	Bond rate yield, 2020 to 2025
Plant Degradation rate	0.5%	Assumed all plants degrade at the same rate as solar PV to understand worst case, (Langer, Kwee, et al., 2023)
Debt ratio	65%	(IEA, 2023)
Loan Term	15 years	(IEA, 2023)

The projects were valued from the perspective of investors, meaning that the NPV calculated represents the value to investors only. Projects were evaluated based on NPVs (Equation 2.1). The specific calculation of the base investor NPVs for a single technology are based on the following equation:

Equation 3.8 Calculating NPV of a project from the Investor Perspective

$$\pi_{tech,i} = -CE * (1 - D_r) + \sum_{t=1}^{T_{\text{life}}} (R_t - OE_t - DE_t(1 - r_t) - A_t - IE_t - TE_t) \left(\frac{1}{1 + r_e}\right)^t$$

As seen, there are 7 main line items to calculate: Capital Expense (CE), Revenue (R), Operational Expense (OE), Depreciation (DE), Amortization (A), Interest Expense (IE), and Tax (TE).

Capital costs refer to the overnight costs paid to fund the project. CE is determined as follows:

Equation 3.9 Calculation of Capital Expense

$$CE = \overline{CE} \cdot C$$

Where CE represents the capital expense, CE-bar represents the average CAPEX, and C represents the capacity installed.

Revenue is determined by multiplying the annual production by the power price (Equation 3.10). Since plants degrade over time, the generation is calculated as seen in Equation 3.11.

Equation 3.10 Calculation of Revenue in year t

$$R_t = g_t \cdot \bar{R}_t$$

Where R_t represents the revenue in year t, g_t represents the generation, and R-bar represents the price.

Equation 3.11 Calculation of Generation in year t

$$g_t = \mathrm{C} \cdot 8760 \cdot c_f \cdot (1 - \delta)^t$$

Where g_t represents the generation, C represents the capacity, c_f represents the capacity factor, t represents time, and δ represents the plant degradation rate.

Operational expenses refer to expenses needed to ensure the power plant operates and produces electricity. The OE for a given project in a given year is calculated as follows:

Equation 3.12 Calculation of Operational Expense in year t

$$OE_t = (\overline{OE}_F \cdot C + \overline{OE}_V \cdot g_t) * (1 + r_{inflation})^t$$

Where OE represents the OPEX, OE_f-bar represents the average fixed OPEX, OE_v-bar represents the variable OPEX, C represents the capacity, g_t represents the generation, $r_{inflation}$ represents the inflation rate, t represents the time.

Depreciation expenses are non-monetary expenses related to the degradation of A straight-line depreciation method was used with a rate of 6.25% as stated in the Indonesian tax code over a 16-year period. DE is calculated as follows:

Equation 3.13 Calculation of Depreciation Expense in year t

$$DE_t = BV \cdot r_d$$

Where DE_t represents the depreciation expense, BV represents the book value, and r_d represents the depreciation rate.

Amortization refers to the gradual repayment of the initial loan provided by lenders. For the sake of simplicity, amortization was assumed to occur over the half the lifespan of the project, with data for this assumption provided by the (Roth et al., 2021). This is represented by the t_{loan} term in Equation 3.14.

Equation 3.14 Calculation of Amortization Owed in year t

$$A_t = (CE \cdot D_r)\left(\frac{r_i(1 + r_i)^{t_{loan}}}{(1 + r_i)^{t_{loan}} - 1}\right)$$

Where A_t represents the annual amortization, CE represents the CAPEX, D_r represents the debt-ratio, r_i represents the interest rate, t_{loan} represents the loan life time.

Interest expense refers to the interest payment paid to lenders on the principal loan. The interest expense is calculated at each time step based on the remaining balance. The initial balance is the amount first loaned out and is calculated as seen in Equation 3.17.

Equation 3.15 Calculation of Interest Expense in year t

$$IE_t = B_t \cdot r_i$$

Where IE_t represents the interest expense, B_t represents the remaining balance, and r_i represents the interest rate.

Equation 3.16 Calculation of Remaining Balance in year t

$$B_t = B_{t-1} - A_t$$

Where B_t represents the remaining balance at a time, B_{t-1} represents the remaining balance in the period prior, and A_t represents the amortization paid.

Equation 3.17 Calculation of Initial Balance

$$B_0 = D_r \cdot \mathrm{CE}$$

Where B_0 represents the initial balance, D_r represents the debt ratio, and CE represents the CAPEX.

The tax expense represents the tax owed to the government in a year t. Since tax owed is dependent on the revenue at the year less tax-deductible expenses. Tax-deductible expenses are OE, DE, and IE. The difference between revenue and tax-deductible expenses is known as the Earnings Before Tax and Amortization (EBTA). Tax is calculated as such:

$$TE_t = \begin{cases} 0, EBTA < 0 \\ EBTA \cdot r_t,\ EBTA > 0 \end{cases}$$

Where TE represents the tax expense, r_t represents the tax rate, EBTA represents earnings before taxes and amortization.

To ensure bankability, positive cash flows before amortization was deducted was placed as a requirement. This ensures that the project has the funds to pay debts in accordance with the principle of debt seniority. If the cash flow in a year was positive following the deduction of the amortization, the remaining cash flow was assumed to go to investors.

3.5. Subsidy Policy Design & Valuation

Following the principles of a "good" policy design as described in Section 2.3, the subsidy should be consistent and targeted at addressing the barriers that hinder development. Given the specific barriers to investment in Indonesia as described in Section 1.2, it was opted to use two subsidy policies: a capital-oriented subsidy and a production-oriented subsidy. The capital subsidy aims to lower the barrier to entry into the energy market by lowering initial investment costs. The production subsidy aims to increase benefits to investors by ensuring minimum revenue levels. The subsidy is also tied to production so as to ensure that energy is actually produced. For these reasons, a similar subsidy policy as proposed in Rigter & Vidican (2010) was used. The subsidy policy parameters represent the decision variable in this problem given as the goal is to identify the optimal subsidy policy. The equation below details the generic subsidy template used:

$$s_t' = A(1-\delta)^t$$

s'_t represents the subsidy value in year "t"

A represents the initial subsidy value

δ represents the digression factor, i.e. the rate at which the subsidy value decreases

t represents time in years since the start of the policy

In the case of the capital-oriented subsidy, the subsidy value calculated in a year "t" represents the percentage of the CAPEX that the government will subsidize. In the case of the production-oriented subsidy, the subsidy value represents a feed-in-premium over the prescribed ceiling price as listed in PR 112/2022.

Given that the subsidies will be distributed over time, there is also a need to determine the present value of future subsidies by discounting them at an appropriate rate. The rate used in this case is the government 10-Y bond yield of 6.5% as it represents the rate at which the government can raise its own capital in a broad sense. The total value of the subsidies awarded was measured using the TSE method. Equation 3.18 describes the value of the subsidies awarded to a single project. The total of the subsidies awarded is given in Equation 3.19

Equation 3.18 Calculating Cost of Subsidies for a Single Project form the Government Perspective

$$s_{tech,\mathrm{t}} = s_C + \sum_{t=1}^{T_{life}} s_{r,t} * \left(\frac{1}{1+r_g}\right)^t$$

Where s_c represents the capital subsidy awarded, s_r represents the production subsidy awarded, and r_g represents the government bond yield.

Equation 3.19 Calculating Total Cost of Subsidies for All Projects Required

$$S_{total} = \sum_{techs} \sum_{t=0}^{T} s_{tech,i} \cdot \left(\frac{1}{1+r_g}\right)^t$$

Where S_{total} represents the total present value of subsidies, $s_{tech,i}$ represents the total subsidies received by the project, r_g represents the government discount rate, and t represents time.

3.6. Solution Strategy & Objective Function Design

The solution strategy refers to the method used to solve the problem. The perspectives considered in this model include the government and private sector, each with their own sets of constraints and decisions. The assumptions made already place constraints on both actors. First, the assumption that all planned development occurs places an implicit constraint that new capacity installed must be equal what the scenario describes. Second, since the private sector perspective is considered, it also places a burden on the government to provide, at a minimum, a subsidy policy that will create favorable conditions for investments. The assumptions therefore discount the use of agent-based and game theory models as the constraints placed make it so that there is only 1 outcome. This means that a simplistic approach, such as objective programming, would be most appropriate.

Given the varying needs of different technologies, each technology was given its own capital- and production-oriented subsidy policies. This means that the algorithm has 30 decision variables that it can control: the initial value, the degression factor, and the duration of the policy. The problem can then be further simplified by capping the length of the policy to be the number of years until project NPVs are positive without the use of subsidies. This reduces the number of decision variables to 20.

The next key element in the solution strategy is identifying the objective function. Given that this is a blended perspective, the objective function will depend on both the private and government perspectives. This also means that the objective should reflect maximizing the subsidy efficiency. For this reason, the objective function being maximized is:

Equation 3.20 Objective Function Definition

$$\max_{A_0, \delta_x} \left(\frac{\Pi'_P - \Pi_P}{S_{Total}}\right)$$

Where Π' represents the present value of all subsidized NPVs, Π represents the present value of all unsubsidized NPVs, S_{Total} represents the total cost of subsidies, A_0 represents the matrix of intial policy values and δ represents the policy digressionr rates.

The objective function above represents the desire to maximize the change in NPV between the subsidized and unsubsidized case per dollar subsidy spent. The maximum of this ratio in theory represents the most efficient subsidy since it generates the greatest value for the cheapest cost. Moreover, the numerator expresses the investor desire to maximize profit while the government aims to decrease the cost.

In order for the solution to be practical, the decision variables had to be bounded. For the capital subsidies, the initial value was bounded from 0% to 40% of the initial average CAPEX. The 40% cap was based on similar policies implement in other countries at the beginning of the energy transition such as in Sweden (IRENA, 2013) which used an initial capital subsidy of 30% of CAPEX. An additional 10% was provided as a buffer in the event that it was needed. For the production subsidies, the initial value was bounded from 0 $/MWh to the LCOE in the first year. The decision for the upper bound is to ensure that projects are not overly subsidized since the tariff rate at which NPV is 0 is by definition the LCOE.

Tackling the denominator is calculated using Equation 3.19. The numerator of the objective function involves calculating the NPVs of the projects with and without the implementation of the subsidy policy. Then we need to calculate the NPVs of the projects with the subsidies included. The NPV of all the projects is calculated in 3 layers. The highest layer is the total NPV of all the projects (Equation 3.21). The second layer is the total NPV generated by each technology which is inflation adjusted (Equation 3.22). The third layer is the value of a single project under the subsidy scheme (Equation 3.23). These equations are congruent with those presented in Section 3.4.

Equation 3.21 Calculate Total Project NPV under Subsidy Schemes

$$\Pi'_{\mathrm{P}} = \sum_{tech}^{Techs} \Pi'_{\mathrm{tech}}$$

Equation 3.22 Calculate the Total Technology NPV under Subsidy Schemes

$$\Pi'_{tech} = \sum_{t_1=0}^{T_{\mathrm{P}}} \left(\frac{1}{1+r_i}\right)^{t_l} \cdot \pi'_{tech,\ t_1}$$

Equation 3.23 Calculate Project NPV under Subsidy Schemes

$$\pi'_{tech,i} = (-CE + s_C) * (1 - D_r) + \sum_{t=1}^{T_{life}} \big((R_t + s_{r,t}) - (0E_t\ ) - \ DE_t(1 - r_t) - A_t - \ IE_t\ - TE_t\ \big) * (\frac{1}{1 + r_e})^t$$

3.7. Secondary Calculations

Secondary metrics were also calculated in order to assess the policy and provide insight into the solution proposed. The two metrics also considered are the Subsidies Awarded-to-Required (SAR) ratio and Total Value-to-Subsidies ratio (TVS). The SAR is calculated using Equation 3.24. TVS is calculated using Equation 3.25. SAR represents the ratio between the value of subsidies awarded versus the minimum value of subsidies needed. The minimum value of subsidies needed can also be thought of as the net present value of all projects with a negative NPV. A value of 1 represents an efficient policy since it ensures the policy exactly meets the requirement. A value less than 1 implies that the policy is under subsidizing projects whereas values greater than 1 represent the case of over subsidizing. The TVS represents the ratio between total project value to the subsidies awarded within the policy term. In essence, it represents the dollar value realized of the program per dollar of subsidy provided. Ideally, the TVS should be greater than 1 which represents the case when a dollar spent on a subsidy unlocks more value for investors.

Equation 3.24 Formula for Calculating SAR

$$SAR = \frac{S_P}{\left|\sum \pi_{tech,i}\right|}, \pi_{tech,i} < 0$$

Where S_p represents the total subsidies awarded, $\Sigma\pi_{tech}$ represents the present value of all projects which are negative.

Equation 3.25 Formula for Calculating TVS

$$TVS = \frac{\Pi'_P}{S_P}$$

Where Π'_p represents the present value of all projects under the subsidy regime and S_p represents the present value of subsidies awarded

An additional parameter calculated was the LCOE. The LCOE in this case was calculated by using Equation 3.8 while excluding the revenue. The total cost was then divided by discounted electricity generation to obtain the effective LCOE of the project.

The final parameter calculated was the carbon abated by the projects. This parameter provides no indication or impacts the output, but it does identify how much carbon is saved by the installation of new renewable energy. It was baselined to 2020 and was calculated using the Avoided Emissions Calculator provided by IRENA for a rough estimate of carbon savings.

Chapter 4. Results of Objective Program

This chapter will present the results of the simulation and the different runs. First, the different energy pathways will be presented. Second, the three base case runs will be presented without the inclusion of subsidies to assess subsidy requirements and identify if the current policy is sufficient for the specific technology. Third, the results of the optimized subsidy policies will be presented. Finally, the sensitivity analysis will highlight the impact of changing parameters on total subsidy requirement and policy efficiency.

4.1. Energy Pathways

The calculations used to determine the likely pathways resulted in the average technology growth rates as seen in the Table 4.1. This in turn resulted in the pathways as seen in Figure 4.1 (BAU), Figure 4.2 (GP), and Figure 4.3 (NZE). As seen in the figures, fossil energy has the largest share in the BAU accounting for almost half of total capacity. Other renewables, such as offshore wind, nuclear, and battery, only account for a small portion of total generation. In the GP, fossil energy plays a smaller role, accounting for ~30% of total capacity installed in 2050. Solar PV represents the largest renewable energy producer. Small and medium scales of hydropower and geothermal are the most prominent other renewables, with some offshore wind installations and PV rooftop being installed. Finally, the NZE scenario does not reach complete independence from fossil energy until 2055 according to the growth rates calculated. Energy storage, offshore wind, and PV rooftop (classified as other) become more prominent in this scenario by 2050. When comparing the total carbon abated by each scenario, the NZE abates 240 MtCO_2e from 2025 to 2050, GP abates 158 MtCO_2e, and BAU abates 50 MtCO_2e relative to 2020.

Table 4.1 Calculated Selected Technology Capacity Growth Rates

	Solar PV	**On shore wind**	**Biomass**	**Large scale geothermal**	**Large scale hydropower**
BAU	19%	18%	3%	4%	6%
GP	26%	23%	5%	6%	8%
NZE	28%	25%	6%	8%	9%

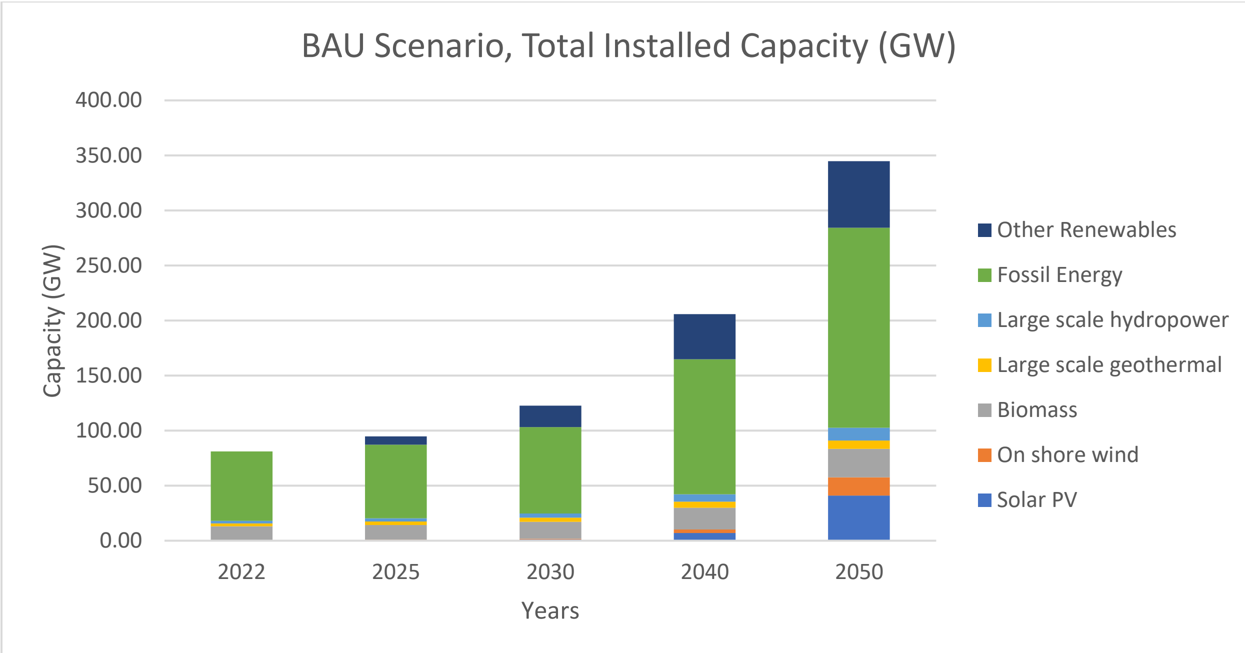

Figure 4.1 BAU Energy Transition Pathway

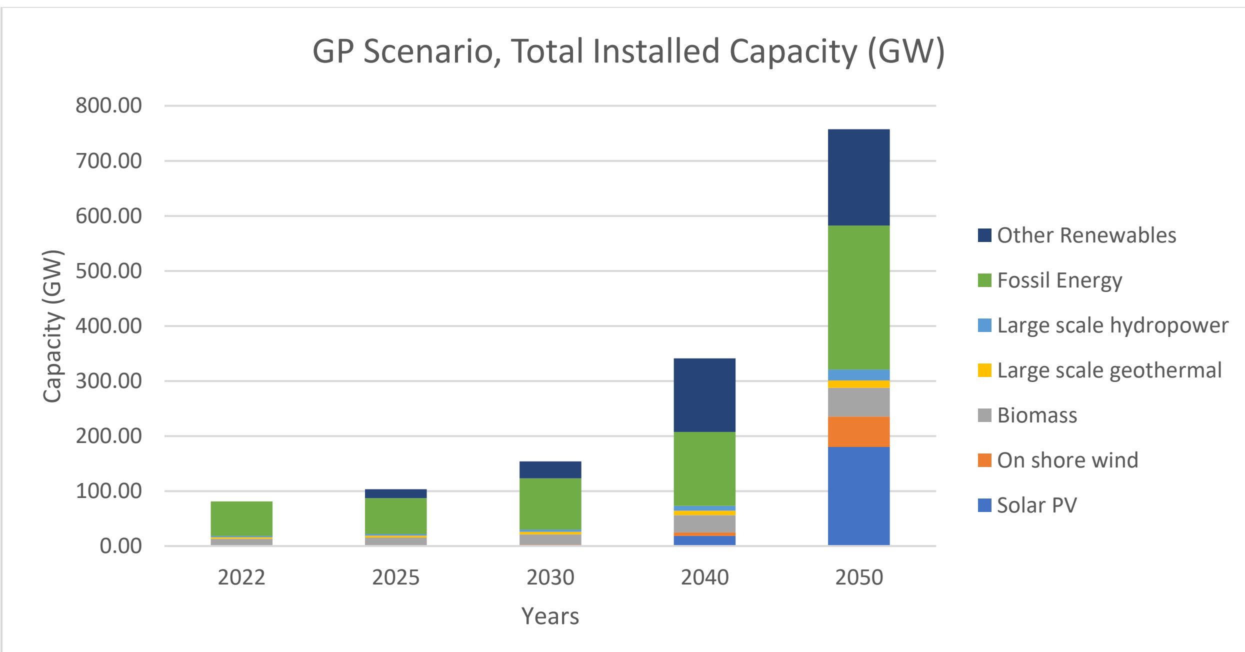

Figure 4.2 GP Energy Transition Pathway

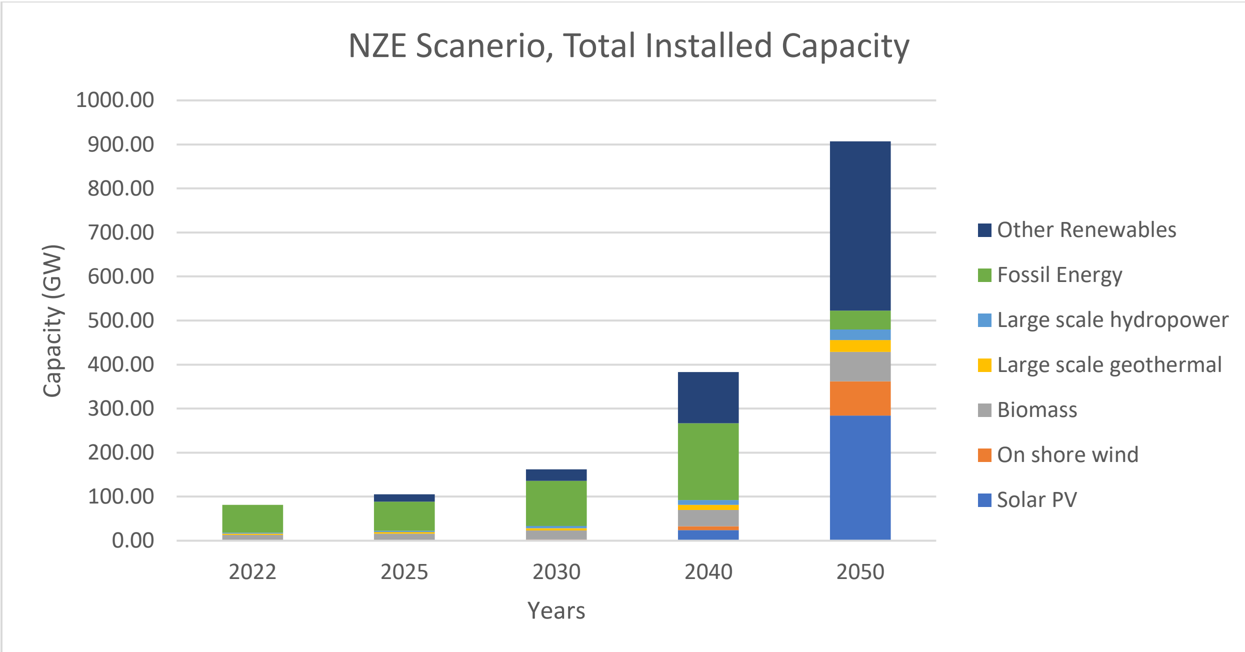

Figure 4.3 NZE Energy Transition Pathway

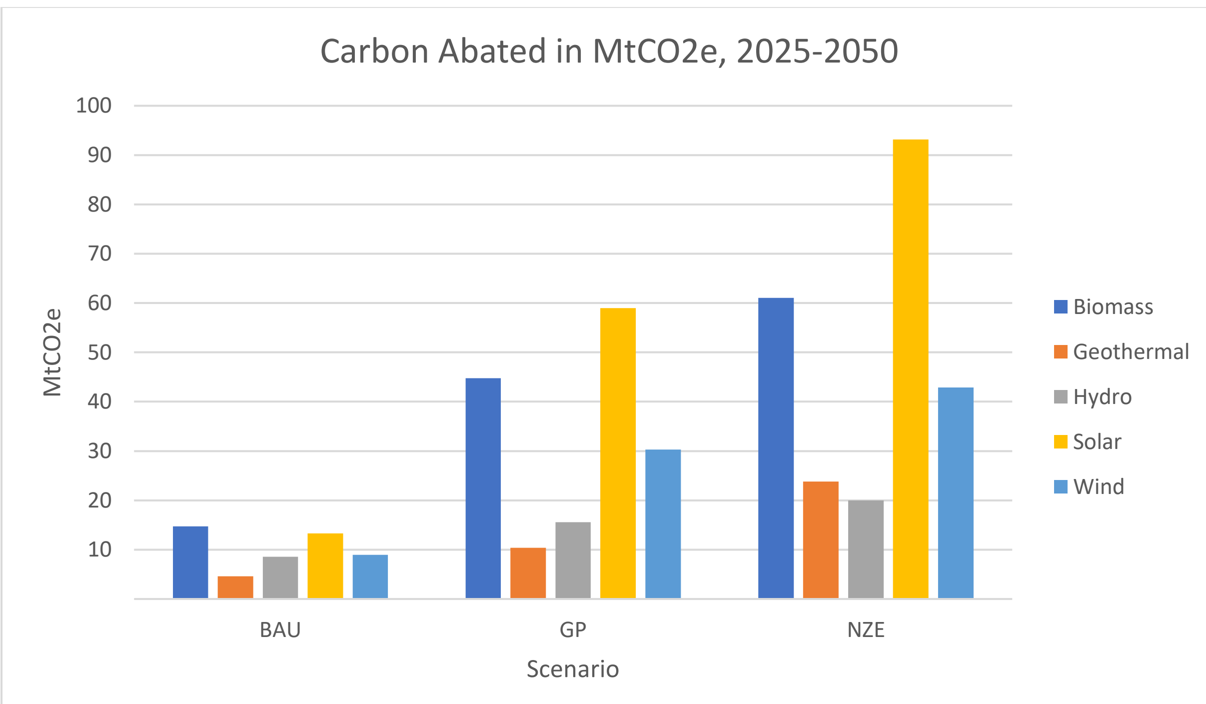

Figure 4.4 Total Carbon Abated in Each Scenario

4.2. Base Case Project Performance

Figure 4.4 showcases the base case IRRs of installed capacity over time for each technology. As seen in the figure, biomass is in fact profitable under current regulations. This is further corroborated when comparing the LCOE to the ceiling prices under the PR 112/2022. The jump exhibited by wind in 2040 and solar in 2037 represents the point at which under current regulations it no longer needs capital subsidies and is thus entitled to the higher tariff rate. The same trends of a continuously increasing unsubsidized NPV is expected as cost decline, hydropower sees the least change due to the lower cost reductions.

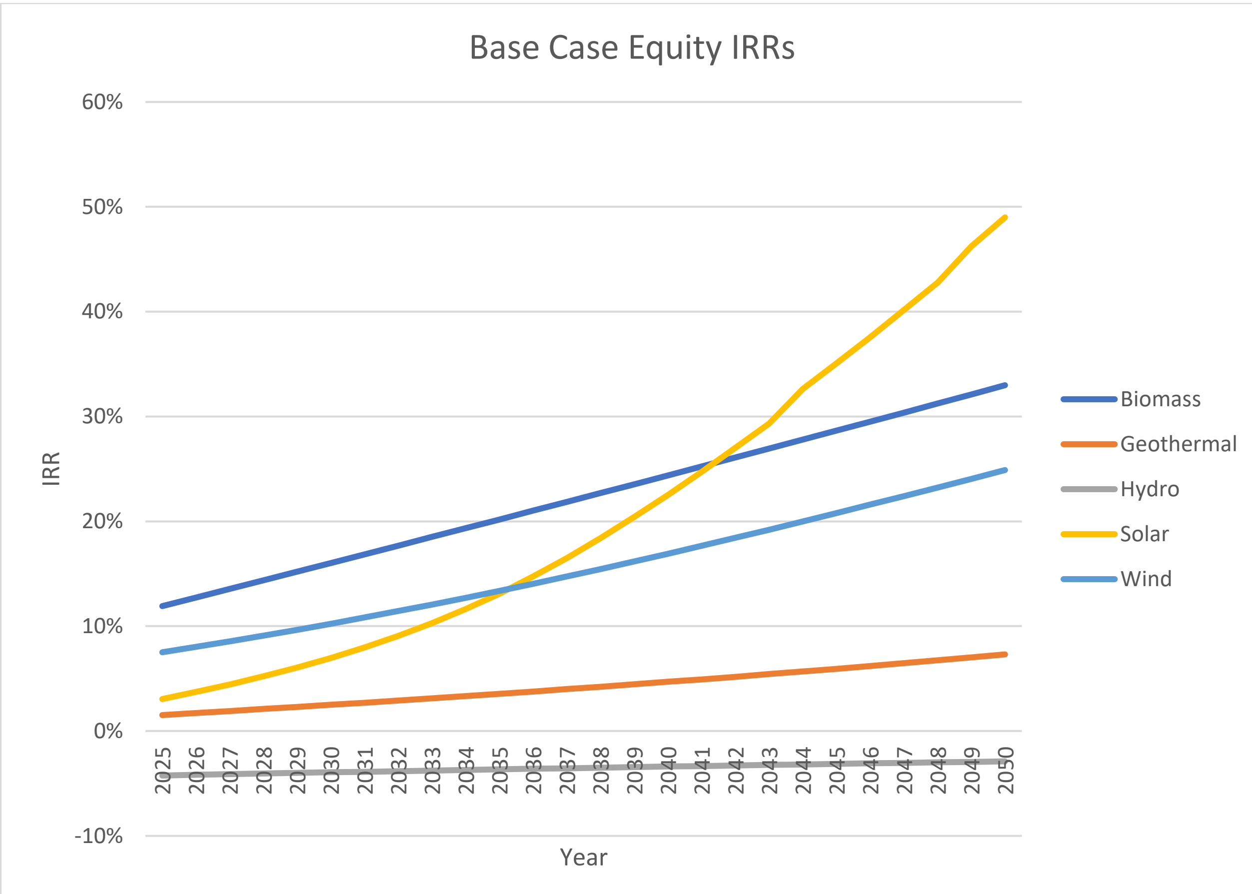

Figure 4.5 Base Case Equity IRRs over Time

There is also a noticeable increase in project NPV over time which is due to reductions in cost and financing costs. This is visualized in Figure 4.6 that shows the LCOE for each technology over time.

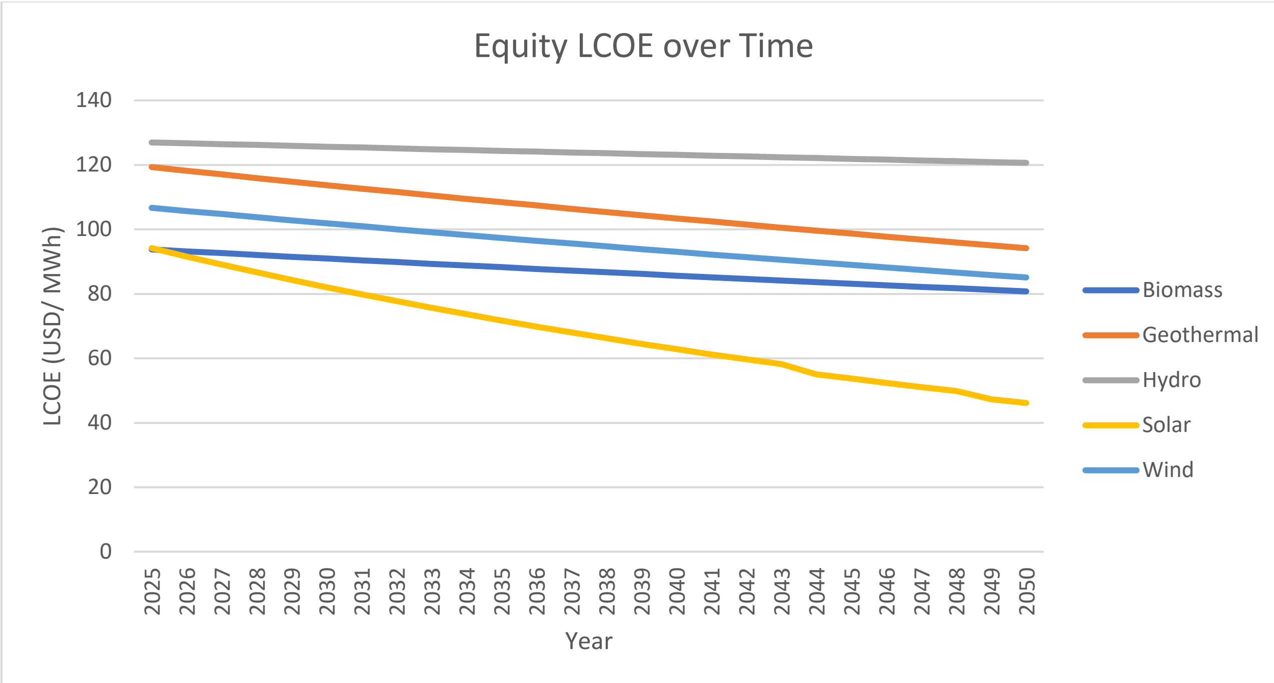

Figure 4.6 Equity LCOE Trends over Time

Figure 4.7 highlights the average subsidy per MWh required by an investor for each technology. The trends are all negative, the same as the LCOE trends. This is expected because costs decline over time. Of importance to note is that solar, wind, and biomass all do eventually reach 0 additional subsidy requirements within the time frame.

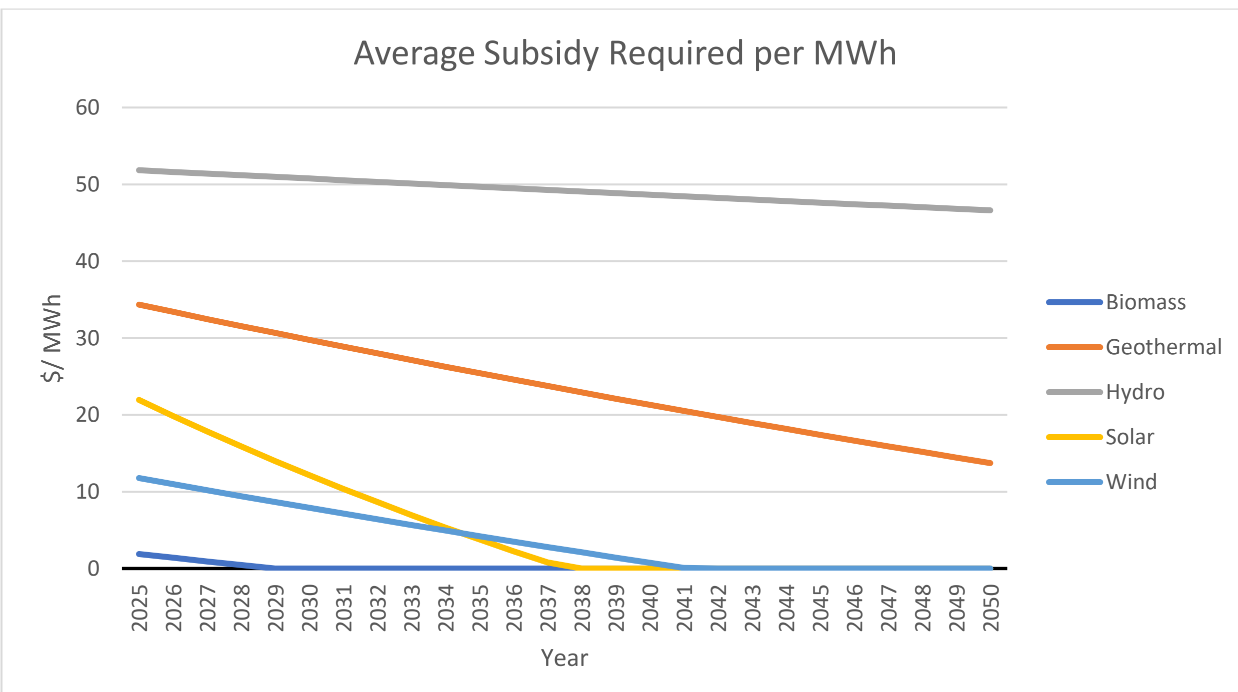

Figure 4.7 Average Subsidy Required per Discounted MWh over Time by Technology

4.3. Optimized Subsidy Policy Results

The table below shows the key metrics for each scenario while using the base case values and a constant ceiling price. As can be seen in the table, all objective values vary with technology, with SARs close to 1 indicating that minimal over subsidization occurred. The objective value is also greater than 1, indicating that each dollar of subsidy yielded a positive net change in project value. The entry for biomass is 0 for all since it is already profitable under the current regulation. Since the objective function is a ratio, it is path independent and the same values were found under all three scenarios in the Base Case.

Table 4.2 Summary of Optimization Output for Base Cases

Technology	Objective Value	SAR	TVR	Years subsidy policy is active
Solar	1.0	1.7	4.8	13
Wind	1.3	1.6	1.5	17
Geothermal	1.0	1.5	0.04	26
Biomass	0.75	1.5	4.8	26
Hydropower	1.0	1.5	0.35	5

The proposed subsidy policies parameters are summarized in Table 4.3. As indicated, solar, hydropower and geothermal both start off with the maximum possible capital along with a production subsidy. Wind on the other hand only relies on the presence of capital subsidies to aid in its development. When comparing digression factors, solar subsidies decrease at the fastest rate and hydropower at the slowest rate.

Table 4.3 Parameters for Subsidy Policy

Scenario	Technology	Initial Capital (% of cost)	Capital Digression (%)	Initial Revenue ($/MWh)	Revenue Digression (%)
	Solar	30.0	8	23.95	7.2
	Wind	30.0	0	29.70	3.1
BAU	Geothermal	30.0	0	21.53	6.0
	Biomass	30.0	36	-	35.4
	Hydro	30.0	0	70.74	0.3
	Solar	30.0	8	23.11	6.3
	Wind	30.0	0	29.70	3.1
GP	Geothermal	30.0	4	20.37	1.3
	Biomass	30.0	36	-	35.4
	Hydro	30.0	0	70.58	0.3
	Solar	30.0	8	24.00	7.1
	Wind	30.0	0	29.70	3.1
NZE	Geothermal	30.0	4	20.68	1.4
	Biomass	30.0	36	-	35.4
	Hydro	30.0	1	70.67	0.1

When investigating the subsidized project IRRs under the proposed subsidy policy, as shown in Figure 4.7, it is evident that a consistent policy tends to over-subsidize projects initially with the amount over subsidized slowly decreasing and then increasing after reaching the minimum investor MARR. This provides an indication that policy decisions could be reevaluated at those points in time when the deviation is too large. The main driver behind this trend is the relationship between cost decline and the subsidy digression factor.

When investigating dominating mechanism as seen in Figure 4.9, it is evident that the use of capital subsidies varies by technology. Solar is the only technology that sees a decrease in relative share of capital subsidies over time.

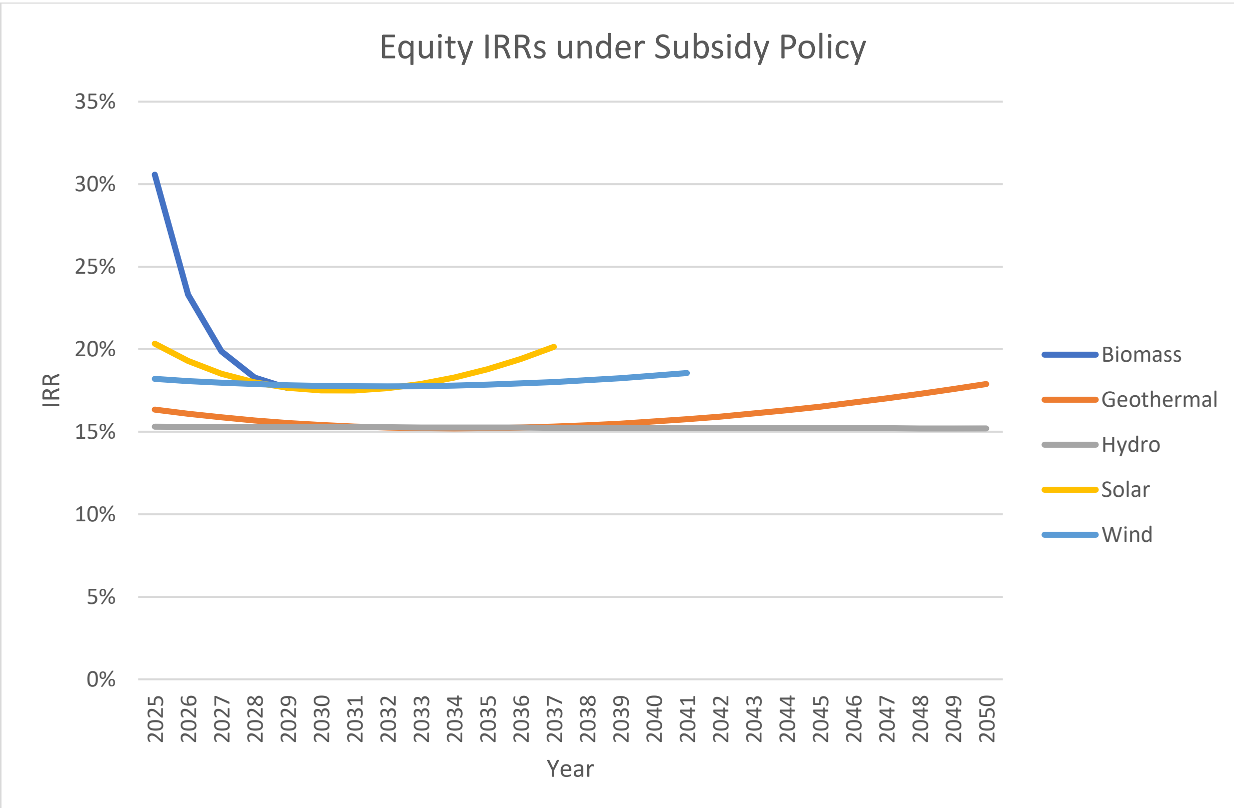

Figure 4.8 Subsidized Equity IRRs

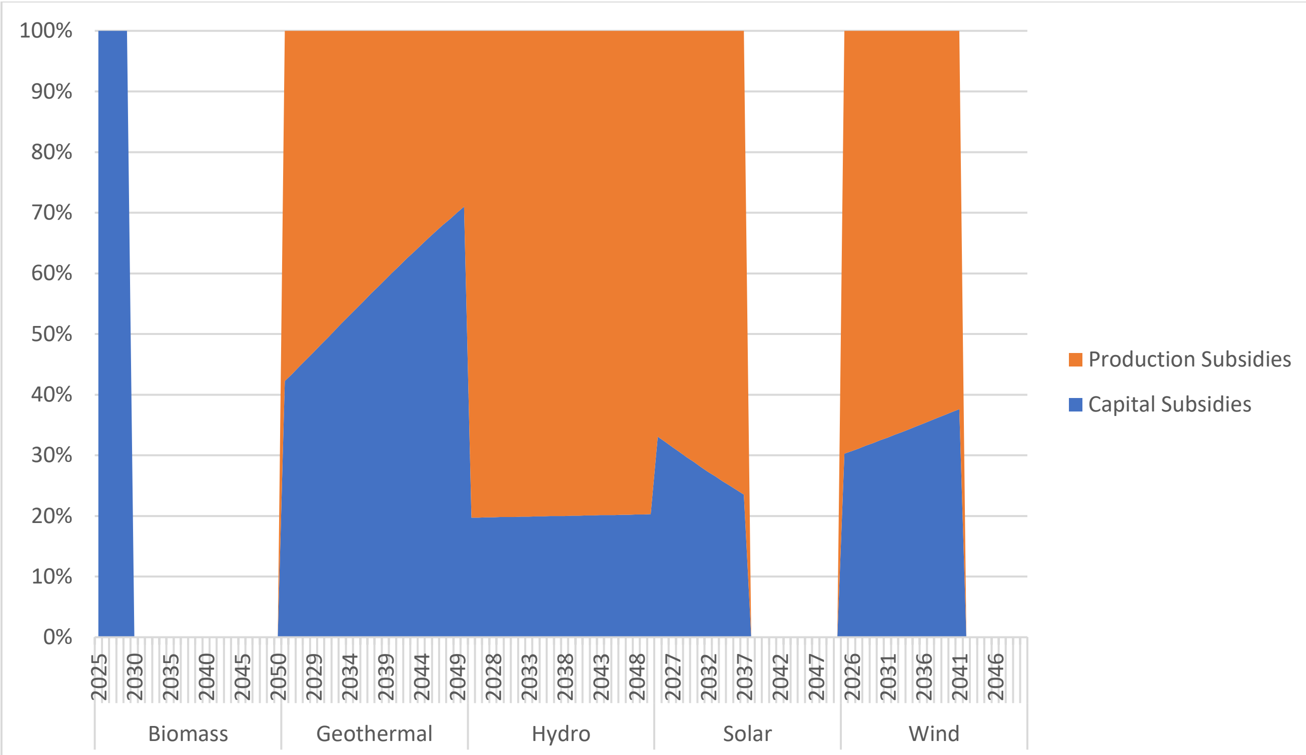

Figure 4.9 Share of Subsidies by Policy Type, Technology and Year

4.4. Trends Under Changing Tariff Rates

The figures below show the NPVs of each technology under de-escalating and escalating tariff rates, respectively, in the BAU scenario.

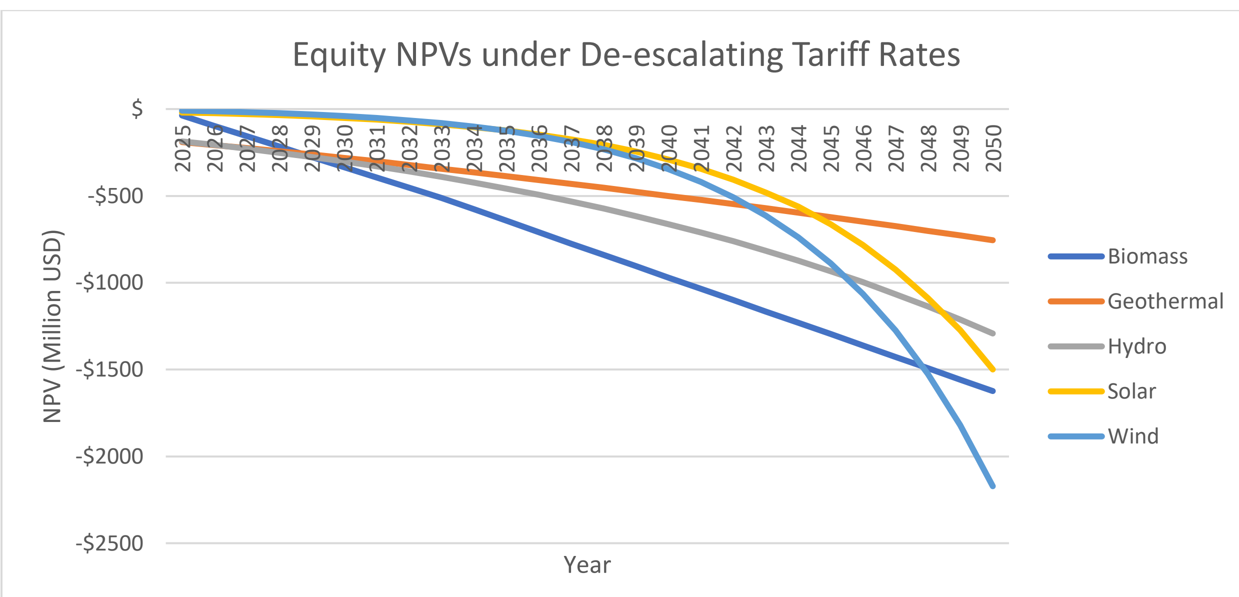

Figure 4.10 Equity NPVs under De-escalating Tariff Rates

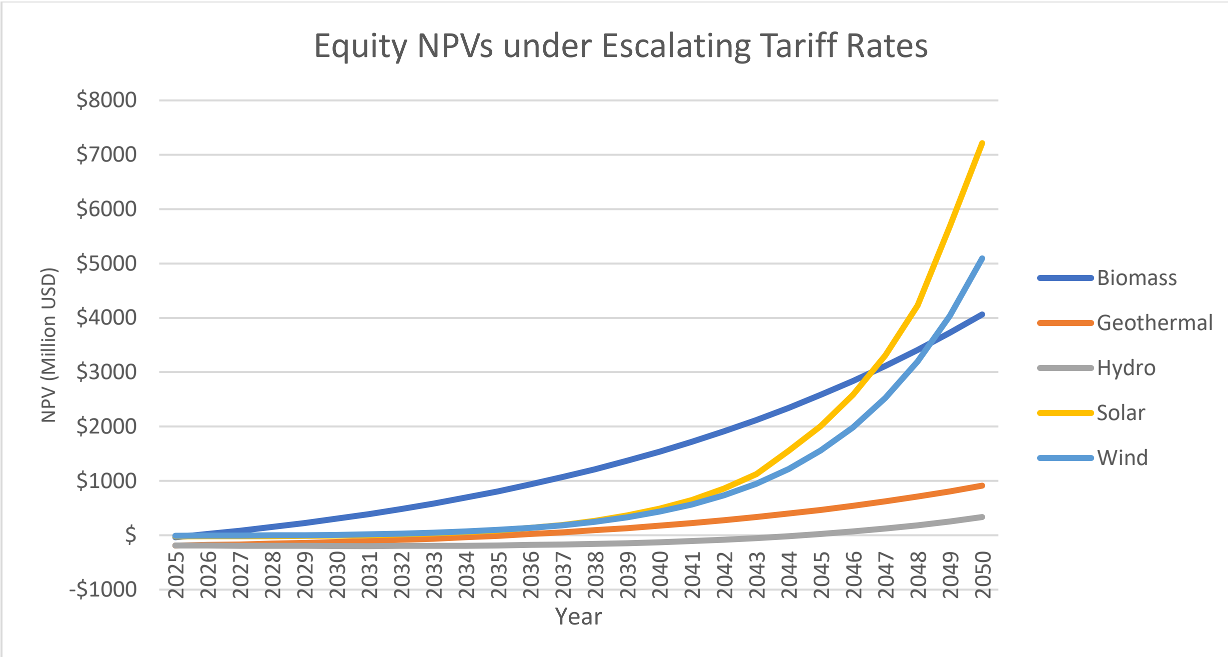

Figure 4.11 Equity NPVs under Escalating Tariff Rates

As can be seen, escalating tariff rates are useful for reducing additional government support; however, the burden is simply shifted towards the PLN. Moreover, after a certain point in time, it no longer makes sense to escalate prices as the actual returns become much greater than the MARR. The reason behind this is that the tariff escalates while costs decrease over time. This means that at some point the LCOE and the tariff will intersect at which point, further escalation is not needed. In the case of de-escalating tariffs, it is evident that the main driver for longer subsidy policies is due to the tariff decreasing at a rate faster than the cost declination rate. An interesting aspect to note is that the total support required does not change since the tariff rate is independent of costs. Overall, the results imply a need to appropriately balance the tariff rate awarded and the change factor. Using a combination of these tariff policies may result in a more efficient case via appropriate selection of the tariff escalation rate and then identifying the point at which it should begin to decline.

4.5. Subsidy Requirements in Reference to Society

An important aspect of the subsidy policy is in relation to the burden borne by the government. To assess this, the following graph shows the proposed additional subsidy as a share of forecasted GDP. Using 2022 as a base and assuming a constant GDP growth rate of 3% (ACE, 2022), the following figure was derived using the payouts of subsidies at each year:

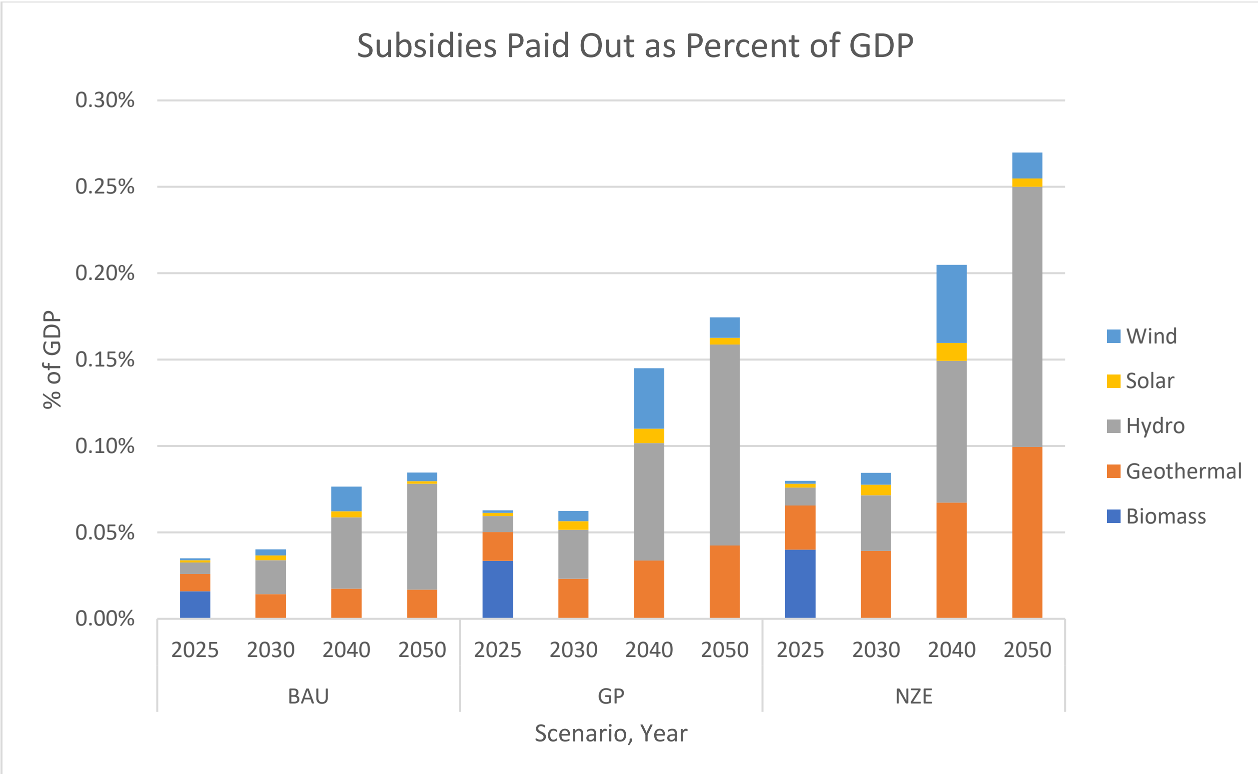

Figure 4.12 Subsidies paid out as % of GDP

The following figure summarizes the total subsidy given by technology over time. The NZE shows the largest subsidies awarded due to the additional capacity. On an average basis, the values are path independent. In addition, biomass plants no longer receive any subsidies in 2030 since projects from that year onwards are bankable under current regulations. The same holds true for wind and solar.

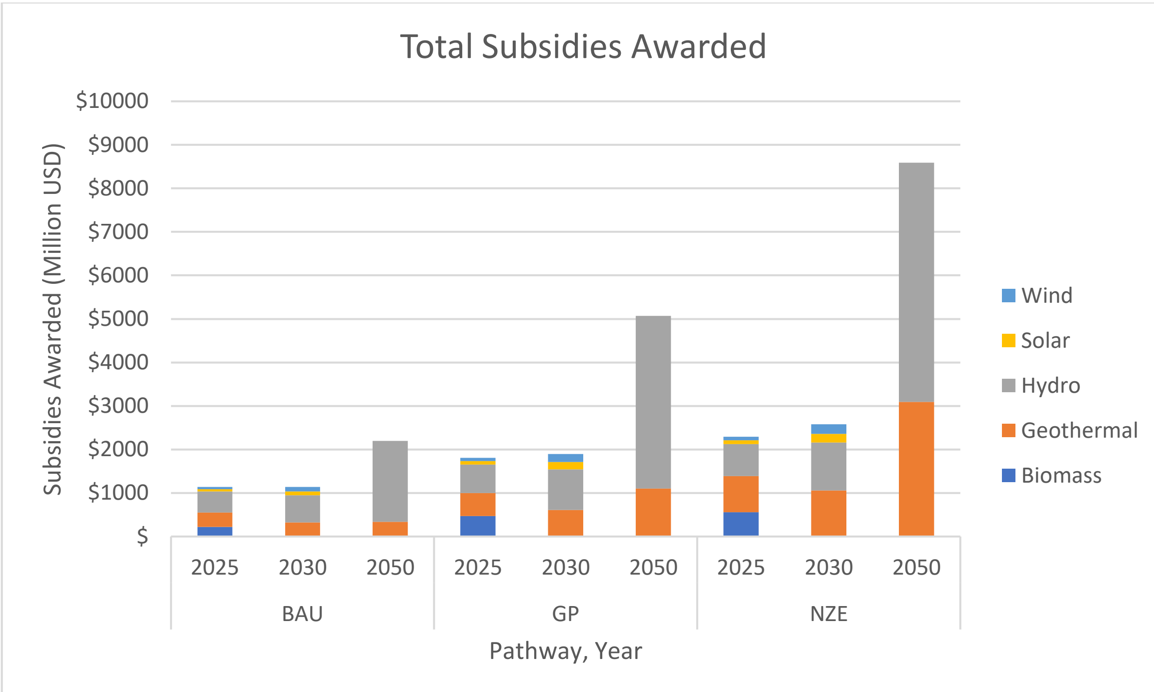

Figure 4.13 Total Subsidies Awarded, Project Level

The following figure shows the total investment requirements of each technology and in each pathway. As can be seen in the figure, the NZE has the largest investment requirement due to the significantly larger installed capacity. Total investment needs in 2050 also vary quite steeply between the three scenarios.

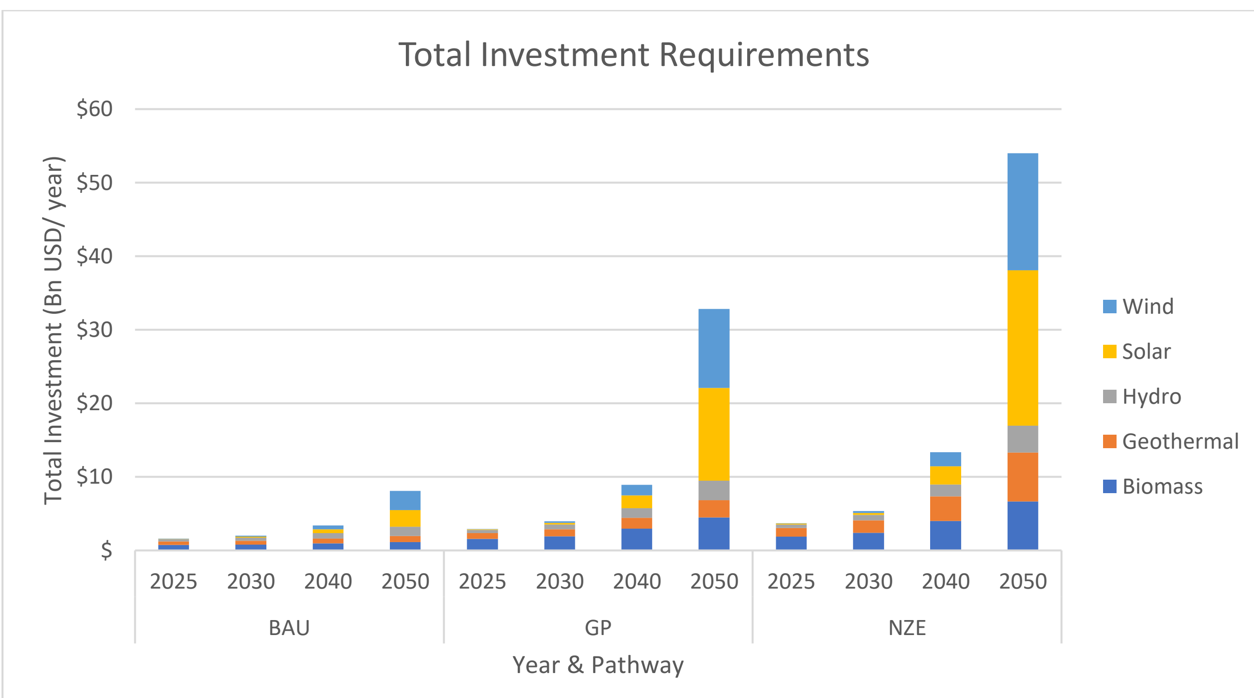

Figure 4.14 Total Investment Requirements

4.6. Sensitivity Analysis

A sensitivity analysis on all input parameters was performed to understand how subsidy requirements could change under uncertainty (Chapter 3). The figures below show the change in subsidy requirements following the testing of the different cases. The figure shows the ratio between the percent change in the initial LCOE (i.e. LCOE in 2025) from the base case to the percent change in input parameter. As can be seen, the parameter with the largest impact is CAPEX, followed by the country and equity risk. The large impact in the CAPEX is due to the testing of CAPEX values for wind and solar which result in 0 need for subsidy. This is true for CAPEX reductions of 20%. Variable operational costs are only a major cost factor for biomass technology. Extending this logic to include total subsidy requirement, the same impacts are expected; however, early changes have a much larger impact as the effects are compounded over time. This means that targeting the most sensitive parameters as listed in the figure below will also be the most effective for targeting overall subsidy cost reduction.

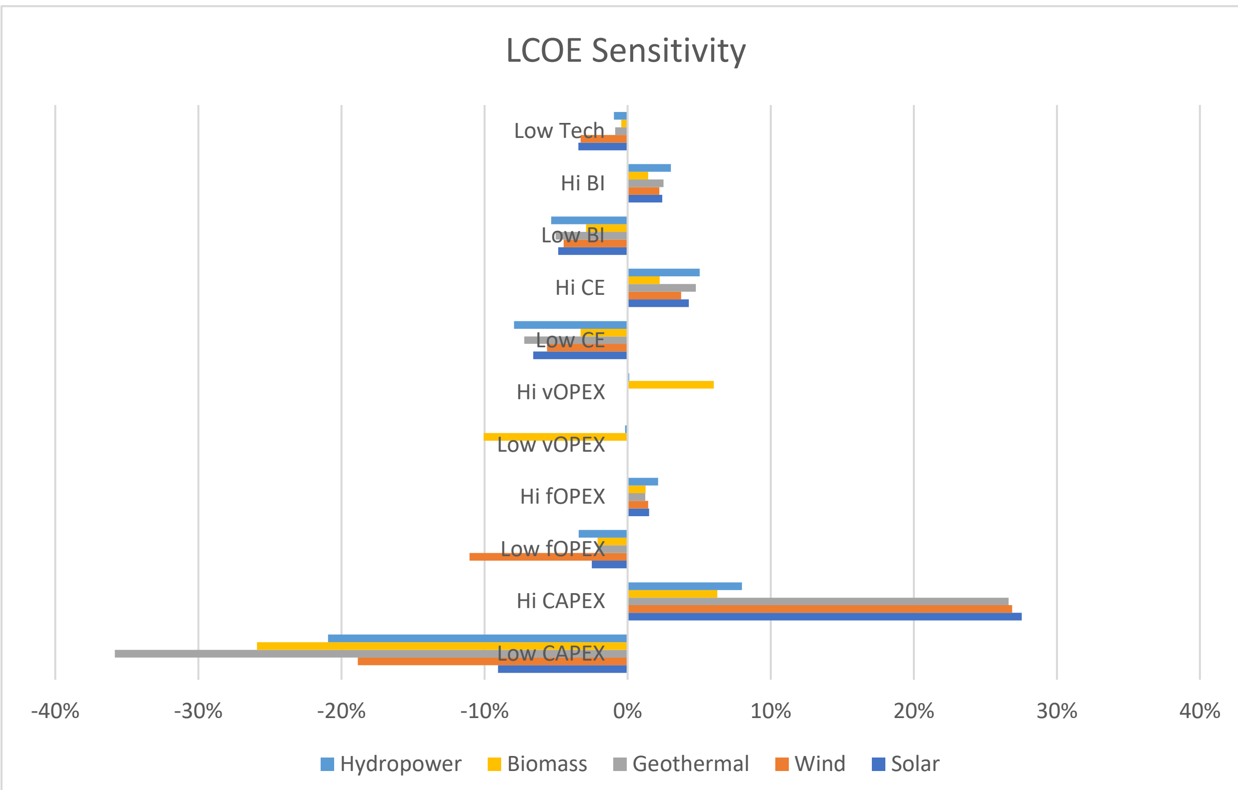

Figure 4.15 Sensitivity of Parameters

Chapter 5. Discussion

This section will highlight and discuss the key trends notices in the results and their real-world implications. First, the impact of subsidies on investment trends will be analyzed. Second, the periods of dominating subsidy regimes will be explained. Third, the key parameters that impact subsidy requirements will be shown. Finally, the model limitations will be discussed.

5.1. Comparison of Results with Literature Values

The research and literature findings provide a comprehensive perspective on various aspects of the model's outcomes. The comparison of results with literature values will focus primarily on the subsidy requirements, investment requirements, and forecasted LCOE.

Firstly, the estimated subsidy needs, when analyzed within reason by 2050 for all scenarios, remain constrained, never accounting for more than 0.3%. This aligns with literature predictions, especially when considering the share of installed capacity, which represents about half of the total. Consequently, the total share of energy subsidies is projected to hover around 0.7%, in line with the expected range for a reasonable percentage of GDP dedicated to subsidies (IRENA, 2020).

Second, the model predicts lower investment figures, which can be attributed to differing costing and pathway assumptions. It is essential to note that the presented investment figures are not inflation-adjusted, reflecting nominal amounts needed in each respective year. (IEA, 2020) anticipates that by 2030 total investment needs will be around 14 billion USD annually in accelerated transition pathways; however, the model predicts less than half of that amount. This can be explained by the considered technologies amount to about half of new annual installations. Using a simple calculation on an equivalent per MW basis implies that the large-scale capacity additions presented should total 7 billion USD in 2030. This is more in line with the results presented; however, there is still a 2 billion USD deficit that is most likely explained by the fact that total investment costs are lower due to using a constant growth rate as opposed to higher growth rates until 2030 followed by lower capacity growth rates. Looking at forecasted investment needs by 2050 that places the investment need in the range of 100 bn USD in 2050 (Kanugrahan & Hakam, 2023). This is in line with the model predicted values of 30 bUSD and 60 bUSD in the GP and NZE cases respectively, following the same assumption that the capacity additions modelled account for ~50% of new capacity.

Third, the initial LCOE calculations appear to be on the higher end of the ranges presented in an IESR (2023) report. This assumption then trickles down as the forecasted LCOE in 2050 is much higher than those described in the same report. This discrepancy is due to the different cost and cost reductions assumptions made. This also results in an overestimation of the subsidy needs.

In conclusion, the research findings and literature insights served to illustrate the model's successes and shortcomings. The key takeaway is that the subsidy schemes provided seem to be affordable despite the overestimation. Further research is required to predict project bankability more precisely.

5.2. Optimized Subsidy Policies

The findings from the analysis suggest that the existing competitive auction system falls short in adequately supporting the requirements of investments in renewable energy in the early years, with the existing policy becoming effective in later years. An intriguing revelation is the path independence of the optimized subsidy policy metrics. This stems from the ratio's explicit consideration of how various paths influence the NPV, assuming identical inputs in the base case. It becomes evident that an over-subsidization rate of 50% could serve as a compelling incentive base for promoting private sector investments. It also implies that the main driver behind a policy's success is the absolute value the government is willing to provide.

Furthermore, the wide range of the TVS ratio correlates directly with the active years of a technology. Technologies that can quickly become self-sustaining have proportionally more value captured when the recommended policy is no longer in effect. This insight underscores the advantages of establishing robust markets sooner rather than later. Examining the objective values, solar, geothermal, and hydropower achieve the ideal ratio of 1, signifying complete benefit transfer. Wind, with a ratio of 1.3, demonstrates how it is more sensitive and under the current regulation, the subsidy scheme proposed is in fact more efficient than the existing regime. This is attributed to wind's lower initial IRR deficit and enhanced early over-subsidization benefits, allowing investors to capitalize more effectively on the subsidy schemes.

In contrast, biomass records a ratio of 0.8 representing the fact that the model proposed scheme is not as effective as the current. One reason for the model error in producing a reasonable policy is due to its shorter support duration of 5 years and the exponential nature of the policy mechanisms used in the model. As the objective program attempts to ensure that all projects in the scheme are bankable, it tries to ensure that a certain minimum benefit is imparted for the later years. Since this minimum benefit is the desired one, the model then back casts from there to find the exponential rate that meets the requirements. Another aspect that separates biomass from others is that it did not rely on production-oriented subsidies. The reasoning behind this is unclear; however, it is likely that given the initial guess and that capital subsidies are the first decision variables to be modified, the solver identified the possibility of simply relying on capital subsidies. Another interesting aspect is that the capital subsidy scheme proposed also similarly follows the wind market in Denmark with capital subsidies starting at 30% and rapidly reaching 5% in the final year of the policy (IRENA, 2013). Furthermore, specific optimization can still be made to reduce the initial burden and attempt to rectify the excessive initial over subsidization. Alternatively, a linear subsidy policy could prove more effective given the lower cost declination rate.

The intricate dynamics uncovered in this analysis shed light on the nuanced relationship between subsidy policies, technology-specific characteristics, and their long-term impacts on renewable energy investments. Addressing the identified shortcomings in the current auction system and tailoring subsidy policies to the unique attributes of each technology could pave the way for a more sustainable and efficient renewable energy landscape. This research underscores the importance of continuous evaluation and adaptation in the pursuit of a greener and more sustainable energy future.

5.3. Subsidy Policy Mechanisms and Design

The model yielded three key insights for enhancing subsidy policy design. Firstly, it emphasized the importance of tailoring support to the specific needs of each renewable energy type. For example, solar PV exhibited a decreasing share of capital subsidies while geothermal and wind showcased an increasing reliance on capital subsidies, while hydropower maintained a relatively constant split between capital and production subsidies. The reasoning behind this is due to the relative decline in capital costs and the capital digression factor. The model opted for a 0% digression factor for wind and geothermal and instead aimed to fine-tune the returns by manipulating the production subsidies exclusively due to slower cost declines compared to solar PV. This is seen as an indication of the efficiency of FITs for better control whereas for solar, the rapid nature of its cost decline necessities the use of both mechanisms to ensure an optimal policy (Harvey et al., 2018). A secondary comment on the policy design is the similar trend in capital subsidy policy for solar and biomass as was exhibited in Denmark indicating a degree of model fidelity (IRENA, 2013).

The second crucial observation pertained to the difference between LCOE, and the tariff provided. In the base case, the LCOE exceeded the tariff in the first year but for solar, wind, and biomass, the LCOE eventually dropped below the tariff. This underscores the need for a policy adjustment to align with the real-world economic dynamics of each renewable energy technology. Hosan et al. (2023) identified the same trend of subsidy policy needing to be updated appropriately to ensure that innovation and free-market forces to lower prices naturally.

The third insight focused on identifying the optimal timing for subsidy policy reform, illustrated in Figure 4.8. The graph exhibited a parabolic shape for subsidized IRRs. The left portion represented initial over-subsidization, fostering strong returns and market sustainability. A real-world counterpart was seen in both Vietnam (Do et al, 2021) and in Spain (Mahlingam & Reiner, 2016). The minimum point marked the ideal time for subsidy reform, where maximum efficiency was achieved, and alterations to parameters are needed to minimize governmental burden. The portion right of the minimum represents the region in which the burden of subsidizing begins to increase at which point a re-evaluation is needed or as the model shows, a complete termination of subsidies when industry is able to support itself. This shape is due to two elements. First, the model values future subsidy costs less than current costs meaning that it is given freedom to over subsidize future projects. Conversely, this is also means that it aims to minimize costs near the start. Second, NPV and capital subsidies change at a certain rate relative to cost whereas the production subsidies do not. This then results in a mismatch in which the relative impact of production subsidies become greater relative to cost.

In conclusion, these insights contribute to the refinement of subsidy policies, emphasizing adaptability to technology-specific needs, aligning subsidy levels with economic realities, and identifying optimal timings for reform. Such considerations are pivotal for fostering sustainable and efficient renewable energy markets.

5.4. The Impact of Capital Costs and Financing Costs

Project bankability hinges significantly on capital costs and financing costs, a consensus supported by sources such as IESR (2023), IESR et al. (2021), Langer, Zaaijer, et al. (2023b), and Langer, Kwee, et al. (2023b). This thesis reinforces the pivotal role of these factors in project bankability, emphasizing their sensitivity, particularly illustrated in Figure 4.10, where total subsidy requirements respond most to changes in capital and financing costs.

An intriguing finding arises from the CAPEX cases for solar and wind, revealing that a 20% reduction in capital costs could eliminate the need for additional subsidies entirely. In the case of solar, where CAPEX constitutes 85% of total costs, a 20% reduction translates to an 18% drop in overall costs. Furthermore, a distributed approach can be considered, where improvements in parameters like capacity factors due to better locations may compensate for a challenging direct reduction in CAPEX. The significance of CAPEX is further emphasized in low CAPEX scenarios, where subsidy requirements for solar and wind reach zero, highlighting the substantial impact of capital costs. This observation raises the possibility that the model might overestimate subsidy needs, possibly due to conservative cost estimates.

Secondly, interest rates emerge as a significant impediment to RET deployment in Indonesia, a sentiment echoed in the model's results. Actions such as offering better guarantees for lower financing costs, exemplified by Indonesia's recent implementation of Green Bonds, could be instrumental. However, the model suggests that achieving financing rate parity between RET and fossil fuels may be challenging due to reluctance from the PLN. De-risking actions become imperative for wider RET deployment. Notably, experiences from Vietnam and Italy indicate that while the sudden removal of early over-subsidization may impact growth, the goal should prioritize stability over unchecked expansion, as observed in studies by Do et al. (2021) and Mahalingam & Reiner (2016). Ordonez et al., (2022) further echoes this sentiment as the cases in which RET costs of capital reached parity with fossil fuels resulted in broader adoption and lower overall system costs.

In summary, the key takeaway is twofold. Firstly, real-world experiences align with the model's findings, emphasizing CAPEX and financing costs as crucial factors. And second, it provides a basis for a strategy for improving RET penetration in Indonesia.

5.5. Model Limitations

This section addresses critical limitations inherent in the model's assumptions and design. There are four key limitations which are the predetermined growth path, the static cost decline assumptions, improper modelling of investor actions, and the policy design.

The Predetermined Growth Pathway:

The model relies on a predetermined pathway, assuming constant exponential growth of capacity until 2050. Contrary to real-world dynamics, where literature suggests varying growth rates over time, this oversimplification might result in an underestimation of subsidy costs. For instance, technologies like solar and wind often experience higher growth rates between 2025 and 2035, potentially leading to the construction of more capacity when these technologies are costlier. Furthermore, the model's approach results in a subsidy policy designed with the path in mind, rather than evolving congruently.

Static Cost Decline Assumptions:

Another limitation arises from the model's assumption that costs decline naturally, disregarding learning effects. Empirical studies indicate that increased capacity building leads to cheaper installation costs (Faber et al., 2022; Grafström & Poudineh, 2021). By neglecting this learning aspect, the model may overestimate future costs of Net Zero Energy (NZE) and Green Power (GP) compared to the Business as Usual (BAU) scenario.

Investor Dynamics and Location Considerations:

The model adopts a static view of investor dynamics, assuming uniform goals and lump-sum project development. In reality, investors vary in objectives, with some, like impact investors, accepting below-market rates of return. Additionally, the model assumes uniform parameters regardless of the plant's location, overlooking location-dependent factors, such as capacity factor and costs. This oversight may lead to an overestimation of subsidy needs, as more bankable locations are selected initially, followed by less economic locations over time.

Policy Considerations:

The model focuses exclusively on direct support for power generation investors and a narrow set of subsidy policies, such as feed-in-premiums and capital subsidies with exponential decay. This limited scope omits potential benefits from subsidies to auxiliary industries like research and development, local material production, and transmission. The model's assumption that the type of policy has no impact on the Minimum Acceptable Rate of Return (MARR) overlooks the real-world impact of policy uncertainty on the Weighted Average Cost of Capital (WACC), leading to potential overestimation of subsidy requirements.

In conclusion, the model is likely prone to overestimating subsidy requirements due to assumptions of higher costs and an inefficient method of determining plant prioritization. While the magnitude impact of each element is uncertain, acknowledging these limitations is vital for a nuanced understanding of the costs associated with accelerated growth. As future research refines these assumptions and incorporates a more dynamic representation of real-world complexities, a more accurate depiction of subsidy needs will emerge, guiding informed decision-making in the pursuit of sustainable energy transitions.

Chapter 6. Conclusion

The goal of this thesis is to answer the question of:

How can the government of Indonesia maximize the dollar effectiveness of a subsidy policy to provide the maximum benefit to private-sector investors?

To do so, this thesis answers four sub-questions first. The following section summarizes the responses to each sub-question and finally the main research question.

<u>What is a likely transition pathway for the energy sector from 2025 to 2050 in Indonesia?</u>

Literature reviewed indicates that the transition pathway for the energy sector highly varies depending on assumptions made. The key element of determining the future state is the average electricity demand growth rate and renewable energy penetration. Moreover, literature also tends to follow the themes of business-as-usual (BAU), government planned (GP), and net-zero emissions (NZE). The BAU has the highest reliance on fossil energy while NZE results in the highest renewable energy penetration. It is expected that total installed capacity range between 350 and 900 GW by 2050 with average capacity growth rates between 5% and 9%.

<u>How can we value subsidies and investments in the future?</u>

A DCFA is the opted approach to valuing energy projects from the equity perspective. This results in cementing the actual needs of the private investors after accounting for deal structuring and other elements such as degradation. The NPVs are then inflation adjusted to 2025 as a way of equalizing future projects with earlier projects. Subsidies are valued using the TSE methodology and incorporated the government bond yield as a discount factor to equalize future subsidies with earlier ones.

<u>What does a good subsidy policy look like and how can it be modelled?</u>

From a theoretical perspective 5 key principles are identified of a good subsidy that can be condensed in the following definition: a good subsidy policy is a goal-oriented and time-limited policy that is stable over its lifespan and aims to provide an appropriate but generous level of aid that is benchmarked to real costs in congruence with the removal of institutional barriers to facilitate new entrants into a market. The research also reveals that subsidies can be modelled using decaying exponential functions with 2 parameters: the initial value and the digression rate.

<u>Which policies are effective at which point in time?</u>

The results of the optimization reveal that policy splits change over time and is dependent on the specific technology. On the topic of timing, it is evident that certain technologies become independent and profitable in shorter time frames, such as solar, wind and biomass, whereas hydropower and geothermal will need continual support. The key drivers behind the duration of a policy are the initial profitability gap and the overall change in net costs. Solar and wind have higher cost declination rates whereas the initial profitability gap is relatively small for biomass. On the policy split, once again the results indicate that policies should be benchmarked to the technology. More specifically, solar is likely to reduce its dependence on capital-oriented subsidies due to its rapid capital cost reduction; whereas sustained capital-oriented subsidies that decay in value over time but remain as a main source of subsidies are more effective for wind and geothermal. Hydropower and biomass are both unique in the trends exhibited with the split between capital and production subsidies remaining constant for hydropower due to low cost changes and biomass can perform well with only capital subsidies due to its much smaller initial profitability gap.

Overall, the sub-research questions lead to the answer of the following main question:

How can the government of Indonesia maximize the dollar effectiveness of a subsidy policy to provide the maximum benefit to private-sector investors?

The government can maximize the subsidy effectiveness by maximizing the ratio between the change in equity NPV under a subsidy policy to the total subsidy amount given. Under this goal, the results reveal that the ideal subsidy policy is path independent, meaning that the government can influence the pathway and it provided an insight into how much a dollar of subsidy nets in total value. Moreover, the optimization also reveals that over subsidizing can allow for more stable, inter-year policies to be enacted that has affects not modelled in this thesis. Finally, the scientific contribution of this thesis shows that it is possible to use a unitless ratio as a means of assessing subsidy effectiveness.

6.1. Policy Recommendations

There are three key recommendations to the government for fostering increased private-sector investment. First, it is recommended to address the issue of policy uncertainty by offering the proposed subsidy package as a fund outside the direct control of the Indonesian government and instead establish a separate wealth custodian who will manage the funds. This should in theory reduce the market return rates as certainty of subsidy availability increases. The second recommendation focuses on capital cost reduction strategies. It is recommended that, at least temporarily, the local content requirement laws be modified to allow for cheaper plants to be built now. Due to the issue of energy security, it is also recommended that any tariffs on imported goods be used to developing local production capacity. And third, it is recommended that the government slowly phase out its fossil subsidies and dedicate those funds towards renewable energy development.

6.2. Private Sector Recommendations

There are three key recommendations to the private sector aiming to enter the renewable energy market of Indonesia. First, improved deal structures can yield a lower WACC. The deal structure can be improved by targeting different kinds of investors (such as impact investors) who are willing to accept below market rates, increasing the debt ratio can also result in lower WACC, and finally, working with the government to obtain concessional debt rates. The second recommendation is careful area consideration. Indonesia is a large country with widespread renewable energy potentials and different levels of connectivity. By targeting areas that are inherently more economical either due to better resources or better access can either increase future revenues or decrease construction costs. And third, the current local content laws provide an interesting opportunity for new investors to instead focus on developing local production. This is more of an auxiliary consideration; however, could potentially yield market rate returns if well structured.

6.3. Model Improvement & Future Research Recommendations

To enhance the model's effectiveness, several key improvements are recommended. Firstly, in policy decision-making, the model should be granted flexibility to review policies after subsidies are no longer effective or have been in effect for a minimum of 5 years. This not only introduces adaptability but also provides alternatives in cases of over-subsidization. Secondly, the inclusion of a carbon market is crucial, especially with the rise of carbon taxes impacting the energy industry. The model currently overlooks the value of carbon abated, presenting an opportunity for additional revenue streams, such as selling carbon credits to fossil energy producers. Lastly, achieving congruence between scenario design and policy design is imperative. While the model assumes a fixed transition path, integrating the LEAP model with the subsidy policy design component can create scenarios that align with optimized subsidy policies rather than being exclusively investor centric. This approach introduces a dynamic element, allowing decisions based on capacity installations while maintaining a consistent objective function. These enhancements collectively ensure a more robust and adaptable modeling framework for navigating uncertainties in the real-world energy industry.

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Appendix

Appendix A. Scenario Design Data

The following object is a link to the full Excel file, the tables are attached below.

Scenario Design.xlsx

	BAU, Total Installed, GW					
Year	Solar PV	On shore wind	Biomass	Large scale geothermal	Large scale hydropower	Total Capacity
2022	*0.29*	*0.15*	*12.50*	*2.87*	*2.34*	*81.20*
2023	0.35	0.18	12.83	2.97	2.48	85.50
2024	0.41	0.21	13.17	3.08	2.63	90.04
2025	0.49	0.25	13.51	3.19	2.78	94.81
2026	0.59	0.30	13.87	3.30	2.95	99.83
2027	0.70	0.35	14.23	3.42	3.12	105.12
2028	0.84	0.42	14.61	3.54	3.31	110.69
2029	1.00	0.49	14.99	3.66	3.50	116.56
2030	1.20	0.58	15.39	3.79	3.71	122.74
2031	1.43	0.69	15.79	3.92	3.93	129.24
2032	1.70	0.82	16.21	4.06	4.16	136.09
2033	2.03	0.96	16.64	4.21	4.41	143.31
2034	2.43	1.14	17.07	4.36	4.67	150.90
2035	2.90	1.35	17.52	4.51	4.94	158.90
2036	3.45	1.59	17.98	4.67	5.23	167.32
2037	4.12	1.88	18.46	4.84	5.54	176.19
2038	4.92	2.22	18.94	5.01	5.87	185.53
2039	5.87	2.62	19.44	5.18	6.22	195.36
2040	7.00	3.10	19.95	5.37	6.59	205.72
2041	8.36	3.66	20.48	5.56	6.98	216.62
2042	9.97	4.33	21.02	5.75	7.39	228.10
2043	11.90	5.11	21.57	5.96	7.82	240.19
2044	14.20	6.04	22.14	6.17	8.29	252.92
2045	16.95	7.14	22.72	6.39	8.78	266.32
2046	20.23	8.43	23.32	6.61	9.29	280.44
2047	24.14	9.96	23.93	6.85	9.84	295.30
2048	28.80	11.77	24.56	7.09	10.43	310.95
2049	34.37	13.91	25.21	7.34	11.04	327.43
2050	41.01	16.43	25.87	7.60	11.69	344.79

	GP, Total Installed, GW					
Year	Solar PV	On shore wind	Biomass	Large scale geothermal	Large scale hydropower	Total Capacity
2022	*0.29*	*0.15*	*12.50*	*2.87*	*2.34*	*81.20*
2023	0.37	0.19	13.16	3.03	2.53	87.94
2024	0.46	0.23	13.85	3.20	2.72	95.24
2025	0.58	0.29	14.58	3.39	2.94	103.14
2026	0.73	0.36	15.35	3.58	3.16	111.70
2027	0.92	0.44	16.15	3.78	3.41	120.98
2028	1.15	0.54	17.00	4.00	3.68	131.02
2029	1.45	0.67	17.90	4.22	3.96	141.89
2030	1.83	0.83	18.84	4.46	4.27	153.67
2031	2.30	1.02	19.83	4.71	4.61	166.42
2032	2.89	1.26	20.88	4.98	4.97	180.24
2033	3.64	1.55	21.97	5.26	5.35	195.20
2034	4.57	1.91	23.13	5.56	5.77	211.40
2035	5.76	2.36	24.35	5.88	6.22	228.94
2036	7.24	2.91	25.63	6.21	6.71	247.94
2037	9.11	3.59	26.98	6.56	7.23	268.52
2038	11.46	4.43	28.40	6.93	7.80	290.81
2039	14.42	5.47	29.89	7.33	8.40	314.95
2040	18.14	6.74	31.46	7.74	9.06	341.09
2041	22.82	8.32	33.12	8.18	9.77	369.40
2042	28.71	10.26	34.86	8.64	10.53	400.06
2043	36.12	12.66	36.70	9.13	11.35	433.27
2044	45.44	15.62	38.63	9.65	12.24	469.23
2045	57.17	19.27	40.66	10.20	13.19	508.17
2046	71.92	23.77	42.80	10.78	14.22	550.35
2047	90.48	29.32	45.05	11.39	15.33	596.03
2048	113.83	36.18	47.42	12.03	16.53	645.50
2049	143.21	44.63	49.92	12.71	17.82	699.08
2050	180.17	55.05	52.55	13.44	19.21	757.10

	NZE, Total Installed GW					
Year	Solar PV	On shore wind	Biomass	Large scale geothermal	Large scale hydropower	Total Capacity
2022	*0.29*	*0.15*	*12.50*	*2.87*	*2.34*	*81.20*
2023	0.37	0.19	13.27	3.11	2.55	88.51
2024	0.48	0.24	14.09	3.37	2.77	96.47
2025	0.61	0.30	14.96	3.65	3.00	105.16
2026	0.78	0.37	15.88	3.95	3.26	114.62
2027	1.00	0.47	16.86	4.28	3.55	124.94
2028	1.27	0.58	17.90	4.63	3.85	136.18
2029	1.63	0.73	19.01	5.02	4.19	148.44
2030	2.08	0.91	20.18	5.43	4.55	161.80
2031	2.66	1.14	21.43	5.88	4.94	176.36
2032	3.40	1.42	22.75	6.37	5.37	192.23
2033	4.35	1.78	24.15	6.90	5.83	209.53
2034	5.56	2.22	25.64	7.47	6.34	228.39
2035	7.11	2.77	27.22	8.10	6.88	248.94
2036	9.10	3.46	28.90	8.77	7.48	271.35
2037	11.63	4.32	30.69	9.50	8.13	295.77
2038	14.88	5.40	32.58	10.28	8.83	322.39
2039	19.02	6.74	34.59	11.14	9.59	351.40
2040	24.33	8.42	36.72	12.06	10.42	383.03
2041	31.11	10.52	38.99	13.06	11.32	417.50
2042	39.78	13.14	41.40	14.15	12.30	455.08
2043	50.87	16.41	43.95	15.32	13.36	496.04
2044	65.05	20.49	46.66	16.60	14.52	540.68
2045	83.18	25.59	49.54	17.97	15.77	589.34
2046	106.37	31.96	52.60	19.47	17.14	642.38
2047	136.03	39.92	55.84	21.08	18.62	700.19
2048	173.94	49.86	59.29	22.83	20.23	763.21
2049	222.43	62.27	62.95	24.73	21.97	831.90
2050	284.44	77.77	66.83	26.78	23.87	906.77

Appendix B. Costing, Pricing, and Rate Parameters

Costing Parameters
and Declination Rate

Table of Inflation Data:

No	Period	Inflation Data	Year
2	Desember 2022	5.51%	2022
3	November 2022	5.42%	2022
4	Oktober 2022	5.71%	2022
5	September 2022	5.95%	2022
6	Agustus 2022	4.69%	2022
7	Juli 2022	4.94%	2022
8	Juni 2022	4.35%	2022
9	Mei 2022	3.55%	2022
10	April 2022	3.47%	2022
11	Maret 2022	2.64%	2022
12	Februari 2022	2.06%	2022
13	Januari 2022	2.18%	2022
14	Desember 2021	1.87%	2021
15	November 2021	1.75%	2021
16	Oktober 2021	1.66%	2021
17	September 2021	1.60%	2021
18	Agustus 2021	1.59%	2021
19	Juli 2021	1.52%	2021
20	Juni 2021	1.33%	2021
21	Mei 2021	1.68%	2021
22	April 2021	1.42%	2021
23	Maret 2021	1.37%	2021
24	Februari 2021	1.38%	2021
25	Januari 2021	1.55%	2021
26	Desember 2020	1.68%	2020
27	November 2020	1.59%	2020
28	Oktober 2020	1.44%	2020
29	September 2020	1.42%	2020
30	Agustus 2020	1.32%	2020
31	Juli 2020	1.54%	2020

32	Juni 2020	1.96%	2020
33	Mei 2020	2.19%	2020
34	April 2020	2.67%	2020
35	Maret 2020	2.96%	2020
36	Februari 2020	2.98%	2020
37	Januari 2020	2.68%	2020
38	Desember 2019	2.72%	2019
39	November 2019	3%	2019
40	Oktober 2019	3.13%	2019
41	September 2019	3.39%	2019
42	Agustus 2019	3.49%	2019
43	Juli 2019	3.32%	2019
44	Juni 2019	3.28%	2019
45	Mei 2019	3.32%	2019
46	April 2019	2.83%	2019
47	Maret 2019	2.48%	2019
48	Februari 2019	2.57%	2019
49	Januari 2019	2.82%	2019
50	Desember 2018	3.13%	2018
51	November 2018	3.23%	2018
52	Oktober 2018	3.16%	2018
53	September 2018	2.88%	2018
54	Agustus 2018	3.20%	2018
55	Juli 2018	3.18%	2018
56	Juni 2018	3.12%	2018
57	Mei 2018	3.23%	2018
58	April 2018	3.41%	2018
59	Maret 2018	3.40%	2018
60	Februari 2018	3.18%	2018
61	Januari 2018	3.25%	2018
62	Desember 2017	3.61%	2017
63	November 2017	3.30%	2017
64	Oktober 2017	3.58%	2017
65	September 2017	3.72%	2017
66	Agustus 2017	3.82%	2017
67	Juli 2017	3.88%	2017
68	Juni 2017	4.37%	2017

69	Mei 2017	4.33%	2017
70	April 2017	4.17%	2017
71	Maret 2017	3.61%	2017
72	Februari 2017	3.83%	2017
73	Januari 2017	3.49%	2017
74	Desember 2016	3.02%	2016
75	November 2016	3.58%	2016
76	Oktober 2016	3.31%	2016
77	September 2016	3.07%	2016
78	Agustus 2016	2.79%	2016
79	Juli 2016	3.21%	2016
80	Juni 2016	3.45%	2016
81	Mei 2016	3.33%	2016
82	April 2016	3.60%	2016
83	Maret 2016	4.45%	2016
84	Februari 2016	4.42%	2016
85	Januari 2016	4.14%	2016
86	Desember 2015	3.35%	2015
87	November 2015	4.89%	2015
88	Oktober 2015	6.25%	2015
89	September 2015	6.83%	2015
90	Agustus 2015	7.18%	2015
91	Juli 2015	7.26%	2015
92	Juni 2015	7.26%	2015
93	Mei 2015	7.15%	2015
94	April 2015	6.79%	2015
95	Maret 2015	6.38%	2015
96	Februari 2015	6.29%	2015
97	Januari 2015	6.96%	2015
98	Desember 2014	8.36%	2014
99	November 2014	6.23%	2014
100	Oktober 2014	4.83%	2014
101	September 2014	4.53%	2014
102	Agustus 2014	3.99%	2014
103	Juli 2014	4.53%	2014
104	Juni 2014	6.70%	2014
105	Mei 2014	7.32%	2014

106	April 2014	7.25%	2014
107	Maret 2014	7.32%	2014
108	Februari 2014	7.75%	2014
109	Januari 2014	8.22%	2014
110	Desember 2013	8.38%	2013
111	November 2013	8.37%	2013
112	Oktober 2013	8.32%	2013
113	September 2013	8.40%	2013
114	Agustus 2013	8.79%	2013
115	Juli 2013	8.61%	2013
116	Juni 2013	5.90%	2013
117	Mei 2013	5.47%	2013
118	April 2013	5.57%	2013
119	Maret 2013	5.90%	2013
120	Februari 2013	5.31%	2013
121	Januari 2013	4.57%	2013
122	Desember 2012	4.30%	2012
123	November 2012	4.32%	2012
124	Oktober 2012	4.61%	2012
125	September 2012	4.31%	2012
126	Agustus 2012	4.58%	2012
127	Juli 2012	4.56%	2012
128	Juni 2012	4.53%	2012
129	Mei 2012	4.45%	2012
130	April 2012	4.50%	2012
131	Maret 2012	3.97%	2012
132	Februari 2012	3.56%	2012
133	Januari 2012	3.65%	2012
134	Desember 2011	3.79%	2011
135	November 2011	4.15%	2011
136	Oktober 2011	4.42%	2011
137	September 2011	4.61%	2011
138	Agustus 2011	4.79%	2011
139	Juli 2011	4.61%	2011
140	Juni 2011	5.54%	2011
141	Mei 2011	5.98%	2011
142	April 2011	6.16%	2011

143	Maret 2011	6.65%	2011
144	Februari 2011	6.84%	2011
145	Januari 2011	7.02%	2011
146	Desember 2010	6.96%	2010
147	November 2010	6.33%	2010
148	Oktober 2010	5.67%	2010
149	September 2010	5.80%	2010
150	Agustus 2010	6.44%	2010
151	Juli 2010	6.22%	2010
152	Juni 2010	5.05%	2010
153	Mei 2010	4.16%	2010
154	April 2010	3.91%	2010
155	Maret 2010	3.43%	2010
156	Februari 2010	3.81%	2010
157	Januari 2010	3.72%	2010

Calculation of Rate Parameters

Country	Indonesia	Comments
Moody's sovereign rating	Baa2	
S&P sovereign rating	BBB	
CDS spread	1.75%	
Excess CDS spread (over US CDS)	1.43%	
Country Default Spread (based on rating)	2.33%	
Country Risk Premium (Rating)	3.29%	
Equity Risk Premium (Rating)	9.23%	
Country Risk Premium (CDS)	2.02%	
Equity Risk Premium (CDS)	7.96%	
Data taken from behaviour, 2015 to 2022		

US Treasury Bill Rate, 10Y Average	1.90%	Global risk free rate
Indonesia Gov't Bond Yield, 10Y	6.50%	Country risk-free rate i.e. = Global risk free rate + country risk
Tax Rate	16.25%	*Taken from Government guidelines on Tax rate for RETs
Rounding to the nearest 0.5%		
Debt	Cost of debt = (global risk-free rate + country default spread + lender margin + technology premium beyond lender margin) x (1 – tax rate)	
Debt Rate, based on Damodarn #s	3.54%	*ROUNDED, it becomes 3.5%, it looks nicer
Debt Rate, based on Bond Yield	5.44%	*ROUNDED, it becomes 5.5%, it looks nicer
Based on a bad case	7.35%	*Based on the same deviation between Damodaran & 10Y Bond Yield
Equity	Cost of equity = (global risk-free rate + equity risk premium + country premium + technology premium)	
Equity Rate, based on Damodaran	11.87%	*ROUNDED, it becomes 12%
Equity Rate, based on Bond Yield	14.46%	*ROUNDED, it becomes 14.5%
Based on a bad case	17.04%	*Based on the same deviation between Damodaran & 10Y Bond Yield

Details on Technology Premia Used

Specific Tech Risk Premia for Geothermal, Biomass, & Hydro were not found, as a proxy, a st dev approach was used to determine relative risk compared to solar PV & on shore wind, given that those 2 have data available							
Index Values per month, 5 Y of data							
Month	Solar	Wind	Hydro	Geo	Bio		
1	1313	1707	1656	1053	1016		
2	1373	1706	1684	1070	1047		
3	1328	1644	1648	1027	1023		
4	1334	1692	1656	1035	1019		
5	1300	1685	1664	1016	982		
6	1384	1684	1658	1006	993		
7	1552	1771	1699	1007	1006		
8	1440	1738	1701	988	985		
9	1454	1751	1727	993	976		
10	1463	1758	1685	1014	1010		
11	1463	1688	1674	1024	998		

12	1473	1674	1683	1014	971		
Grand Total	1408	1708	1678	1020	1002		
STDEV	78.92	38.42	23.08	23.52	22.12		
Relative Risk	1.00	0.49	0.29	0.30	0.28	Solar benchmark	
Relative Risk	2.05	1.00	0.60	0.61	0.58	Wind benchmark	
Scaled	3.00%	1.46%	0.88%	0.89%	0.84%	Start Solar	3%
	1.70%	0.83%	0.50%	0.51%	0.48%	End Solar	1.70%
	6.68%	3.25%	1.95%	1.99%	1.87%	Start Wind	3.25%
	3.08%	1.50%	0.90%	0.92%	0.86%	End Wind	1.50%
Average Start, "New Market"	3.04%	1.48%	0.89%	0.91%	0.85%		
Average End, "Mature Market"	2.37%	1.15%	0.69%	0.71%	0.66%		
Proxy Indices Used:	*Part of NASDAQ Green Economy Index						
GRNSOLAR	Solar						
GRNWIND	Onshore Wind						
QGREEN	Hydropower						
GRNGEO	Geothermal						
GRNBIO	Biomass						

Appendix C. Model Validation Check Sheets

Algorithim Validation Check.xlsx