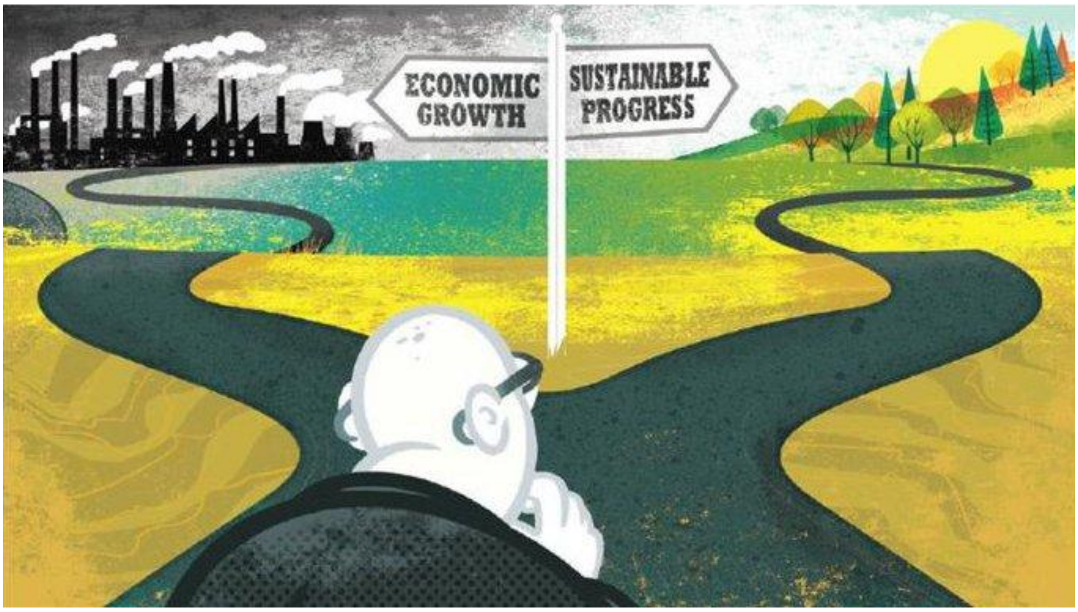
Green growth or degrowth: The way forward in the Dutch energy transition



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Summary

Climate change is considered to be one of the most pressing issues of our time. To address this problem, 159 countries agreed in Paris in 2015 to reduce net carbon emissions to 0 in 2050. The methods to reach this goal are however still undecided. Net carbon emissions could be achieved through either a green growth or degrowth approach. Green growth is a strategy to reach net zero emissions through innovation, green investments and technological progress. Degrowth assumes these methods will not be enough, so consumption must decrease significantly to become carbon neutral in 2050.

This research has investigated whether green growth or degrowth is a more feasible strategy regarding economic costs and efficacy in reaching net zero emissions. This was done through the main research question: 'What is the influence of green growth and degrowth on the Dutch economy and energy transition in the Netherlands?'. This question assessed the influence of both strategies on the Dutch economy and energy transition and looked at their impact on the quality of life of Dutch citizens. The main research question was answered through the following sub-questions:

1. What is the current state of the Dutch economy and Dutch energy transition?
2. How are the external factors innovation and geopolitics impacting the energy transition?
3. What is the influence of a green growth and degrowth approach on the Dutch economy?
4. What is the influence of a green growth and degrowth approach on the Dutch energy transition?
5. What strategies are the most effective in tackling the energy transition while maintaining the quality of life of Dutch citizens?

The methods used in this research include a mixture of literature research and macroeconomic modelling. This information was synthesised in a multi-criteria analysis to find the most effective strategies among green growth and degrowth alternatives. Five scenarios explored different combinations of high and low innovation, as well as high and low geopolitical cooperation. These five scenarios were: 'long-lasting trade war', 'Chinese invasion of Taiwan', 'Business as usual', 'Fourth industrial revolution' and 'Extended war in Europe'.

The economic situation of the Netherlands should offer the necessary space for investments in the energy transition. This can be seen in the low debt to GDP, which is between 40% and 45%. It can also be seen in the relatively stable level of inflation and low unemployment rate. Currently only 15% of total energy consumption is provided through green energy sources. This shows a lot of investments into the transition are still needed, which are expected to be about 750 billion euros total until 2050.

It is unlikely that all sectors within the Dutch economy can become climate neutral through innovation and technological progress, as for example sustainable aviation is still nowhere near possible. Either carbon capture storage or degrowth of these specific sectors would be required to make them sustainable by 2050. However, innovation would speed up climate neutrality in several other sectors. For example, innovative battery technologies such as solid-state, as well as improvements in current lithium-ion batteries will likely help the transition to renewables, causing less net congestion. Small Modular Reactors could also help with more stable energy production, although these might be more expensive than renewable alternatives. Technologies such as nuclear fusion are unlikely to make an impact before 2050.

The other external factor, geopolitics, also heavily influences the energy transition and the efficacy of green growth and degrowth policy. Low geopolitical cooperation could cause more trade wars and more wars in general, disrupting global supply chains. A degrowth policy could lead the Netherlands to become more dependent on other countries, while a green growth policy could allow the country to export more green energy and increase geopolitical leverage. This could allow the Netherlands to get other countries on board with the energy transition as well.

The macroeconomic model used in this research found climate neutrality to be achievable with both degrowth and green growth policy. The costs for the transition would be the lowest in the most optimistic scenario 'Fourth industrial revolution' and the highest in the 'Chinese invasion of Taiwan' scenario. Four alternatives were researched, which the government could use in a green growth and degrowth path respectively. Degrowth policies such as increasing luxury consumption taxes or making taxes more progressive would not result in sufficient consumption reduction to reach climate neutrality before 2050 without additional investments. The green growth policies of higher infrastructure investments and household energy transition subsidies would result in net zero emissions in 2050 in most of the scenarios, through their additional government and private investments. Total real investments needed with green growth policy would come down to an increase of 5-15 billion euros extra per year, or about 0.5% to 1.5% of GDP. Real consumption reductions with degrowth policy would have to be about 50% compared to 2024, higher than what can be achieved through these alternatives alone.

Future research could focus on more accurately determining the costs of the energy transition through a degrowth or green growth approach, as the economic model used in this study can only give more general conclusions. More research can also help ascertain whether there is enough public support for degrowth and green growth strategies and what can be done to improve the willingness to accept such a strategy or a mixture of both strategies. Finally, further research could look at how geopolitics influences the energy transition and vice versa. This could show how degrowth and green growth can be paired with energy independence and geopolitical leverage.

In conclusion, this research finds green growth has a more positive impact on the Dutch energy transition and economy than degrowth has. However, a combination policy where energy consumption decreases while green investments are considerably higher, is still very helpful to reach the energy transition goals even more smoothly. Whichever strategy is chosen; it is clear the Dutch government will have to take much more action to reach climate neutrality in 2050.

Foreword

I wrote this report as graduation thesis for the master Complex Systems Engineering and Management at the TU Delft. The topics green growth and degrowth are very interesting to me, as I often hear these terms in political discourse about the energy transition and wanted to know the scientific backing of these two approaches to the energy transition. I specifically wanted to know how these would influence the Dutch energy transition. For that reason, I wanted to write a report in such a way policy makers could use the results to know the advantages and disadvantages of a degrowth and green growth approach and therefore speed up the Dutch energy transition. This research was conducted between March 2025 and June 2025, edited in July 2025 and presented in August 2025. I want to thank my supervisors Servaas Storm and Ivo Bouwmans for their assistance and feedback during the project. I also want to thank Servaas Storm for helping me find appropriate equations and data for the macroeconomic model.

1 Introduction

1.1 Problem description

Climate change is considered to be one of the most pressing issues of our time. According to the Ministry of Infrastructure and Water Management the sea level is expected to rise by 0.6-1.2 metres in the Netherlands in 2100 with an upper bound of 3 metres in the worst climate scenarios (Rijksoverheid, 2023a). Countries worldwide have signed the Paris agreement to become climate neutral in 2050 and thus try to limit heating to 1.5 degrees Celsius higher than pre-industrial times. However, the temperature in 2024 already was 1.5 degrees Celsius higher than pre-industrial times (NOS, 2024). While climate change seems to be a major problem, a large part of the population still rates other problems such as the housing crisis, immigration and healthcare much more important than climate change with respectively 52%, 51% and 41% compared to climate change with 23% in September of 2024 (Avrotros, 2024).

Two major movements have started among climate activists, green growth and degrowth (Sutherland, 2024). The green growth movement advocates for using innovation to reduce resource consumption, by shifting from a quantity to a quality approach and grow our economy while still reducing our greenhouse gas emissions (Vazques-Brust et al, 2014). This movement can also be seen in the Netherlands with the instalment of the Ministry of Climate and Green Growth. The degrowth movement argues the only way to really combat climate change is by limiting our consumption, stating society should stop focussing on economic growth, often through a top-down government approach (Cosme et al, 2017). This movement thinks innovation alone will not be enough to stop the climate crisis, so society will have to limit its consumption as well.

This research focuses on the different approaches to climate mitigation, green growth and degrowth. It will focus on how these approaches utilise technology, influence our economy and determine the political will of the citizens of the Netherlands. This research will be done for the master's degree Complex Systems Engineering & Management, specifically focusing on the energy domain of this master's degree. CoSEM focuses on the integration between the technological, societal, political and economic domains. This research uses a similar multidisciplinary approach, as it looks at the influence of technological innovation on productivity, economic growth and climate mitigation, as well as whether this innovation is sufficient to combat climate change. A comparison between green growth and degrowth should cause a better understanding of energy transition policy. This helps societal actors choose better policy to achieve the Dutch climate goals in time and get enough public support for energy transition.

1.2 Literature review

To identify green growth and degrowth, former scientific literature must be reviewed. This has been done through looking up scientific articles on the database Scopus using the search terms 'degrowth' and 'green growth'. All relevant articles have been combined in table 1, showing which articles are about degrowth or green growth and which geographic area is used for the research.

Reference	Degrowth	Green growth	Geographic area
(Cosme et al, 2017)	x		Worldwide
(Hao et al, 2021)		x	G7 countries
(Hickel & Kallis, 2019)	x	x	Worldwide
(Kallis, In defence of degrowth, 2011)	x		Worldwide
(Lorek & Spangenberg, 2014)	x	x	Worldwide
(Metze, 2018)	x		Netherlands
(Schneider et al, 2010)	x	x	Worldwide
(Vazques-Brust et al, 2014)		x	Worldwide
(van Vuuren et al, 2017)		x	Worldwide
(van den Bergh, 2011)	x		Worldwide
(O'Dell et al, 2025)	x		United States

Table 1: Article analysis

As can be seen in the table, most articles use a worldwide approach focusing on the impacts of degrowth and green growth on societies and economies in general. Only Hao et al (2021) focuses on green growth in a more specific group of countries. Metze (2018) focuses on degrowth of the Dutch fracking industry, which is quite specific but can still be used to see a more Dutch perspective to degrowth. O'Dell (2025) et al focuses on public support for degrowth in the United States, which can be used as an indicator for which factors can increase and decrease public support for degrowth in the Netherlands. They conclude that support for degrowth is quite large when it is combined with welfare programs such as work time reductions and public healthcare.

The articles do not show a clear consensus regarding green growth and degrowth. Van den Bergh (2011) quotes Schneider (2010), referring to the paper as one of the initiators of the new term 'degrowth' while opting himself to focus on 'a-growth' instead of degrowth. Kallis (2011) in turn refers to van den Bergh and states degrowth is not as ambiguous as van den Bergh stated and follows up with a defence of degrowth. In terms of green growth, van Vuuren et al (2017) concludes implementing a sustainable development agenda in combination with climate policy might gain more public support than climate policy alone. Hickel & Kallis (2019) outright reject the notion that green growth can be enough to combat climate change, stating the existing imperial evidence does not support the theory of green growth. Hao et al (2021) comes to an opposite conclusion, stating the G7 countries should focus on a green growth approach.

In conclusion, the debate of degrowth vs green growth is still ongoing and current research regarding this topic is of yet still inconclusive. There is a knowledge gap whether green growth is possible and whether there would be enough societal support for degrowth in combating climate change. This knowledge gap is especially prevalent in the case of the Netherlands as there is a lack of research on the topic in this geographic area.

1.3 Research question and sub-questions

The knowledge gap found in the literature review leads to the main research question: 'What is the influence of green growth and degrowth on the Dutch economy and energy transition in the Netherlands?'. This research question is chosen to analyse how green growth and degrowth influence the energy transition and the Dutch economy. This tackles both the knowledge gap whether green growth is possible and whether degrowth would have enough societal support. It also addresses the geographical knowledge gap as there is a lack of research regarding this subject in the Netherlands.

The main research question will be split up in several sub-questions. The research will start with more clear definitions of green growth and degrowth. Then, an assessment is made of the status quo of the Dutch economy and energy transition. This is followed by analysis of near future innovations impacting the energy transition as well as other important geopolitical factors. With that knowledge, the influence of green growth and degrowth on the Dutch economy and energy transition can be analysed. This information will then be summarised into strategies which are most effective in tackling the energy transition while maintaining the quality of life of Dutch citizens. The sub-questions are as followed:

1. What is the current state of the Dutch economy and Dutch energy transition?
2. How are the external factors innovation and geopolitics impacting the energy transition?
3. What is the influence of a green growth and degrowth approach on the Dutch economy?
4. What is the influence of a green growth and degrowth approach on the Dutch energy transition?
5. What strategies are the most effective in tackling the energy transition while maintaining the quality of life of Dutch citizens?

2 Method

2.1 Research approach

The goal of the research is to present a recommendation of policy to meet the Dutch energy transition goals while retaining sufficient economic wealth for Dutch citizens. The research approach will be a combination of a qualitative and quantitative approach, which combines several forms of data. It is assumed both degrowth and green growth strategies want to reach the goal set in the Paris agreement of being climate neutral in 2050.

Firstly, information about both the Dutch economy as well as the Dutch energy transition goals is collected through literature research. This data will be used as input for a macroeconomic model of the Dutch economy to measure the economic effects of certain climate policy on the economy. In the case of a degrowth approach, the Gross Domestic Product (GDP) would shrink due to a reduction in consumption (Cosme et al, 2017) while in the case of a green growth approach the GDP would rise through the adoption of innovative techniques (Vazques-Brust et al, 2014). While this second approach allows for economic growth, the question remains whether the level of technological innovation will be high enough to meet the energy transition goals, which are set at 0 greenhouse gas emissions in 2050 (Rijksoverheid, 2024a). Another aspect of the literature research will therefore be to look at upcoming technological innovations and assess the likelihood of them being implemented in the short term. This data will be used in a multi-criteria analysis using different scenarios based on the external factors innovation and geopolitical cooperation.

A downside to this approach is the lack of measuring societal support for green growth and degrowth as a quantitative approach would. Societal support is an important aspect of whether the energy transition will be successful. If the Dutch government would propose measures which would cause people's wealth to decrease, that government would likely be voted out next elections. This could result in a government being chosen which is less focused on climate goals, causing the energy transition to be delayed. While a quantitative approach such as this is beneficial to the discussion of green growth and degrowth in the Netherlands, it is quite difficult to hold surveys which are representative for the entire Dutch population. Research agencies such as Ipsos or I&O Research are more suitable for such an approach. A qualitative approach is therefore more feasible for the time of a master's thesis and capabilities of an individual student. The combination of literature research with economic modelling should also allow for a deeper understanding of green growth and degrowth policy and their effects on society. The results can be used as recommendation to the Dutch government and other Dutch organisations of the way forward in the energy transition.

2.2 Data-requirements

This research will focus on data found through literature review as well as data gained through macroeconomic modelling. The data from the literature review can be split into three distinct parts: scientific articles, government reports and news articles. Scientific articles found through Scopus and Google Scholar will be important for the theoretical background of green growth and degrowth. The lack of research about this in the Netherlands means general information has to be translated to an appropriate context in the Netherlands such as the economy, political climate and geographic limitations. For example, the Dutch economy is very different and also much smaller than the US economy.

The second part of the literature review, government reports, will therefore be useful to find the appropriate data about the Netherlands. This also includes a lot of information about the economy for which the CBS (Central Bureau of Statistics) and CPB (Central Planning Bureau) will be useful sources. Finally, the literature review will include reports and articles indicating changes in the political landscape, energy transition and economy of the Netherlands as well as upcoming innovations. Preferably, scientific articles and government reports will be the main source of information but sometimes news articles will be used as well. This information will then be used to create the scenarios in the report.

3 Green growth and degrowth

3.1 Green growth

Green growth is a movement which advocates for the continuation of economic growth while protecting the environment (Capasso, et al., 2019). An important requirement for green growth to exist are scientific institutions which provide knowledge and skill for the energy transition to innovate and put innovations into practice (Capasso, et al., 2019). Hickel & Kallis (2019) mentions definitions for green growth can be quite vague and are different from organisation to organisation. This can range from slightly caring more about sustainability to increasing human well-being while significantly reducing environmental damage.

The Dutch Ministry of Climate and Green Growth is an example of this, as they do not explain what their definition of green growth is, even though they use the term in the name of their ministry (Ministerie van Klimaat en Groene Groei, 2025). The Dutch government defines green growth as making Dutch society more sustainable while strengthening the economy (Rijksoverheid, sd). The government also defines green growth as growth without damaging the environment but remains unclear as to whether this means not damaging the environment more than has been done so far or reducing overall pollution in the Netherlands.

Papers such as Hao et al (2021) are also not very precise in defining green growth, mentioning it as ‘environmentally sustainable economic growth’ being unclear as to what this exactly entails. Vazques-Brust et al (2014) mentions green growth as a ‘recoupling’ of economic growth and environmental protection, in contrast to earlier notions where climate goals were seen as a cost instead of an economic investment. Vazques-Brust et al (2014) also sees green growth as environmentally sustainable economic growth but uses scenarios in which there are still net positive greenhouse gas emissions in 2100, albeit severely reduced compared to 2010. Economic growth is often defined as an increase in GDP (Gross Domestic Product), which will therefore also be used as a metric for green growth in this paper. This paper will use the Paris agreement of 2015 to assume both green growth and degrowth achieve net zero emissions in 2050.

This research will use the following definition of green growth:

Green growth is a strategy to reach net zero emissions in 2050 under the assumption there is no real trade-off between economic growth and a reduction of greenhouse gasses. This means the economy or GDP can grow while net zero emissions can be reached due to enough carbon-saving innovation, green investments and technological progress.

While the goal of green growth is to reach a climate neutral society in 2050, it is possible that this goal will not be met depending on several factors which will be discussed in the scenarios. For example, emerging technologies such as carbon capture storage, hydrogen networks or nuclear fusion could massively influence the state of the energy transition and therefore the feasibility of green growth. A lack of innovation could cause the opposite of these goals not being met in time.

3.2 Degrowth

Degrowth is a movement which advocates for decreased resource and energy consumption and therefore resource and energy throughput, reducing economic growth to protect the environment (Kallis, et al., 2018). Degrowth looks at other aspects of measuring wealth than GDP (per capita) through for example increasing social cohesion and quality of life, which could be reached through for example fewer working hours (Kallis, 2013) (van den Bergh, 2011). Kallis (2013) also argues for instead of focusing on paid work, shifting work back to the unpaid sector in which people could get more gratification from their work. Cosme et al (2017) mentions this as well, stating social equity is an equally important aspect to degrowth as climate mitigation is. Cosme et al (2017) also states degrowth, while often mentioned as a bottom-up process, often needs top-down policy to be implemented. In practice this comes down to a lot of government intervention, often on a national level. O'Dell, et al (2025) concludes increases in social welfare are required for sufficient support of degrowth policy.

Van den Bergh (2011) argues against going for degrowth due to its vague policy recommendations and degrowth policy likely lacking the public support necessary to effectively combat climate change. As with green growth, there is no clear agreed-upon definition of degrowth except for it advocating for net zero emissions through a reduction in consumption and therefore GDP. This paper will therefore focus on the reduction in GDP as it is still a widely used metric for economic performance.

This research will use the following definition of degrowth:

Degrowth is a strategy to reach net zero emissions in 2050 under the assumption there is a real trade-off between economic growth and a reduction in greenhouse gasses. This means the economy or GDP must shrink through lower levels of consumption, as carbon-saving innovation and technological progress will not be enough to reach net zero emissions on their own.

As with green growth, degrowth focuses on reaching a climate neutral society in 2050. It is possible this goal will not be met due to a lack of societal support or decreased willingness of businesses to innovate due to lower returns on investments. On the other hand, while green growth is more reliant on emerging technologies, degrowth already works toward climate neutrality by decreasing consumption. This means degrowth should be less scenario dependent than green growth.

4 State of the Dutch economy and energy transition

4.1 State of the Dutch economy

An important aspect to determining how green growth and degrowth will impact the Dutch economy is by first assessing the current state of the Dutch economy. This chapter will go in depth to which economic factors are used to determine the state of the Dutch economy, using main factors of the Dutch economy provided by the Dutch economy dashboard of the Central Bureau of Statistics (CBS).

GDP	Business cycle	Unemployment	Housing market	Inflation	Companies	International trade	Government finances

Table 2: Factors of Dutch economy dashboard (CBS, 2025a)

4.1.1 Gross Domestic Product (GDP)

The CBS has included the following important economic factors in their Dutch economy dashboard indicating some of the most important factors in the economy: GDP, business cycle, job market, housing market, inflation, number of companies being founded and abolished, international trade and government finances (CBS, 2025a). The dashboard includes an external comparison with other European countries and an internal comparison between the Dutch provinces as well. The first important factor, GDP or Gross Domestic Product, is a measurement of the growth or degrowth of an economy (Munichello & Potters, 2024) (CBS, 2025b). The CBS defines GDP using the general equation of:

Y (GDP) = C (consumption) + I (investments) + G (government expenditure) + X (exports) – M (imports) (CBS, sd)

This approach, rooted in Keynesian macroeconomics, is the most used approach to measuring GDP known as the expenditure approach (Ross et al, 2023) and will be used in this paper.

GDP growth can be seen through looking at a historic perspective on the Dutch economy since 1960 to 2024 in which the economy has grown from 153.6 billion euros real GDP in 1960 to 833.6 billion euros real GDP in 2024 (European Commission, 2024a). This is a growth of (833.6/153.6) x100-100 = 442.7%. In figure 1, GDP grows at a relatively stable rate except for the late 1970's due to the oil crisis, the early 2000's due to the internet bubble, 2008 due to the global financial crisis and 2020 due to the Covid crisis. However, after these crises GDP recovered and started increasing again above the level before the crisis. As for future GDP growth, the Central Planning Bureau (CPB) expects GDP in 2050 to be about 1.5 to twice as large as GDP in 2000, depending on different scenarios (CPB, 2024). In the lowest case scenario this would mean GDP in 2050 would only be slightly higher than GDP in 2024, which the CPB explains is due to lower levels of per capita consumption (CPB, 2024). This would already be a slight degrowth scenario, meaning in a status quo or green growth scenario, expected GDP growth would be more akin to the earlier mentioned doubling in size compared to 2000.

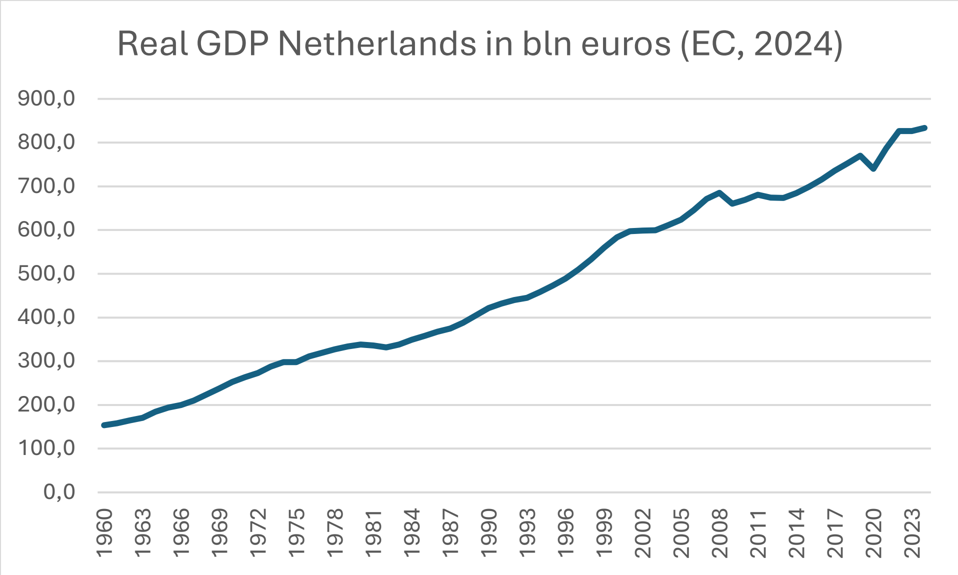

Figure 1: Real GDP in billion euros (European Commission, 2024a)

4.1.2 Business cycle and unemployment

The second factor of the Dutch economy dashboard, the business cycle, is an important measurement for the state of the economy in the short term, measured against an average growth or degrowth of the economy (CBS, 2025d). As this research focuses on the state of the economy in the long term it will not focus on short-term deviations from the trend such as the business cycle. Individual factors which are used to calculate the business cycle, such as production, consumption and export are important, but these are already included in the formula for GDP. Number of work hours is however a factor not included in GDP, which is relevant in the degrowth/green growth discussion. This is due to the degrowth movement arguing for fewer working hours due to the focus shifting away from economic growth (Kallis, 2013)

The next factor mentioned is the job market which the CBS measures through the unemployment rate which is defined as all the people in the Netherlands between the age of 15 and 75 who are searching for a job but do not have one compared to those in that age bracket who have a job plus those who are searching for a job (CBS, 2025e). The unemployment from 2018 until 2024 is roughly 4% with a peak of 5.5% during the Covid crisis and a bottom of 3.2% just after the Covid crisis ended. The unemployment rate is an important economic factor to measure economic activity, and it also influences the rate of inflation which can be seen in the Phillips curve (Hoover, 2008). The importance of unemployment could however change if for example universal basic income were to be implemented, as is advocated for in many degrowth proposals (Langridge, 2024). The reason for this is universal basic income allowing people to have a living wage, even when they are not employed.

4.1.3 Housing market and population growth

The fourth factor mentioned in the Dutch economy dashboard, the housing market, constitutes a large problem facing current Dutch society but one which has less to do with the economics of climate change. While this factor is less important to this research, it does influence population growth in the Netherlands, which in turn influences consumption and therefore Dutch GDP. Population estimates from the CBS estimate the Netherlands to have a population between 17.8 million and 21.8 million inhabitants with a prognosis of 19.6 million in 2050 (CBS, 2024a). The main factor the CBS states for this increase in inhabitants is immigration, which is also the cause of the large uncertainty in the model. Currently, the Dutch population consists of about 18.1 million inhabitants (CBS, 2025f) which means the population would slightly shrink in the lowest scenario. On average 1.5 children are born per woman in the Netherlands while 2.1 children per woman would be needed for a stable population assuming net migration was 0 (CBS, 2022a). This showcases the enormous effect immigration has on the Dutch population, as without immigration the population would significantly decrease. In the case of worsening climate change, climate refugees would cause the population to grow even further (Berchin et al, 2017).

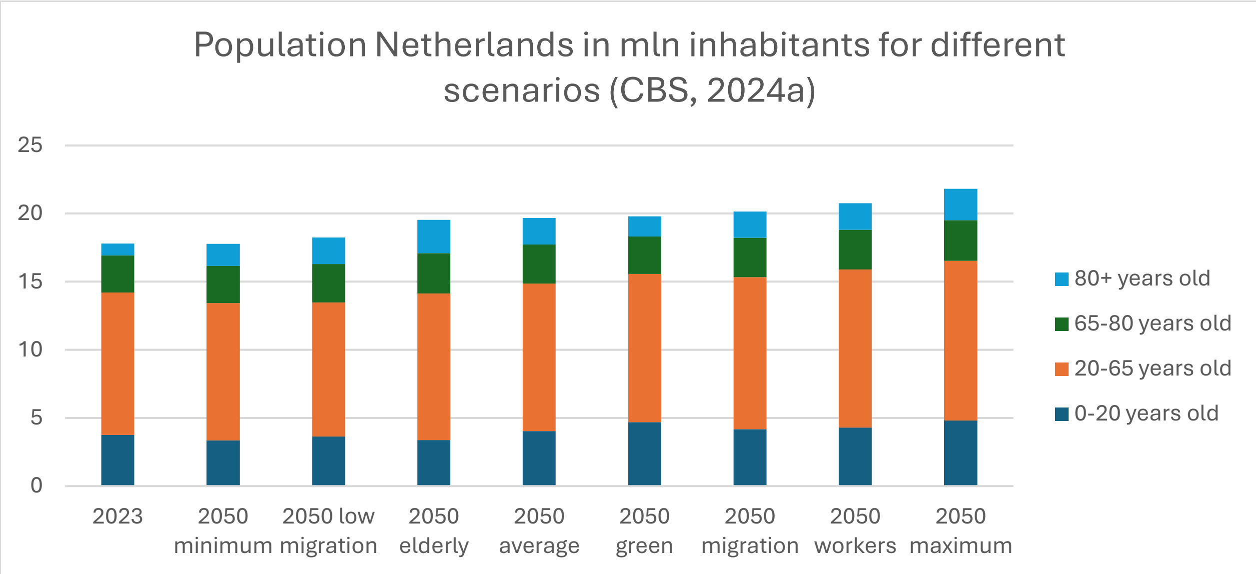

Figure 2: Population projections Netherlands (CBS, 2024a)

4.1.4 Inflation

The fifth factor, inflation, is under New-Keynesian/New-Classical macroeconomic theory supposed to be roughly 2%, a goal which is also being put in place by the European Central Bank (ECB) (ECB, 2025a) (Storm & Naastepad, 2012). This 2% is being put into place to cause the inflation not to accelerate and cause hyperinflation. It is also not lower than 2% to not cause deflation (ECB, 2025a). Deflation would in theory cause people to consume less, having an adverse impact on wages, investment and economic growth. Very low levels of inflation would also cause more unemployment as can be seen in the Phillips curve. However, the strength of this link changes over time and the theory of the Phillips curve sometimes contradicts reality, for example during the stagflation of the Oil crises of 1973-1975 (Anderson & Velasquez, 2024). While criticism of both the Phillips curve (Anderson & Velasquez, 2024) as well as the associated Non-Accelerating Inflation Rate of Unemployment (NAIRU) (Storm & Naastepad, 2012) remains plentiful, the 2% inflation target is still used by most central banks around the world including the ECB (ECB, 2025a).

In case of green growth, investment and consumption will likely still increase, allowing for a continued use of a 2% inflation target. Despite this however, inflation from 1946 to 2024 was about 1350% (CBS, 2025c) while with an average inflation of 2% this would be expected to be about 1.02 ^ (2024-1946)-100 = 370% inflation. This means actual inflation during this period was about 3.5% per year. Even looking at 1980-2024 a 2% inflation would result in 1.02 ^ (2024-1980)-100 = 140% inflation while actual inflation was 185% in this period (CBS, 2025c). This means the inflation during this period was about 2.5% per year. In case of degrowth, consumption would decrease, causing inflation to potentially fall below the average 2% or even causing deflation.

4.1.5 Companies

Similar to inflation, the number of companies being founded and abolished, is a factor which can change a lot depending on whether a degrowth or green growth strategy is chosen. Most companies in the Netherlands have a self-employed company structure, with about 2 million self-proprietorships existing in the Netherlands in early 2025, an increase of more than half a million since the beginning of 2020 (CBS, 2025h).

While the Covid crisis of 2020 decreased consumption and GDP by a large amount, most companies received state funding to stay afloat, while EU countries ensured the risk of subsidising so called zombie companies (companies which would go bankrupt in normal circumstances as well) would be minimised (ECB, 2020). The risk and number of zombie companies is however generally much lower than what is commonly believed, through a system of relatively efficient bailouts (Nakamura, 2023). In a degrowth economy the government would probably have to use a similar mechanism of efficient bailouts, as the decreased amount of production and consumption could lead to a lot of bankruptcies in crucial sectors as well. This could be mitigated through using a controlled approach, slowly decreasing production and consumption so companies can adapt to the new economic policy. This will however curb investment into the energy sector, due to diminished returns of companies, which means the government will likely have to do more investment than in green growth scenarios where private companies can finance a lot of the energy transition. The space for deficit spending will also be smaller, due to the lower (or even negative) levels of inflation in a degrowth economy as discussed before as well as a lower overall GDP.

4.1.6 International trade

The second to last factor from the Dutch economy dashboard is international trade, meaning the combination of imports and exports of the Netherlands. This factor is important to determine GDP. Dutch imports and exports follow a rather similar pattern with exports shrinking with 10.8% in the Covid crisis (second quarter of 2020) and imports shrinking with 8.8% in the same quarter (CBS, 2025i). Comparatively, exports and imports majorly recovered in 2021 with exports rising with 18.9% in the second quarter of 2021 and imports with 18.3% (CBS, 2025i). The overall trend shows an increase in both imports and exports with variations depending on the business cycle.

4.1.7 Government finances

This also leads into the final factor of the Dutch economy dashboard, government finances. Government debt is often measured in debt/GDP, meaning GDP is also an important metric in the discussion of government finances (CBS, 2025j). In the European Union (EU) governments have decided upon limiting debt to 60% of GDP and the yearly deficit ratio to 3% of GDP in the Excessive Deficit Procedure (EDP) (CBS, 2025j) (European Council, 2025). In case the government cannot meet these goals, they can get a fine up to 0.05% of GDP or higher in case of successive failures to meet this goal (European Council, 2025). This procedure was put into place to ensure responsible government spending, but it will be increasingly difficult to reach this goal in case of GDP stagnation or even GDP decline.

While the Netherlands has a debt of only 42% of GDP at the end of 2024 and thus has a lot of financial room left (CBS, 2025j), other countries such as Belgium, Greece and Italy have a debt above 100% of GDP and even more stable economies such as Germany now have a debt above

60% of GDP (CEIC DATA, 2024). With an average EU GDP to debt ratio above 80% (CEIC DATA, 2024) it is clear the EU is not able to meet their own goals regarding debt to GDP.

Another factor is the credit rating of the Netherlands which is currently triple A (AAA) (S&P Global, 2023) but would likely decrease were the debt to GDP ratio to increase. Assuming the current EDP stays in place, the Netherlands will have difficulty transitioning to a degrowth economy, as a shrinking economy means the government budget also needs to decrease, while the energy transition as well as numerous other issues require a lot of government investment. Conversely, in a green growth economy the increase in GDP allows for more deficit spending, while deficit spending can allow for a higher GDP growth due to fiscal multipliers (Ganti, Estevez, & Rosenston, 2024). The effect of the fiscal multipliers could however be higher in a degrowth economy, due to the lower levels of inflation, as the set interest rate would not have to be increased to stabilise inflation.

4.1.8 Consumption & investments

Aside from these factors stated on the Dutch economy dashboard, there are key factors making up Dutch GDP such as overall consumption, overall production and investments. Consumption went up nominally with 8.1% in 2023 compared to 2022 and the real consumption growth (adjusted for inflation) was 0.8% in 2023 compared to 2022 (CBS, 2024b). While consumption growth is not as high as it was during the recovery of the Covid crisis, consumption still shows an upward trend even when adjusted for inflation. Recent numbers also show an overall consumption increase during 2024 with a 1.8% increase in consumption in December 2024 compared to December 2023 (CBS, 2025l). On the other hand, overall production has decreased with 4.4% in December 2024 compared to December 2023 and shows an overall decreasing trend after the recovery period following the Covid crisis (CBS, 2025k). Innovation can be measured through the Research & Development (R&D) expenditures of companies, which rose from 13 billion euros in 2021 to 14.8 billion euros in 2022 (CBS, 2025h). As more recent numbers are not available here yet, it is difficult to compare how the decrease in production compares with the innovation in 2024.

4.1.9 Conclusion

Overall, the current economic outlook of the Netherlands is good. Unemployment is relatively low with roughly 4% of the population being unemployed. The government budget is also good with only 42% debt to GDP, well under the required 60% by EU agreement. This in turn also causes Dutch interest rates on government bonds to be very low due to its triple A rating, meaning the government can lend money at a relatively low cost. Consumption growth is relatively low but whether this is good or not depends on whether a green growth or degrowth strategy is chosen. The same goes for production growth which is currently negative. Business investments seem to be in an upward trend but as there is a lack of data for 2023 and 2024 it cannot be said for certain whether this trend is continuing. The more business investment into the energy sector, the less the Dutch government must pay to become climate neutral, although only a small part of total business investments goes into the energy transition.

The next chapter will look at the state of the energy transition, which in combination with the state of the economy, will provide the basis on which green growth and degrowth policy can be built.

4.2 State of the Dutch energy transition

Chapter 4.2 will look at the current state of the Dutch energy transition, how far the Netherlands already is in the transition to green energy and what future plans the government has in order to meet climate goals such as the 55% reduction of CO_2 in 2030 (Rijksoverheid, 2023b) and the Paris agreement of net zero emissions in 2050. This part will start with a description about the electricity and energy markets of the Netherlands and will then continue with feasibility reports, several types of green energy, infrastructure, hydrogen, heat networks and carbon capture storage.

4.2.1 Electricity and energy sectors

The first aspect which is mainly focused on in the current state of the energy transition is the electricity sector. In the first half year of 2024, the electricity sector of the Netherlands got 53% of their electricity from renewable sources (CBS, 2024c). This also marked the first time renewable electricity outperformed electricity from fossil fuels. The main renewable electricity source is wind with 17.4 TWh, with the second largest source being solar with 11.7 TWh. The share of biomass has decreased to 3 TWh from 3.2 TWh in the second half year of 2023. On the side of fossil fuels, gas was the main contributor with 21.3 TWh followed by coal with 3.9 TWh. The share of other non-renewable and non-fossil fuel sources of electricity, such as nuclear, was 1.5 TWh or 2.6% of the total electricity produced. Total production of electricity rose with 1% compared to the second half of 2023 to 60.5 TWh, which is still somewhat lower than during the Covid crisis of 2020. In total there was a trade surplus of 2.3 TWh electricity (CBS, 2024c).

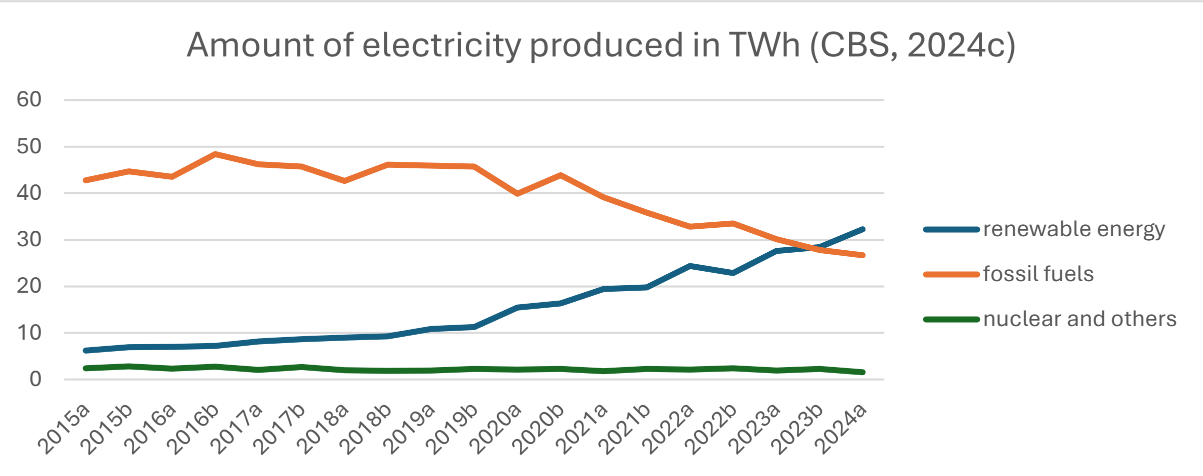

Figure 3: Amount of electricity produced (CBS, 2024c)

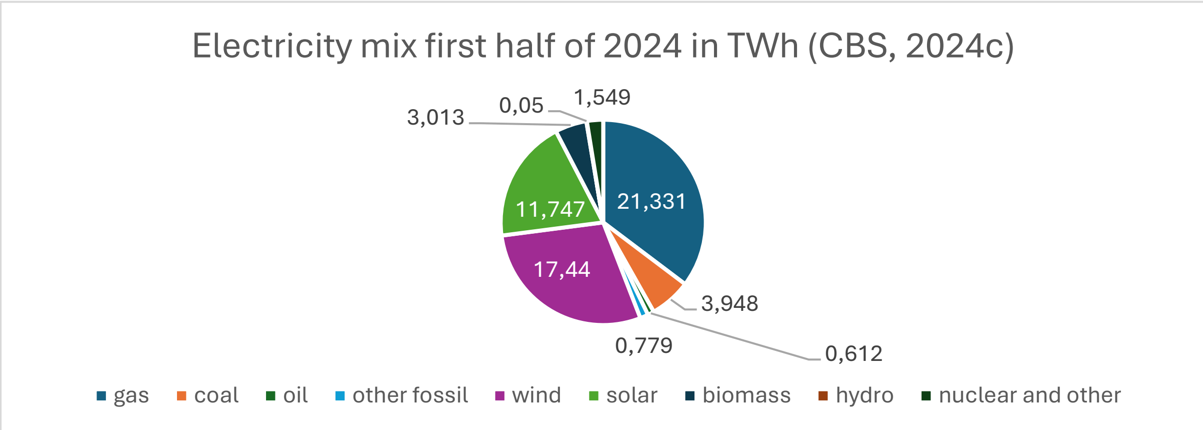

Figure 4: Electricity mix Netherlands 2024 (CBS, 2024c)

The energy sector shows a much different picture from the electricity sector. Here, biomass was the main contributor of renewable energy consumption with 191.9 PJ in 2023 (CBS, 2024d). Biomass was followed by wind with 105 PJ and solar with 73.1 PJ. The total contribution of renewable energy was 403 PJ or 15% of the total energy consumption of the Netherlands. Oil and gas were the highest contributors to the total energy consumption with respectively 1090.2 PJ and 927.8 PJ (CBS, 2024d). Nuclear energy contributed about 3.8 TWh or 13.7 PJ per year (Rijksoverheid, 2022b). While the renewable share is 15%, half of this is biomass which cannot be expanded easily in a sustainable manner, due to biomass often requiring to remove forests for the biomass or turning forests into farmland (Reijnders, 2006).

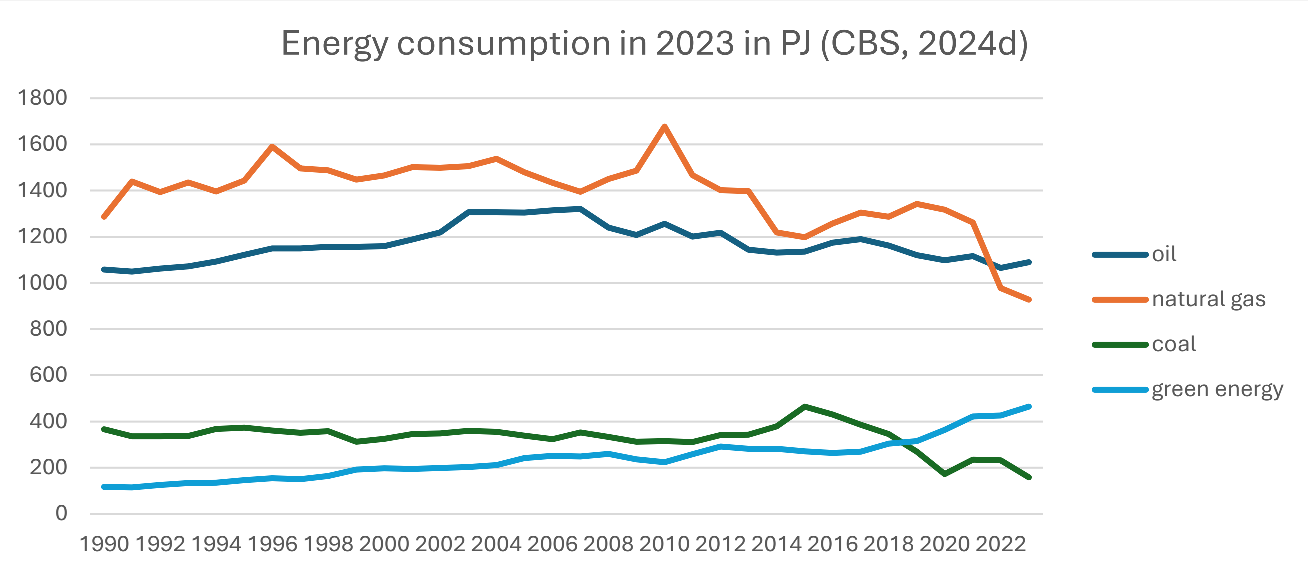

Figure 5: Energy consumption in 2023 in PJ (CBS, 2024d)

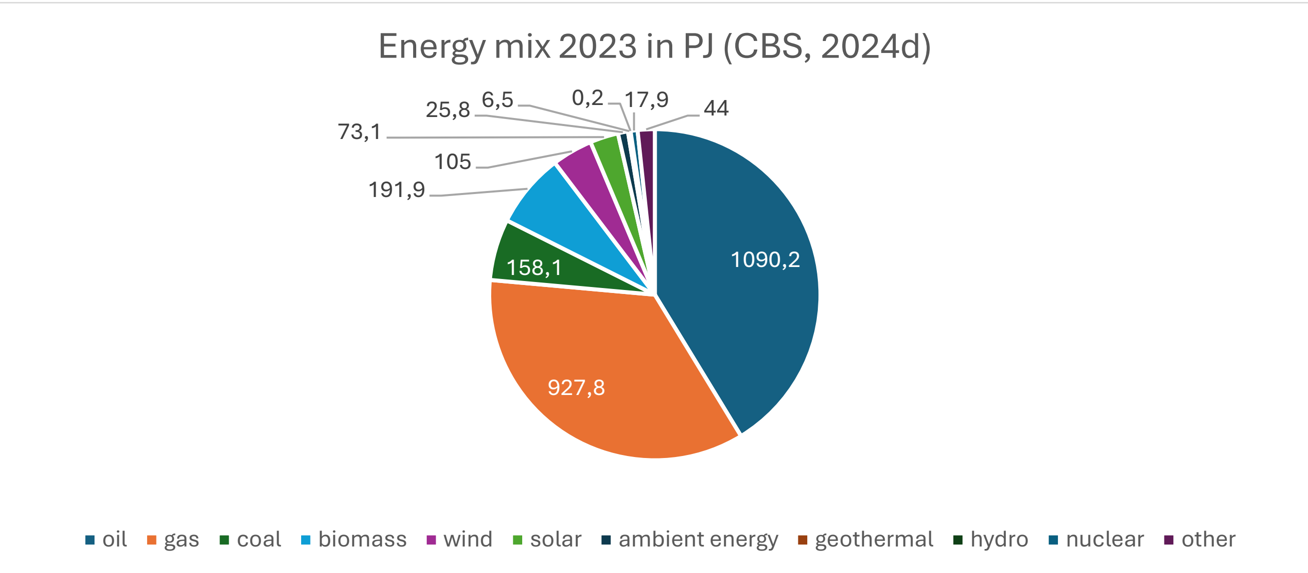

Figure 6: Energy mix 2023 in PJ (CBS, 2024d)

4.2.2 Feasibility of climate policy

Different organisations have done research about the feasibility of climate policy to reach climate neutrality in 2050 or earlier. One of those reports looked at the feasibility of attaining net zero emissions in 2040, as the European Commission set the goal of member states reducing their emissions by 90% compared to 1990 (Kerkhoven & Hanemaaijer, 2025) (PBL, 2024). This report concludes that some emissions, such as methane in farming, cannot be 0 in 2040, which must be compensated by other sectors through using carbon capture storage (Kerkhoven & Hanemaaijer, 2025). The report also states the total energy transition would require an investment of 34 billion euros per year from 2025 until 2040 or 514 billion euros in total to achieve climate neutrality in 2040. This estimate requires about 150 billion euros total investment into infrastructure including heat networks (Kerkhoven & Hanemaaijer, 2025).

The infrastructure costs are however already expected to be between 156 and 282 billion euros, not including storage costs, depending on different scenarios and factors such as shifting demand away from peak hours (Nillesen, de Lange, & van Heugten, 2024) (Ekker, 2025). Electricity is by far the main contributor with an estimated 195 billion euros investment needed (Nillesen, de Lange, & van Heugten, 2024). As this paper does not assume net zero emissions will be reached in 2040, even more investment will be needed for the total energy transition into infrastructure alone, making the cost estimate much higher than the report by Kerkhoven et al stated (Nillesen, de Lange, & van Heugten, 2024). Because of the high investment needed in infrastructure, TenneT invested 10.6 billion euros last year to expand the electricity network both at sea and on land (TenneT, 2025). To reach the required investments, they will have to invest more than this every year, also taking into consideration an average inflation of 2%.

The Dutch government has also reflected on the state of current climate policy through a report which acknowledges the recent reduction in CO_2 emissions between 2021-2023 of 7 Mtons CO_2-equivalent was mainly due to decreased production instead of increasing sustainability (Ministerie van Klimaat en Groene Groei, 2024). The reaction of the Dutch government regarding this is to focus on green growth projects through innovation to meet the 2030 climate goals. The Raad van State (RvS) or Council of State is critical on the lack of progress made in the energy transition and doubts the set goals for 2030 can be met on the ground of several aspects including wind on land, wind at sea and nuclear power. The RvS also advises to set a target goal for 2040 as in between step to help the government, citizens and companies in working towards climate neutrality in 2050 (Ministerie van Klimaat en Groene Groei, 2025).

4.2.3 Solar energy

A major change in the Dutch energy transition is the removal of the ‘salderingsregeling’, the subsidy on solar panels which allowed people to offer the electricity they generated through solar panels to the electricity net for a monetary compensation (Rijksoverheid, 2024b). This subsidy will stop in 2027 with as the government states solar panels are already attractive enough for consumers and small businesses to buy without a subsidy. Other reasons mentioned are the costs for energy companies which must be compensated by people without solar panels as well as the costs the government must pay (Rijksoverheid, 2024b). The results of this policy can already be seen as the market for solar panels has experienced a major downturn with a reduction of new solar panels being placed from 4.9 GWp in 2023 to 3.4 GWp in 2024 (DNE Research, 2025). While this decrease can also be partially attributed to already 3 million households having solar panels, the announcement of the removal of the salderingsregeling has an undeniable effect on the market. The market is expected to recover but will probably not reach the heights of 2023 anymore (DNE Research, 2025).

4.2.4 Nuclear energy

Another aspect the government wishes to use in the energy transition is the expansion of nuclear energy with two or four new nuclear power plants. These power plants should be operational in 2035, and the existing power plant in Borssele should stay open until 2035 instead of 2033 (Rijksoverheid, 2024c). The new power plants should be generation III+ reactors with at least a power of 1000 MW (Rijksoverheid, 2024d). A nuclear power plant takes at least 11-12 years to be built (TNO, 2022) giving doubts as to whether 2035 is a realistic goal.

The other question is who will pay the investment costs of these nuclear power plants. The expected costs for nuclear power plants tend to be between 3000 and 6200 dollars per kW or about 2800 to 5700 euros per kW (Bowen, Ochu, & Glynn, 2023). This would be an average of 4300 euros per kW nuclear power. This means a 1000 MW nuclear power plant would have an average capital expenditure (CAPEX) of 4.3 billion euros per nuclear power plant. This could even be a low estimation, as new nuclear power plants such as Hinkley Point C in the UK are much more expensive than originally planned. This power plant has a capacity of 3260 MW and will likely cost 58 billion dollars or 53 billion euros which is a cost of 16.3 billion euros per 1000 MW power plant (Duckett, 2024). In total the Dutch government wishes to spend 14.1 billion euros on nuclear energy from 2026 until 2035 (Rijksoverheid, 2024f). Even in the case of the average cost of nuclear power plants of 4.3 billion euros per 1000 MW this means there is a gap of 3.1 billion euros which still must be financed through other means such as investment from companies. In the case the nuclear power plants would have costs as high as the Hinkley point C reactor, this would mean the total costs would be 65.2 billion euros. In this case private investors would have to make up for the 51.1 billion euros investment gap.

4.2.5 Wind energy

Wind at sea is one of the most important sources of renewable energy in the Netherlands with 4.5 GW or 16% of the total electricity demand comes from wind at sea (Rijksoverheid, 2023c). The government wishes to expand this to 21 GW in 2032 as agreed upon in the Dutch climate accord of 2019. The subsidy for wind of sea was recently removed, except for the infrastructure to connect the parks which was still paid for by TenneT (Rijksoverheid, sd3) (Kraan, 2025). This is a potential risk for the future of the sector, as recent investments into wind at sea in the UK and Denmark have failed, which is also a possibility in the Netherlands due to the decline of industrial production (Kraan, 2025).

Aside from wind at sea, the government wishes to have 35 TWh of wind energy on land in 2030, while local governments wish to increase this to 55 TWh, up from the total 22.2 TWh of wind energy produced in 2023 (RVO, 2024a). One of the main problems in the increase in wind on land is net congestion, causing delays in the building of the wind farm in Delfzijl for example (RVO, 2024a). Another reason is opposition from local inhabitants to the construction of wind farms, often because of horizon pollution or health concerns (RVO, 2019). Recent research into the health of people living near wind farms shows there is no significant relationship between living close to a wind farm and their health but this research also has restrictions and can therefore not be fully taken for granted (RVO, 2024a).

4.2.6 Hydrogen

Aside from energy production, the energy transition also requires energy carriers such as hydrogen. Currently, the Netherlands produces most of its 10 billion m^3 hydrogen through natural gas, which constitutes 10% of the yearly gas consumption of the Netherlands (NWP, 2024). The goal is to reach 500 MW electrolysing capacity in 2025 and 3-4 GW in 2030 (NWP, 2024). The way hydrogen is produced, is defined through different colours, such as grey hydrogen which is hydrogen produced from fossil fuels, green hydrogen for hydrogen from renewable sources, pink hydrogen for hydrogen from nuclear sources, white hydrogen from natural sources and blue hydrogen from fossil fuel sources with carbon capture storage (CCS) (Incer-Valverde, Korayem, Tsatsaronis, & Morosuk, 2023).

The Dutch planning bureau of the living environment (PBL) expects mainly green hydrogen, through for example wind at sea, combined with blue hydrogen to be used in 2050, but sees a potential role for pink hydrogen and white hydrogen as well (Elzenga & Strengers, 2024). Based on currently considered plans, this would result in 24 GW total capacity of electrolysers in 2040, but it is unlikely that all these plans will come to fruition (Elzenga & Strengers, 2024). It remains clear that a large amount of progress is needed in this sector with a capacity of only 500 MW electrolysers in 2025.

4.2.7 Heat networks

Another important aspect is the implementation of heat networks. In 2023 11,000 buildings, mainly homes, were connected to a heat network, which resulted in an average reduction of 50.9% of CO_2 emissions compared to gas heating (RVO, 2024b). This was lower than the average reduction of 63.1% in 2022 due to outages of three large heat networks, causing them to rely more on heat production from fossil fuels (RVO, 2024b). One of the sources of heat can be geothermal energy, which can be attained through aquifers or other porous types of soil at least 500 metres underground by injecting cold water and pumping up the warm water (Rijksoverheid, 2023d). The government wants to provide 2.2 million households with heat acquired through geothermal energy in 2030 (Rijksoverheid, 2023d). Geothermal energy is not entirely green however, as the geothermal source still emits 4 to 9.8 kg CO_2/GJ (TNO, 2012). However, this is much lower than the gas it replaces, which emits 56.4 kg CO_2/GJ (RVO, 2019).

4.2.8 Carbon capture storage

Carbon capture storage (CCS) is another crucial aspect of the Dutch energy transition, as there will likely be sectors which will not be able to become climate neutral on their own. Those sectors will have to compensate their emissions through capturing emitted greenhouse gasses. The largest of these CCS initiatives currently being implemented is Porthos, which is supposed to operate in 2026, storing 2.5 mega tons CO_2 per year until the storage is full when it hits its capacity of 37 mega tons CO_2 (Porthos, 2024). In 2022 the average CO_2 footprint per inhabitant was 15.7 tons CO_2/inhabitant (CBS, 2023), meaning Porthos can store the average CO_2 emissions of about 160,000 Dutch citizens per year, until the storage is full. This means even a large project such as Porthos cannot capture even 1% of the yearly CO_2 emissions of the Netherlands, showing a lot more CO_2 capturing projects are needed to offer a significant contribution to the energy transition.

4.2.9 Conclusion

In conclusion every part of the energy sector still has a large amount of work to do to become climate neutral in 2050. The electricity sector is the furthest, having just become over 50% renewable but other sectors, such as the hydrogen sector, are not even at 10% of their goals for 2040, making it difficult to reach the set goals in time. The wind energy sector also needs to more than double in size to reach the goals local governments set for 2030 as well as the nuclear sector which requires massive government and/or private investments to reach the goal of 4 new 1000 MW nuclear power plants. At the current pace of the energy transition, the set goals do not seem realistic, meaning much more action is needed.

This can also be seen in the energy sector where only 15% of electricity consumption comes from renewable sources. Half of this is biomass, which cannot easily be expanded in a sustainable way. Total costs for the energy transition are expected to be 514 billion euros to become climate neutral in 2040, which will likely be higher due to the underestimation of infrastructure costs within the energy transition which are expected to be 195 billion euros for the electricity sector alone. If the transition will be finished in 2050, total costs would be even higher due to a larger population and more inflation. The recent removal of wind turbine and solar panel subsidies might make the transition even more difficult. With current policy the 514 billion euros investments would not be reached, showing much more investments are needed.

4.3 Conclusion

The Dutch economy is doing relatively well with a low unemployment percentage of 4% and a low government debt of 42% of GDP. This means the government has the economic opportunity to invest in the energy transition, although they should be careful not to overinvest as that could heat up current inflation which is higher than 2%. As the population of the Netherlands is expected to continue to grow, the economy would likely also keep on growing. The additional consumption will however require more investment into the energy transition. Current projections for 2040 show 514 billion euros investments are needed, which will likely be even higher due to 195 billion euros being needed for electricity infrastructure alone. With only 15% of electricity consumption coming from renewable sources, the Netherlands has a long way to go.

Current government policies such as the removal of the salderingsregeling as well as removal of wind turbine subsidies might make the energy transition a lot more difficult. Although the government is investing in nuclear energy, it remains to be seen whether this investment will be high enough and whether these power plants can be built in time. Overall, a lot of work is needed showing a clear need for an energy transition strategy, either through green growth, degrowth or a mixed approach. This strategy will be influenced by external factors such as innovation and geopolitics. These external factors and their respective scenarios will be discussed in the next chapter.

5 External factors of green growth and degrowth

This chapter will go in-depth into the external factors of green growth and degrowth, mainly innovation and geopolitics. Innovation is important as it increases efficiency and allows for technologies which are currently not feasible. These innovations increase productivity and the effectiveness of investments. Geopolitics are important as wars, trade wars and collaboration have a major impact on worldwide supply chains, as well as the importance governments will put on combating climate change. The more the world cooperates, the easier the energy transition will be. This is however not easy due to scarcity of resources and continuously changing politics. These external factors will be combined into scenarios which will be used to determine in what contexts green growth and degrowth policies will be more effective.

5.1 Innovation

One of the crucial aspects to successfully complete the energy transition is innovation. This is especially the case with green growth policy which relies on innovation and investments. Certain sectors like aviation will have a lot of difficulty transitioning in time, for which innovation is really required. With degrowth policy, the number of flights could be reduced through government policy and social movements, while being replaced with trains. This still requires a lot of investment but does not necessarily require innovative technologies. This chapter will look at innovative technologies and how they shape green growth and degrowth policies.

5.1.1 Nuclear fusion

One of the main innovative technologies which has already been talked about since the advent of nuclear research in the 1920's and 1930's is nuclear fusion (Meschini et al, 2023). Similar to nuclear fission, nuclear fusion produces no greenhouse gasses and is a very dense source of power with an abundant fuel source (Meschini et al, 2023). Two major advantages of nuclear fusion compared to nuclear fission are the lack of chain reactions which could cause a reactor meltdown, as well as the nuclear waste created by the reactor being much less of a problem compared to nuclear fission (Meschini et al, 2023). Currently, about 98% of investments into nuclear fusion are from private investors (Meschini et al, 2023), showing governments could also step up and invest more in this upcoming technology to try to speed up the energy transition.

The downside to investing in innovative technologies is the unknown factor of when that technology will be available and what the returns of said technology will be. The EU did take steps in this with the European Atomic Energy Community (Euratom), as well as signing an international nuclear energy agreement starting a project in France called ITER (European Commission, 2025a). Former prime minister of Italy and former head of the European Central Bank (ECB) Mario Draghi also recommended the EU to strengthen effort and investment into nuclear fusion in his European competitiveness report (Draghi, 2024). However, Draghi also mentioned how nuclear fusion would likely only play a role in the latter half of this century, past 2050. This seems logical, as nuclear fusion has not even been developed yet and when it has, the power plants also need to be built. If a consistent nuclear fusion reaction can be reached in 2040, it would probably take 10 years or longer to build a commercial power plant, meaning it will only make an impact on the energy transition and economy in 2050 or later.

5.1.2 Small Modular Reactors

Another form of nuclear innovation is the advent of Small Modular Reactors (SMRs). Small Modular Reactors are nuclear fission reactors on a much smaller scale than normal nuclear power plants with a maximum capacity of 300 MW (Liou, 2021). Unlike regular reactors these can be factory assembled, meaning they have a pre-existing design and can be recreated in large quantities (Liou, 2021). Another advantage is the smaller capacity putting less pressure on the energy grid. Mario Draghi also mentioned SMR's in his European competitiveness report stating European SMR's would likely be built in the next decade so 2030 onwards and therefore can be helpful in the medium term for completing the energy transition (Draghi, 2024). These would likely still be generation III+ nuclear power plants, as generation IV nuclear power plants are expected to be developed in 2040 (Rijksoverheid, sd2).

The smaller size and factory assembled characteristics of SMR's could lead to faster building times of nuclear power plants, compared to the 10-15 years regular nuclear power plants often take. The price of these SMR's is expected to be about 102 dollars per MWh in 2030 considering inflation (IEEFA, 2023). The International Energy Agency expects the capital costs of a SMR to be 5850 dollars per kW in 2040 compared to 4500 dollars per kW for a standard nuclear power plant using current day prices (IEA, 2025). This means the technology probably costs more than regular nuclear power. If costs can be successfully reduced, this could have a major influence on the energy transition, reducing building times and attracting more investors. This can be used both in a green growth approach to attract more private investors as well as a degrowth approach reducing the payback time for the government. There is still a significant risk of this innovation not being there in time however, leading to potential delays in the energy transition. Compared to nuclear fusion however, SMR's are more likely to take a role in the energy transition before 2050.

5.1.3 Efficient batteries

A major roadblock in the energy transition is storage of electricity, through efficient batteries. One type of more efficient battery which is currently being designed is the Solid-State Battery (SSB) which is a lithium-ion battery which does not experience gas generation, leakage as well as the thermal energy loss regular lithium-ion batteries have (Liu et al, 2021). Some disadvantages compared to lithium-ion are a potential shorter lifetime of the battery and the more complex manufacturing process which could make them more expensive than lithium-ion batteries, even when they are mass produced (Alkhalidi, Khawaja, & Ismail, 2024).

The first (semi) Solid-State batteries are expected to be used in electric car production starting in 2026 (Juu, 2024). It will still take some time before their mass adoption however, as such an innovative technology will likely be first implemented in expensive cars before slowly becoming more affordable. (Alkhalidi, Khawaja, & Ismail, 2024) expects the batteries to be mass produced in 2028 in the best-case scenario for the price of 140 dollars per kWh and in 2032-2033 for the price of 185 dollars per kWh in the worst-case scenario. Comparatively, lithium-ion batteries cost 115 dollars per kWh (Murray, 2024). As the development of solid-state batteries is already quite far and their price is soon comparable with lithium-ion batteries, they can be expected to offer a considerable contribution to the energy transition. Similar to lithium-ion, these batteries can then be used for electricity storage in either homes or neighbourhoods as well, which would help combat net congestion.

Other types of batteries which can be influential in the energy transition are redox-flow batteries and metal-air batteries. Redox-flow batteries are batteries in which charge is dissolved in liquid electrolytes which is then oxidised resulting in the battery alternatively charging and discharging (Armstrong et al, 2022). Metal-air batteries are batteries that discharge electricity through the spontaneous oxidation of metal, using the both the metal and the air. Redox-flow batteries have the advantage of the energy and power components of the battery being separated, meaning they can more easily be tailor-made for specific purposes and their size can more easily vary (Armstrong et al, 2022). Downsides to this type of battery include a lower energy density than lithium-ion batteries as well as a lower lifetime (Armstrong et al, 2022). To overcome the energy density problem of redox-flow batteries, (Flox, Zhang, & Li, 2022) proposes using non-aqueous redox-flow batteries which would offer better energy densities through a wider window of operating voltage.

Metal-air batteries, on the other hand, are good for storage which takes longer than 12 hours and they are made of relatively common materials including zinc, iron and aluminium (Armstrong et al, 2022). Other advantages include higher power output and high safety due to the lack of flammable electrolytes (Liu et al., 2020). The downside to this technology is it still being in the early stages of development, so the costs are still high and the efficiency still relatively low (Armstrong et al, 2022). Innovative technologies such as redox-flow batteries and metal-air batteries, as well as improvements of the already often used lithium-ion batteries are important for the energy transition because of a variety of reasons. New batteries could make electric vehicles more efficient and make them be able to drive longer distances, increasing their consumer potential as well as lowering their price. Another way is through offering more grid stability by saving excess energy from solar panels and wind turbines, which can then be subsequently used for the peak hours. (Armstrong et al, 2022) compares the costs for lithium-ion, reflux-flow and metal-air batteries using three different scenarios, having a base scenario for 2050 with the expected, a low or optimistic scenario and a high or pessimistic scenario.

Type	Year scenario	Discharge cost ($/kW)	Storage cost ($/kWh)	Operating & maintenance cost ($/kWyear)	Operating & maintenance cost ($/kWhyear)	Charge efficiency (%)	Discharge efficiency (%)	Self-discharge rate (%/month)
Lithium-ion	2020	257	277	1.4	6.8	92%	92%	1.5%
	2050 low	32	70.9	0.3	1.4	92%	92%	1.5%
	2050 mid	110	125.8	0.8	2.2	92%	92%	1.5%
	2050 high	154	177	1.4	3.2	92%	92%	1.5%
Redox-flow	2020	583-650	171	4.1	0	92%	88%	0%
	2050 low	297	15.5	4.1	0	92%	88%	0%
	2050 mid	396	48	4.1	0	92%	88%	0%
	2050 high	530	102.2	4.1	0	92%	88%	0%
Metal-air	2020	1068-1135	3.7	26.7-28.4	0.1	72%	60%	7.3%

	2050 low	595	0.1	14.9	0	70%	59%	1.5%
	2050 mid	643	2.4	16.1	0.1	73%	63%	1.5%
	2050 high	950	3.6	23.7	0.1	72%	60%	1.5%

Table 3: Estimated and projected costs and efficiencies of different types of batteries (Armstrong et al, 2022)

5.1.4 Thermal storage

A way of storage of renewable energy which could be used on a larger scale is the development of thermal storage. This works through storing energy in a material which is then insulated so the least amount of energy possible escapes, which currently has a roundtrip efficiency of about 47% (Armstrong et al, 2022). There are several strategies to use thermal energy storage more efficiently in the future, such as reusing old fossil fuel power plants such as coal power plants. Instead of generating heat through burning fossil fuels, these repurposed power plants can use their steam engines as a way of energy storage. The second strategy uses a more efficient power cycle, and the third strategy considers storing thermal energy under higher temperatures in order to increase efficiency with the caveat to these strategies being them requiring a lot of innovation to work (Armstrong et al, 2022). Another crucial factor to thermal storage is economy of scale, as small thermal storage is generally not economically viable (Armstrong et al, 2022). Other sources also talk about the high initial capital costs of thermal energy storage which is the main problem for widescale implementation and requires a lot of innovation to overcome (Alva, Lin, & Fang, 2018).

5.1.5 Solar and wind energy

Innovation can also refer to the improvement of already existing technologies, such as solar panels which are gaining increasing levels of efficiency over the years. One of these examples is a new type of solar cell developed in 2023 which has an efficiency of 26.81% while being made from the same materials as regular solar panels (TU Delft, 2023). Oxford University scientists however were already able to create higher than 27% efficiency solar panels in 2024 using an ultra-thin perovskite material which can be applied to most surfaces, expecting these solar panels to eventually be able to reach 45% efficiency (Oxford University, 2024). Both innovations are impressive considering the average efficiency of solar panels of 22%, and innovations such as these help reduce the price of solar panels per kWh as well, which has already been reduced with 90% compared to 2010 (Oxford University, 2024).

Similar innovations can be seen in wind energy, which has seen improvements in efficiency in the range of 3.6% to 10.2% but unlike solar, wind energy slowly starts to approach its theoretical efficiency limit of 59.3% (The Betz law) (Maradin, Cerović, & Šegota, 2021). In the US, the capacity factor of wind energy (the energy produced compared to the theoretical limit) has increased from 0.25 in 2010 to 0.35 in 2020 for onshore wind energy (Xu, Zou, Ziegler, Wu, & Zeng, 2023). Offshore wind energy can reach much higher efficiencies with a maximum technical efficiency 83 to 98% of the Betz law (Benini & Cattani, 2022).

5.1.6 Sustainable aviation

As mentioned in the introduction paragraph, sustainable aviation is one of the sectors which still require a lot of innovation to come to fruition. About 2.5% of global CO2 emissions come from aviation, with the number of passengers flying expected to more than double between 2025 and

2050 (Battersby, 2025). Sustainable Aviation Fuels (SAFs) are often made of biomass which can come from a plethora of environmentally damaging places such as agricultural land created through deforestation. Although the EU already requires planes to use 2% SAFs this means that an increase in the usage, which several reports expect to be 70-90% in 2050, would lead to a large increase in agricultural land, which is paired with a lot of deforestation or potential food losses (Battersby, 2025).

Other potential solutions such as hydrogen flying, would require airplanes to have much larger fuel tanks. These fuel tanks need to keep the hydrogen at high pressure and low temperature due to the lower energy density of hydrogen (Battersby, 2025). Then there is the issue of lifetime of planes, as commercial planes, such as those of Airbus, tend to have a lifetime of over 30 years (Airbus, sd) meaning airplane operators would likely not want to replace their entire fleet immediately. If sustainable planes were available in 2030, it would take until 2060 or later for them all to be replaced. As it is unlikely sustainable aviation options outside of biomass will be available soon, the aviation sector will likely have to use carbon capture storage to compensate their emissions.

5.1.7 Hydrogen

Hydrogen is often seen as the path forward in the energy transition due to being able to replace current gas and oil infrastructure. A major problem is the current worldwide reliance on grey hydrogen (hydrogen produced through fossil fuels) while the transition to green hydrogen (hydrogen produced through renewables) is hindered due to the high costs and low efficiency of electrolysis (Boretti & Pollet, 2024). Green hydrogen therefore requires major investments into renewable energy infrastructure and electrolysers. Transport of hydrogen also faces large roadblocks as hydrogen either needs to be compressed to 700 bar or more or alternatively cooled to -253 degrees Celsius so it can be stored in liquid form. Both methods are energy-intensive and require special equipment to be stored, meaning a lot of innovation is still needed for these processes and therefore hydrogen more efficient (Boretti & Pollet, 2024).

5.1.8 Carbon capture storage

Carbon capture storage is another aspect of the energy transition which will likely experience a lot of innovation in the coming years, although the extent of that innovation is still relatively uncertain. Currently alkanolamine solutions in water are crucial for the capture of CO2 due to forming carbon nitrogen bonds when reacting with the CO2, however alkanolamine faces challenges such as corrosion and instability caused by heating (Bose et al, 2024). Other potential materials then include amine-modified materials which can capture CO2 at lower temperatures in the range of 35 degrees Celsius, as well as carbon-based absorbents which are relatively cheap (Bose et al, 2024). These however both face the problem of only being able to capture a limited amount of CO2 with amine-modified materials also lacking stability when used in multiple cycles (Bose et al, 2024).

Then there are the different subprocesses of CO2 capture such as the compression of CO2 which would result in about 12% efficiency loss of a power plant with carbon capture storage (Saxena et al., 2024). Higher concentration streams with over 95% CO2 are also found to be much more energy efficient than lower purity streams which could cause an additional 13% conditioning loss per ton of CO2 (Saxena et al., 2024). Out of the pre-combustion and post-combustion carbon capture processes, the post-combustion process is currently furthest developed and therefore the cheapest option, although the pre-combustion process has a higher efficiency (Osman et al., 2022).

There is also the oxyfuel process in which the CO_2 is split into a separate flue gas and a pure oxygen stream. While this is more energy efficient than the earlier mentioned methods, it will likely be difficult to make this option cheaper even with innovation due to the difficulty and therefore high costs of pure oxygen separation (Osman et al., 2022). CO_2 could also be used in fire extinguishers and carbonated beverages, but these options are unlikely to result in any real reductions in emissions. More realistically, more CO_2 can be used in industrial processes, increasing their performance and limiting emissions (Osman et al., 2022). Overall, there are many areas in which carbon capture storage could potentially improve in the future, through materials, specific subprocesses such as compression as well as at which stage the CO_2 is captured. It remains uncertain how efficiency of CO_2 capture will improve in the future.

5.1.9 Conclusion

In conclusion, there are many aspects of the energy transition which can be improved upon. These include the development of small modular reactors or the development of relatively new types of batteries such as solid-state, reflux-flow and metal-air batteries. Innovations also include improvements of current lithium-ion batteries, efficiency increases of solar panels and wind turbines as well as the improvement of the different forms of carbon capture storage. There are however also innovations which are unlikely to have a large influence the energy transition up to 2050. These innovations include the development of nuclear fusion which has already been theorised for almost 100 years as well as the development of sustainable aviation fuels outside of biomass. These still need a lot of development and when they have finally been developed, will take a lot of time to be put in place. Decision makers therefore should consider mainly upcoming technological innovations but keep an eye open for technological innovations which will help improve the energy sector after 2050. After all, there is no guarantee the Netherlands, EU and especially the world is going to be climate neutral in 2050. Especially with the changing geopolitical landscape, as will be discussed in the next chapter.

5.2 Geopolitics

Geopolitics is another external factor within the green growth and degrowth discussion. This chapter will look at how geopolitics effect energy transition policy and vice versa.

5.2.1 General overview

The influence of geopolitics on the energy transition has been widely discussed, as the energy transition requires massive supply chains going through many different countries, as well as worldwide collaboration. If only one country would commit to climate neutrality, climate change would continue as usual. Therefore, this is an issue all the countries in the world will have to collaborate on, even though geopolitical conflicts such as trade wars or even actual wars continue to happen. The International Energy Agency (IEA) considers the role of China to be of the utmost important due to its population size and therefore its large energy consumption, as well as its massive investments into solar and other green energy (IEA, 2024). The IEA also considers investments to be very unequal, stating they are often not done in the places where they are needed the most due to high financing costs and project risks, limiting the spread of cost-competitive green energy developments (IEA, 2024). Other organisations such as the World Economic Forum (WEF) consider global competitiveness in green energy to be a major driver for the energy transition but see a major risk in the scarcity of critical materials (WEF, 2024). On the other hand, the cost of wind and solar energy could decrease with geopolitical cooperation, furthering the energy transition (WEF, 2024).

5.2.2 Russo-Ukrainian war and gas

A major impact of geopolitics on the European energy transition can already be seen in the Russo-Ukrainian and its influence on gas supply. This also had a major influence on Dutch gas and energy prices, due to the earlier closing of the natural gas field of Groningen, which resulted in the Netherlands consuming a lot more Russian gas with about 35% of the Dutch gas consumption being Russian gas in 2021 (CBS, 2022b), the year before the Russo-Ukrainian started. The resulting energy crisis and the inflation which got paired with it, diminished many European citizens' trust in the EU and the energy transition, which was already damaged because of the Covid crisis (Gatto, Mattera, & Panarello, 2024).

The Russo-Ukrainian war also had an impact on CO2 emissions in the EU which is expected to have increased with an average of 0.092 Mton showcasing dependence of industry on geopolitical circumstances (Han, Zhou, Shi, & Wang, 2024). On the other hand, Russia's CO2 emissions declined due to a major decrease in exports because of the boycotts, causing industrial downturn (Han, Zhou, Shi, & Wang, 2024). Russian gas delivery to Ukraine and the EU already has a long history of being intertwined with geopolitical circumstances between Ukraine, Russia and the EU, which could also be seen in the Ukrainian Orange revolution of 2006 when Russia stopped gas delivery temporarily as well as in 2009 when there was a political conflict between the president and prime minister of Ukraine (Universiteit Leiden, 2024). It is then important to realise the energy transition and therefore a green growth or degrowth policy will have a large impact on the energy security of the Netherlands and the EU. Thus, geopolitics influence the energy transition, and the energy transition influences geopolitics.

5.2.3 China and geopolitical leverage

A similar situation can be seen with China, which is currently a main supplier of materials used in for example wind turbines as well as electrolysers, which are both crucial to the energy transition (TNO, 2024). While China has a geopolitical strategy to be as much energy independent as possible, it has also exported energy and materials for the energy transition to other countries, to grow the Chinese economy and try to get leverage over other countries (TNO, 2024). This could make a war between China and Taiwan more likely, as China could threaten to embargo western countries which would try to intervene in a potential conflict. This can already be seen with Lithuania, as China threatened to cut off trade with Lithuania due to them planning to open a representative office for Taiwan in their capital (Andrijauskas, 2022). The economic coercion worked, as Lithuania's industry experienced a downturn, causing the inhabitants to be against the association with Taiwan, which in turn caused the government to call the earlier decision a mistake (Andrijauskas, 2022).

Geopolitical leverage can also be used for better purposes however, through for example persuading other countries to join in collaborative efforts to tackle the energy transition. One country which could pursue such a strategy is Australia, as it has a lot of potential for renewable energy which it could then export in the form of hydrogen (Downie, 2022). The Netherlands could implement a similar strategy, focusing on the expansion of wind energy and then turn it into electricity or hydrogen to export to other European countries, persuading them to work faster on their own energy transition. This would require enough investments and infrastructure, however. However, there is a risk of countries using their leverage for nationalistic purposes which could disrupt global supply chains and damage international cooperation (Downie, 2022). In such cases other countries could start using protectionist measures as well, potentially switching back to fossil fuels and damaging international relations even more.

5.2.4 USA and tariffs

Protectionist measures such as tariffs can also be seen in 2025 US politics. These measures are paired with the US starting the procedure again to leave the UN climate accords, including the Paris agreement. The White House states the US has worked on economic growth while reducing greenhouse gas emissions in the last decade and wishes to continue with sensible climate politics, instead of spending their tax money to help other countries (The White House, 2025). Such a strategy could be seen as a protectionist green growth strategy, if the goal would still be to reach net zero emissions in 2050. The US however also started a trade war with tariffs against Canada, Mexico, China as well as the EU, which decreases the leverage they have in international politics. The White House thinks otherwise however, stating they can use tariffs to attain leverage to reach deals with countries such as Canada, Mexico and China on fentanyl as well as immigrants (The White House, 2025b).

The effects of US tariffs could already be seen immediately after with Canada, Mexico and China opting for retaliatory measures roughly equalling the US set tariffs (Lawder, Ljunggren, & Madry, 2025). These tariffs, in addition to the uncertainty created by the US administration in 2025, resulted in an expected decrease in US GDP in the first quarter of 2025 compared to the earlier prediction of an increase in GDP (McGeever, 2025) (Federal reserve bank of Atlanta, 2025). The EU however is currently dependent on the US in its energy policy, as it moved away from Russian natural gas and started consuming more LNG, with the US now providing 45% of the EU liquified natural gas (LNG) demand (Gurzu, 2025). In case the EU were to become more dependent on US, the US could impose less tariffs, but this strategy would contain the risk of the US gaining increasing leverage over the EU due to overreliance on US LNG (Gurzu, 2025). This could introduce a similar risk of the US pacifying European action against potential aggressive manoeuvres, such as the takeover of Greenland by the US.

5.2.5 European energy independence

To protect itself against international conflicts, the EU and the Netherlands could become more energy independent in a sustainable manner, through increasing the number of solar panels, wind turbines and other forms of renewable energy, as these require no fuel sources to sustain. Alternatively, green sources such as nuclear power could also be used when there is sufficient uranium storage, because of the energy density of uranium. The Netherlands and the EU could then use a strategy of producing more energy than they consume to use as leverage for more equal trade relations with countries with scarce materials. This could also be done to try to convince other countries to take serious climate action as well. Offering cheaper energy to developing countries could also help convince them not to grow their economy through fossil fuels but instead work together on more green growth, as these countries often still have not fully industrialised.

The Netherlands and EU would have to look out for being too protectionist, as this would have an adverse effect, causing other countries to be more protectionist as well. The risk is these policies leading to tariffs with potential trade wars as a result, causing supply chains to be disrupted and energy prices to rise, negatively affecting the energy transition. This would also decrease the leverage on other countries. Instead, a strategy should be to be relatively energy independent but still collaborate much on an international scale, so supply chains of energy and critical materials are secured for all countries, making worldwide climate action much easier.

5.2.6 Conclusion

There are many geopolitical factors which could influence the energy transition such as a prolonged Russo-Ukrainian war, a Chinese invasion of Taiwan, a US invasion of Greenland or a heavy trade war with the US. Aside from these there are many other conflicts which could happen but despite these, the Netherlands and EU will have to find ways to geopolitically cooperate with other countries and use leverage to influence other countries to take stronger climate action as well. A balance will have to be found between energy independence but also trading with countries for this geopolitical cooperation to have a strong foundation. Depending on whether a green growth or degrowth strategy is chosen, this can be more difficult to achieve. This is further explained in the scenarios in the next section.

5.3 Scenarios

With the influence of innovation and geopolitics on the energy transition, green growth and degrowth strategies being discussed, scenarios can be made based on these external factors. Scenarios are important to determine how effective green growth and degrowth policies will be and what the Netherlands can realistically expect in the coming years to 2050. These scenarios are based on the two factors innovation and geopolitics. There are five scenarios in total, four to describe the combination of high/low innovation with high/low geopolitical cooperation and one fifth scenario to describe a more extreme scenario, extended war on the European continent.

5.3.1 Scenario 1: Long-lasting trade war (low geopolitical cooperation, high innovation)

In the first scenario, the trade war between the US and the rest of the world including the European Union, which really started on the 2nd of April 2025 (Shalal, Cash, & Blenkinsop, 2025) (Rankin, 2025) will have a long-lasting effect on the European economy and therefore the Dutch economy. The initial shock of these tariffs is already expected to result in a 750 billion euros decrease in European GDP with risks of a long-lasting US recession which could come over to the EU as well (Shalal, Cash, & Blenkinsop, 2025). In this scenario, the EU will set up more industry and boost innovation and sustainable development. The development of the hydrogen economy will help the EU move away from reliance on American LNG and Russian gas. The hydrogen economy, combined with large increases in the efficiency of batteries and renewable energy will result in a more energy independent Europe. China will in turn also increase its funding in innovation and sustainable development to bridge the gap caused by the lack of trade with the US. Despite the lack of geopolitical cooperation, innovation will still be relatively high in this scenario due to the extra research and development caused by protectionist policies.

5.3.2 Scenario 2: Chinese invasion of Taiwan (low geopolitical cooperation, very low innovation)

In this scenario the increased isolationist policy of the US and therefore lack of protection of Taiwan will lead China to invade Taiwan in 2025 or 2026, disrupting the global economy as most (advanced) semiconductors are produced in Taiwan (Hou, 2025). Aside from a disruption in the global economy as direct consequence of the lack of semiconductors available, this will also result in more sanctions and decreased cooperation with China. As it will take a long time to build the industries required to produce enough semiconductors and microchips, the world will have to deal with a deficit in available electrical devices for several years, leading to much lower levels of innovation as otherwise would be the case. The conflict in Taiwan could even lead in a cascading effect of more wars happening in the world, such as a US invasion of Greenland, increasing investment into defence and decreasing investment in the energy transition.

5.3.3 Scenario 3: Business as usual (high geopolitical cooperation, low innovation)

In the third scenario, the trade war between the US and the rest of the world quickly fades away with geopolitical cooperation returning to a relatively high amount. Major breakthroughs in technology do not happen, however. Investment in technologies such as Small Modular Reactors and nuclear fusion do still not result in any commercially available nuclear power plants and Carbon Capture Storage remains very costly. The only real innovation which does happen are slight increases in the efficiencies of solar panels and batteries. Development in new industries such as Artificial Intelligence also does not result in higher levels of productivity. Unlike innovation, business investments do go up due to the easing of international tensions and higher trust in the economy.

5.3.4 Scenario 4: Fourth industrial revolution (very high geopolitical cooperation, very high innovation)

This scenario, the fourth industrial revolution, refers to a term coined by the founder of the World Economic Forum Klaus Schwab, used to refer to an era with a lot of technological progress in the domains of artificial intelligence, augmented reality and the Internet of Things (Ross & Maynard, 2020). While effects of the fourth industrial revolution can already be seen through AI software such as ChatGPT and GPT-4 (Mao et al., 2024), the effects of these upcoming technologies on productivity are yet to be seen. In this scenario, global cooperation and steady supply chains lead to massive increases in AI development. AI will help solve complex problems, leading to much more investments and many productivity and innovation gains. Using the combination of AI and humans helps create breakthroughs in Small Modular Reactors, the hydrogen economy, much more efficient forms of batteries as well as much more efficient carbon capture storage. Paired with a stable geopolitical climate, this will increase confidence in the economy and boost investments even further.

5.3.5 Scenario 5: Extended war in Europe (very low geopolitical cooperation, mixed innovation)

With the Russo-Ukrainian war already ongoing since February 2022 with no signs of stopping and American support for Ukraine wavering, Russia could decide to attack other European countries such as Moldova as well or even countries in the European Union such as Estonia, Latvia or Lithuania (Clarke, 2025). This would have a major impact on the European economy, which would likely switch to a war economy. The consequences of such an attack would be drastic and could be the trigger of a full-scale World War 3, although it does not necessarily have to come to that. In this scenario economic growth will be a lot lower and sustainability would be much lower on the priority list of the Dutch government, meaning the energy transition would likely be delayed by at least a few years. While innovation in military technology will be high, it would remain to be seen how innovation in the energy transition will develop in this scenario. On one hand, energy independence could be seen as important in a large war, while on the other hand the EU might opt to turn back to fossil fuels in case of an extended war.

5.3.6 Scenario summary

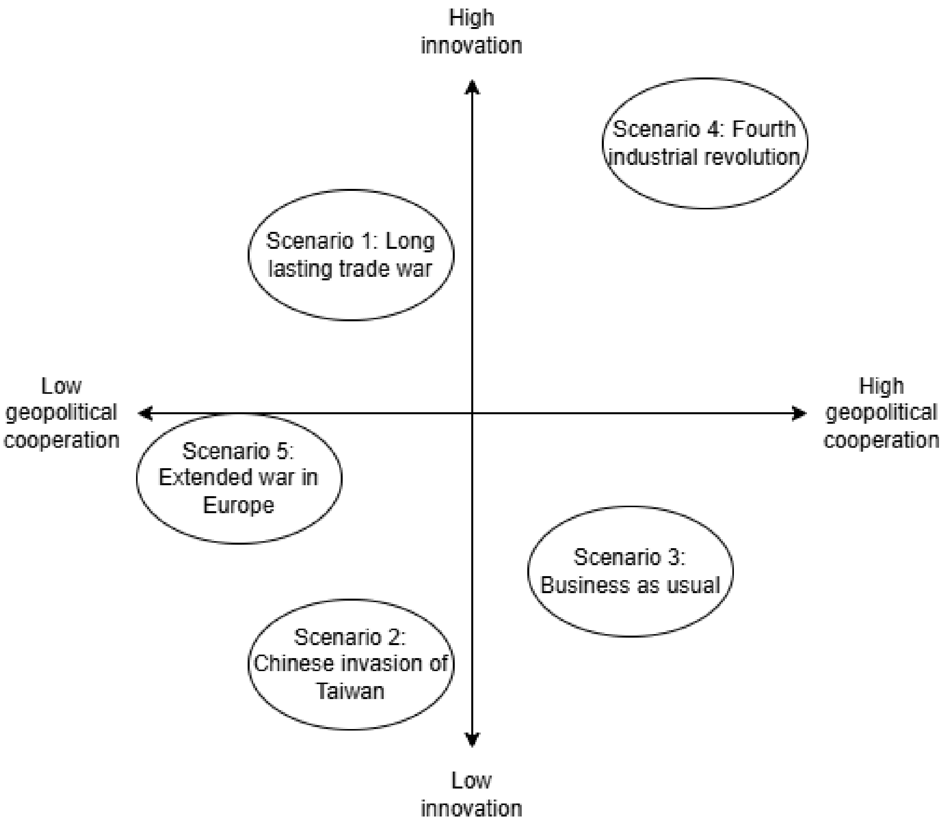

Figure 7: The five Scenarios in four quadrants

Impact → Likelihood ↓	Low	High
Low		Scenario 4: Fourth industrial revolution Scenario 5: Extended war in Europe
High		Scenario 1: Long lasting trade war Scenario 2: Chinese invasion of Taiwan Scenario 3: Business as usual

Table 4: Impact-likelihood table

The estimated impact and likelihood of the scenarios has been summarised in table 10. All the scenarios are in the high impact category, as they would else not be important enough to be taken into consideration. The likelihood does differentiate however, showcasing that even if certain scenarios are unlikely to happen, their high impact could make them worth considering for the future of the energy transition and whether a green growth or degrowth strategy is better.

5.4 Conclusion

In this chapter, several potentially crucial innovations and geopolitical developments have been considered. Some of these innovations include the development of nuclear fusion which is unlikely to have an impact on the energy transition before 2050. Small Modular Reactors, which could also have a considerable influence, are more likely to make an impact before 2050. Other innovative batteries such as the Solid-State, Redox-Flow and Metal-Air batteries could make energy storage much more efficient and therefore cheaper, increasing the reliability of electricity with an increasing number of renewables in the system. On the other hand, the aviation sector seems to have a difficult time to become sustainable before 2050 and will likely have to rely on carbon capture storage which could become much more efficient due to innovation.

As for other external factors, geopolitics is a factor which could have a major impact on the course of the energy transition. War is back on the European continent with the Russo-Ukrainian war, which has a chance of extending beyond just Russia and Ukraine into Europe, having a potentially drastic influence on the economy and energy transition. Former allies such as the United States are now engaging with the European Union in a trade war and coveting countries such as Greenland. Meanwhile global supply chains are disrupted, increasing prices and leading to potential delays in the energy transition. While getting closer to China could help the European Union and the Netherlands get the crucial materials they need, over relying on China could lead to them subjugating Taiwan having another major impact on the world economy due to most of the microchips and semiconductors being produced there. The European Union and Netherlands will have to find the delicate balance between being self-sufficient and trading enough with other countries to decrease costs, gain leverage and get them to take the energy transition serious as well.

Taking all these external factors and their accompanying scenarios into account is important to successfully plan and see whether green growth or degrowth is more effective to manage the economy, quality of life of Dutch citizens and the energy transition. The next chapter will use the external factors and their accompanying scenarios to measure the impact they have on the Dutch economy using both green growth and degrowth policy.

6 Impact of green growth and degrowth on the economy

In this chapter, the impact of green growth and degrowth will be measured through macroeconomic modelling. This economic model is made in Excel and is based on the demand formula for GDP. The scenarios from chapter 5 are used, and their effects are tested in the model to see the impact they have on the feasibility and effects of green growth and degrowth.

6.1 Model setup

6.1.1 General overview

The starting year of the macroeconomic model is 2024 which is the last full year of data available. The ending year will be 2050, as this research only looks at the effects of green growth and degrowth policy on the economy and energy transition up to that point. The macroeconomic model of the Netherlands uses the demand formula for GDP:

Y (GDP) = C (consumption) + I (investments) + G (government expenditure) + X (exports) – M (imports) (CBS, sd)

These variables and most other variables are expressed in billions of euros. Other important variables in the model are inflation as well as the interest rate, both as percentage. Income is determined by gross income minus income tax as well as government transfers such as welfare. Savings can be both positive (savings increase) and negative (savings decrease) and are used in determining total investments, together with business investments. Businesses have material expenses and salary expenses which are subtracted from total corporate revenue to determine gross profits.

The taxes included in the model are the largest sources of tax income of the Dutch government, namely income taxes, consumption taxes (BTW), corporate taxes and healthcare taxes (Rijksoverheid, 2024e). Tariffs are also included to measure geopolitical impacts. Other taxes are for simplification put in consumption or corporate taxes. These taxes depend both on their percentage as well as the height of the respective income, consumption or profit. Government expenditures are slightly higher than government income, as historically government debt keeps on rising. The last factor imports and exports is mainly an external factor but can be influenced through tariffs.

Aside from these economic factors, the model also includes several variables related to the energy transition such as green investments which are determined by private green investments and public green investments. These investments are more effective with higher innovation, which is mainly externally determined as shown in chapter 5. Cumulative green investments compared to total required investments then determine the amount of green energy in the Netherlands and thus how far the country is in completing the energy transition.

6.1.2 Consumption variables

Most of the variables in the macroeconomic model are related to consumption, as consumption makes up a large part of GDP and is an important factor in determining the effectivity of both a green growth and degrowth scenario. These relations between the different consumption variables and their input variables (grey) as well as their influence on the output variables (blue) can be seen in figure 8. Accumulated inflation is an adjustment of the input variable inflation and therefore has a white colour. Green arrows mean positive relations indicating they increase the subsequent factor through addition or multiplication while red arrows indicate negative relations indicating the opposite. Innovation and total investments influence productivity, which together with inflation and negotiating power of unions and workers determines income per worker. Total income is then determined by that amount times the total people working. People can also get income through welfare and dividends, but they must pay several taxes such as income tax, consumption tax, healthcare tax and dividend tax. It is assumed consumption is mainly determined by size of the population, inflation as well as the consumption tax rate. Total household savings are a way to determine quality of life of households. When this is negative it indicates people cannot afford what they need or want to buy anymore, with households going into debt. This is both bad for people's mental health as well as the economy.

Figure 8: Causal-relation diagram consumption variables macroeconomic model

6.1.3 Investments

After consumption, investments also make up an important part of GDP. Private investments mainly come from corporations as consumers only invest a tiny part of their wealth, using it mainly for consumption. Companies also consume as they have material expenses which they use to create their products. Investments can be divided in active investments and passive investments, with active investments being those companies explicitly use to grow their company, for example building new factories. Passive investments are formed through the corporate surplus, money on the bank or lent to others. These investments together increase private savings, which in turn increase national savings and total investments. Investments and material expenses also influence corporate revenue, as the materials and investments are paid to other companies within the economy. For simplicity, it is assumed these are not foreign companies and foreign companies in turn do not increase corporate revenue through their expenses.

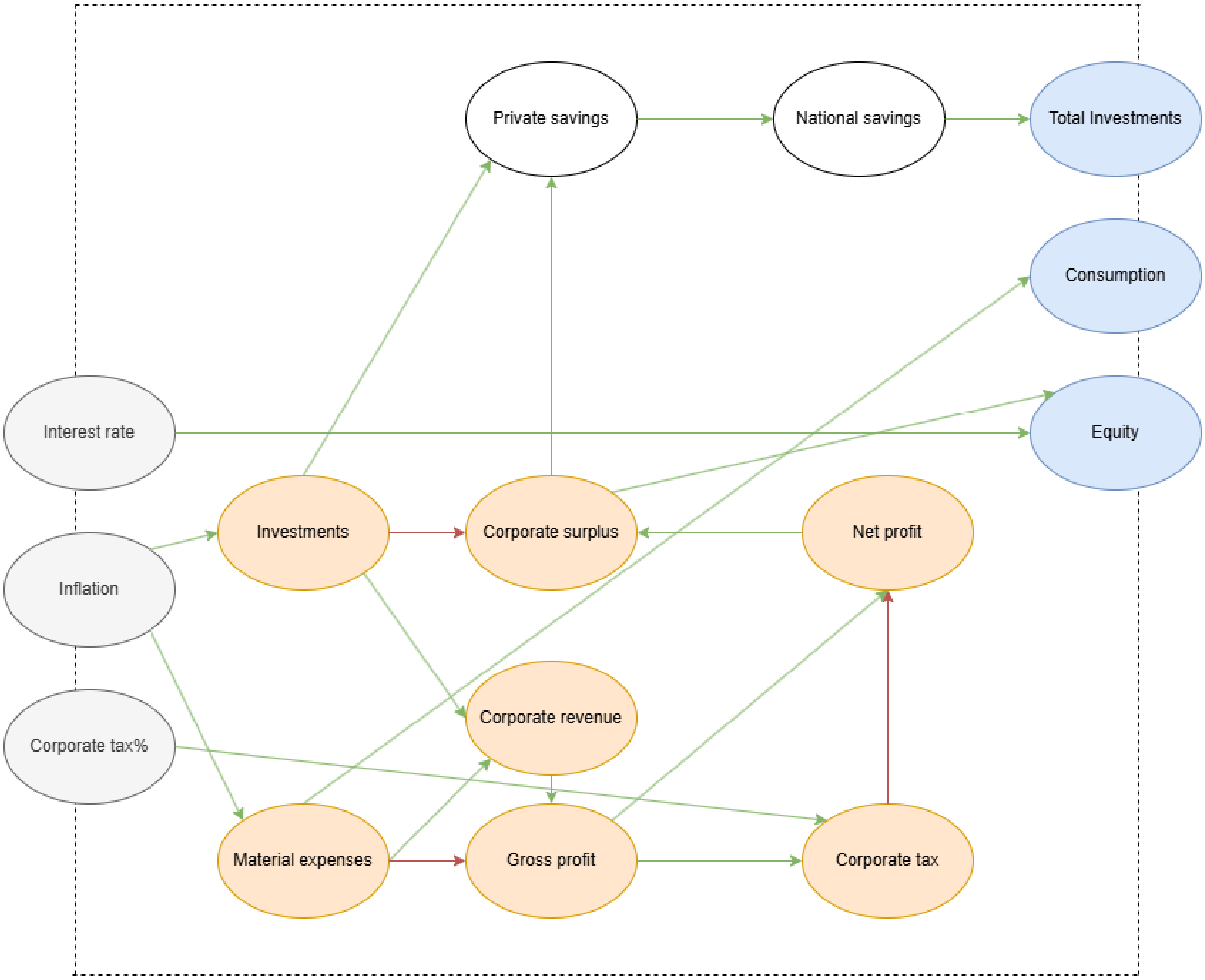

Figure 9: Causal-relation diagram investment variables macroeconomic model

6.1.4 Government

The government also makes up a large part of the economy, collecting income through several taxes such as income tax, consumption tax, corporate tax, dividend tax and tariffs and spending on healthcare, welfare, defence as well as green investments. Most of the government spending in this model is determined by the size of the population as well as the inflation rate. These external factors also influence total government income, balancing the equation. In the middle of the government variables, a potential debt spiral can be seen as higher government spending leads to a lower government surplus, resulting in higher government debt, higher interest payments and therefore higher government spending. This shows the government will have to keep its finances in check for a healthy economy. While government spendings increase total investments, government expenditures and therefore GDP, these extra spendings often lead debt to increase more, increasing the debt/GDP ratio. Government investments lead to higher government income, but this is only a portion of the spending, as this model assumes the fiscal multiplier is between 0 and 1 on average.

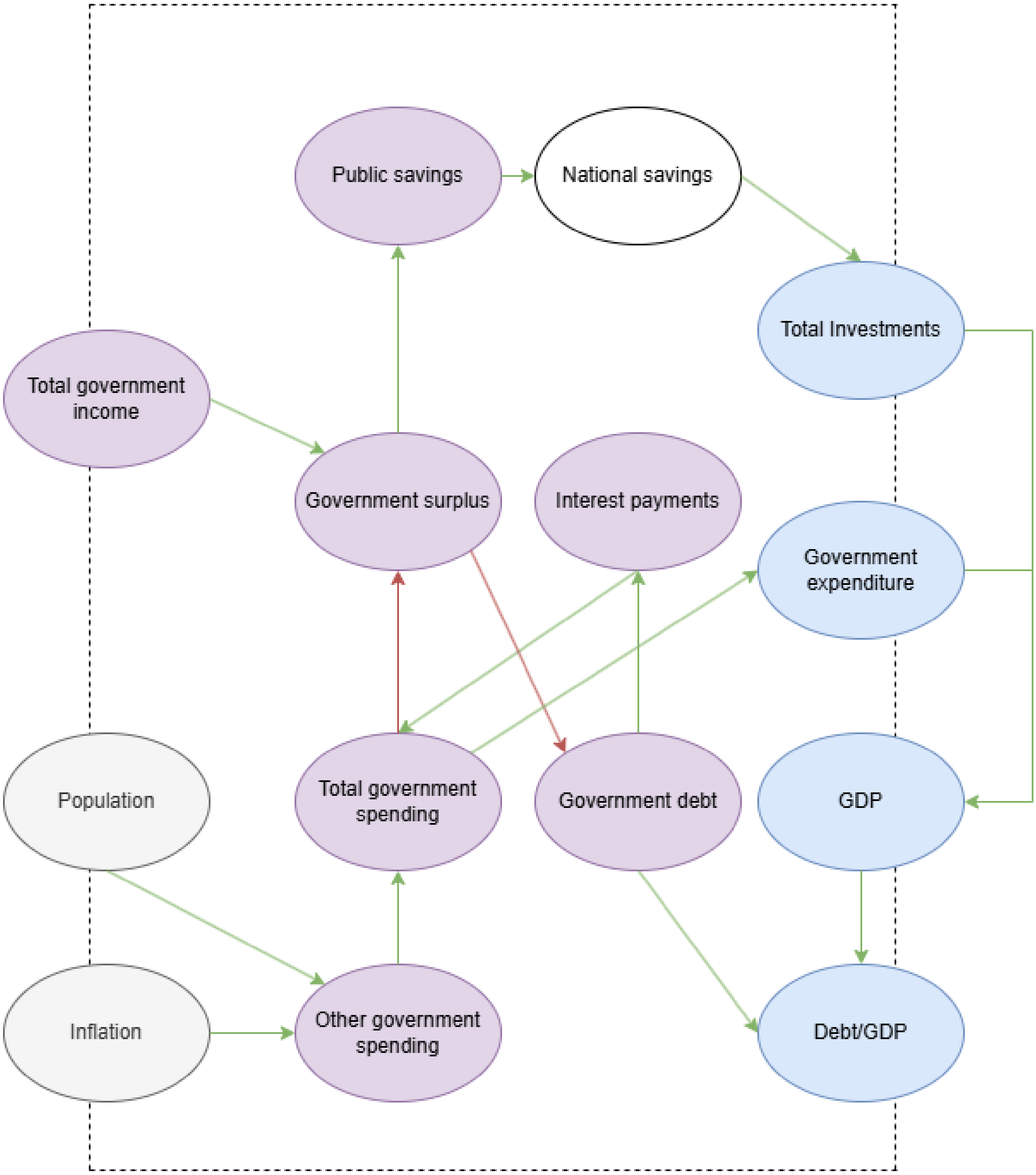

Figure 10: Causal-relation diagram government variables macroeconomic model

6.1.5 Imports and exports

Imports and exports have the least number of variables out of the subgroups. Imports and exports are influenced by inflation, as the nominal value of imports and exports goes up with inflation. Exports in turn are determined by the trade factor, which depends on geopolitical circumstances, while imports are determined by the tariff rate set by the Dutch government. While setting higher tariffs would earn the Dutch government higher profits, it would also decrease imports which is negative for the economy. The tariffs would also have to be paid by consumers and companies in the Netherlands, decreasing total consumption and investments.

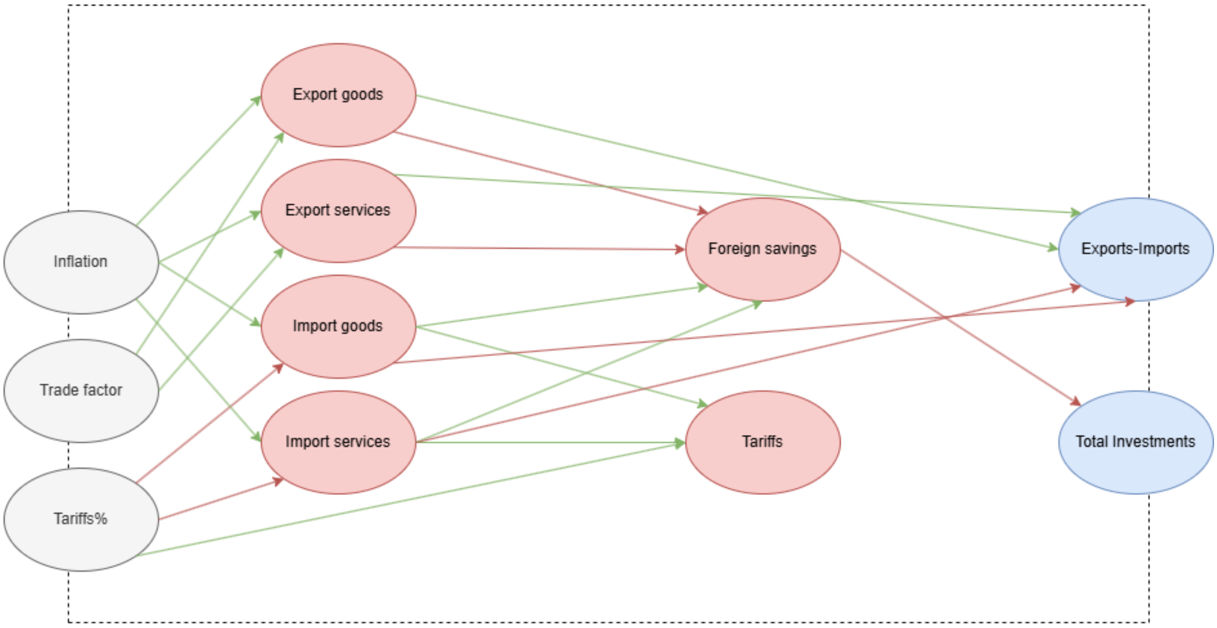

Figure 11: Causal-relation diagram import and export variables macroeconomic model

6.1.6 Green energy

The final subgroup of the model is green energy. This group is, similar to the other subgroups, dependent on the input variable inflation but also on innovation and the green investments factor of companies. The green investments factor indicates the proportion of private investments which is used for the energy transition. Government green investments are assumed to go up with inflation but can be changed depending on government policy. An increase in government green investments as well as an increase in private green investments would be needed with green growth policy while a decrease in consumption causing a decrease in energy consumption would be needed with degrowth policy. Energy consumption also depends on innovation, as higher levels of innovation generally result in lower energy consumption as discussed in chapter 5.

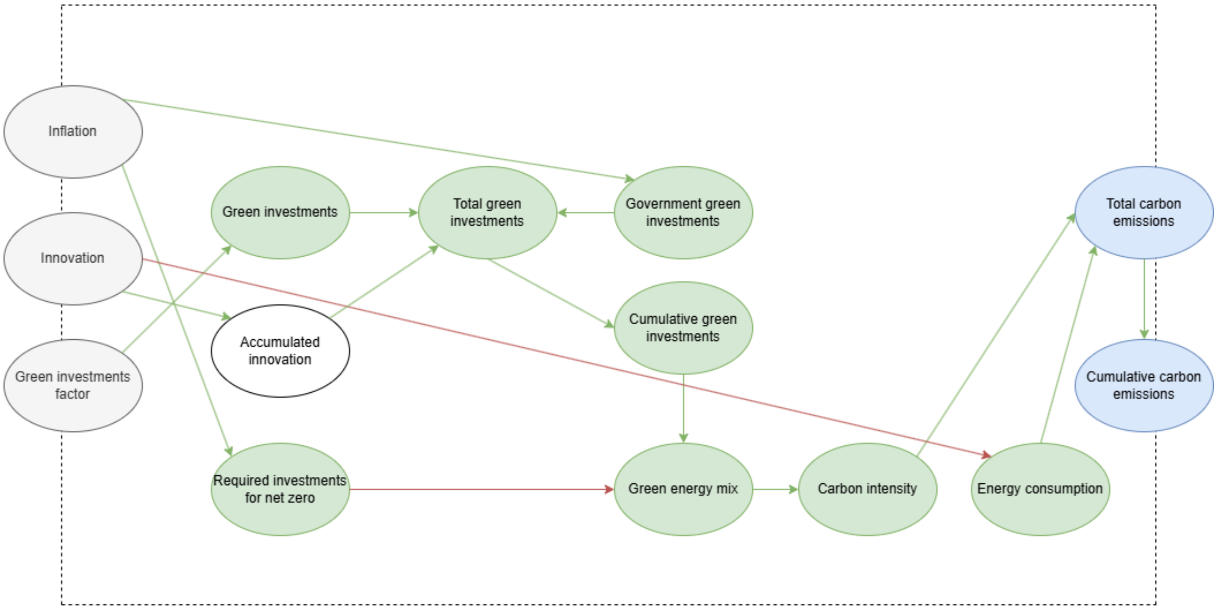

Figure 12: Causal-relation diagram green energy variables macroeconomic model

6.1.7 Overview of the model

To summarise the model, all model variables and their causal relations can be found in figure 13. This figure combines the different subgroups and shows many relations between the subgroups. For example, productivity impacts total green investments as their effectivity will go up with productivity which is in turn caused by higher levels of overall investment and innovation. Another relation is total energy consumption being influenced by real consumption increases.

For further information about the model, model values can be found in Appendix A, while model formulas can be found in Appendix B.

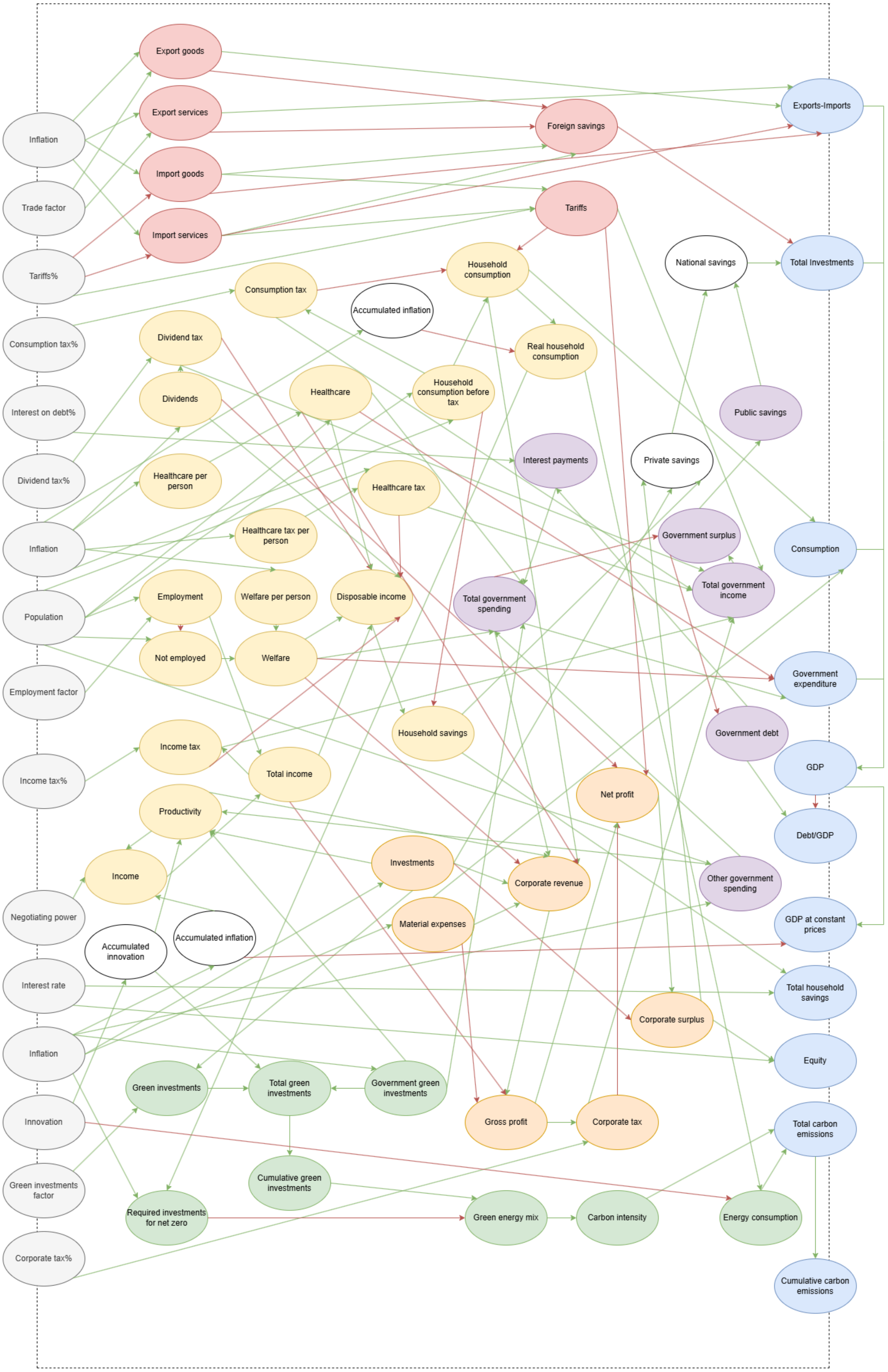

Figure 13: Causal-relation diagram macroeconomic model

6.2 Model validity

To test whether the model attains realistic results, the variables in the model for the years 2024, 2025 and 2026 can be compared to the estimated values by government organisations. The model output for GDP in 2024 is 1109.5 billion euros while the European Union using projected data of the CBS states Dutch GDP in 2024 was 1130.8 billion euros (European Commission, 2024a). This is still a projection as the GDP of 2024 has not been determined yet. GDP in 2025 should be 1182.8 billion euros according to the same projection (European Commission, 2024a) which is still relatively similar to the 1140.7 billion in the model. The estimate of 1228 billion euros (European Commission, 2024a) is a bit further away from the model with a value of 1172.6 billion euros but still close. Debt/GDP is 45.9% in the model in 2024 which is close to the 44% estimated by the International Monetary Fund (IMF) (World Economics, 2025) and the 44.2% estimated by the government (Ministerie van Financiën, 2025). The model therefore predicts Debt/GDP slightly higher than official predictions, but it is close. In the end, it should be taken into consideration that model GDP is projected slightly lower which results in a slightly higher Debt/GDP.

Year	GDP	C	I	G	X-M	Debt/GDP	Real GDP
	bln €	bln €	bln €	bln €	bln €	%	bln € 2024
2024	1109.5	672.5	135.0	211.1	90.9	45.9%	1109.5
2025	1140.7	688.3	157.9	216.9	77.5	47.8%	1118.3
2026	1172.6	704.4	181.6	222.8	63.8	49.6%	1127.1

Table 5: Model values

Year	GDP	C + G	National savings	Private savings	Public savings
	bln €	bln €	bln €	bln €	bln €
2024	1130.8	772.4	345.0	312.3	32.7
2025	1182.8	808.6	359.9	342.1	17.8
2026	1228.0	842.0	371.5	357.3	14.2

Table 6: Estimated values by the European Commission (European Commission, 2024a)

6.3 Model results

With the model validity checked, the next step is to look at the model results and what these projections means for the future of the Dutch economy given the status quo.

6.3.1 Base scenario

Both GDP and GDP at constant prices are expected to rise in the base scenario, with GDP more than doubling in size from 1109.5 billion euros in 2024 to 2363.1 billion euros in 2050. Real GDP will increase from 1109.5 billion euros in 2024 to 1412.2 billion euros in 2050, which is roughly 1.27 times larger than real GDP. Productivity makes up a large part of the real GDP growth, being about 1.2 times higher in 2050 compared to 2024. In the base scenario, the Dutch economy would continue its usual pattern of growth. Real consumption grows by 10%, determined by population growth. The assumption is real per capita consumption stays the same, as can be seen by looking at data from the past 10 years (European Commission, 2024c).

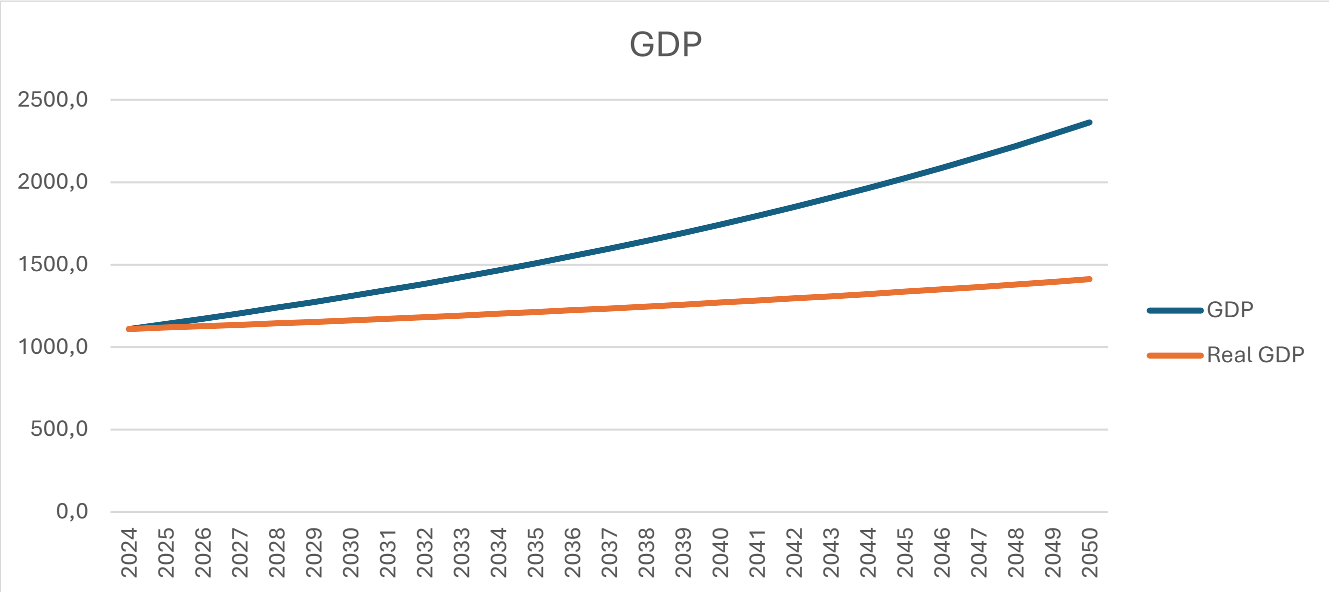

Figure 14: GDP and real GDP in the base scenario

Green energy will make up more than 50% of total energy consumption in this scenario, with 55.5% of the energy demand being met by green energy. This is still far away from 100% green energy in 2050, showing either green growth, degrowth or a mix of both policies are needed to reach the energy transition goals in time. The carbon intensity decreases from 0.391 Mton CO_2/TWh to 0.205 Mton CO_2/TWh due to investments and energy consumption decreases from 302.8 TWh to 198.9 TWh due to the yearly 2% innovation.

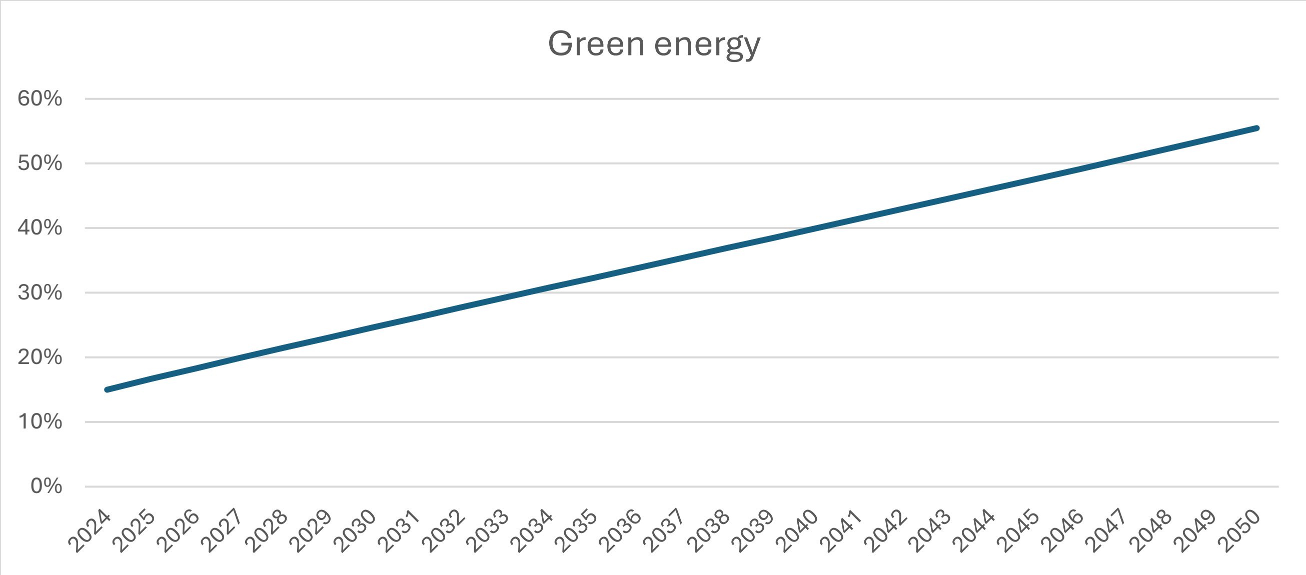

Figure 15: Green energy in the base scenario

Finally, an important factor is government debt/GDP. As the Dutch government ran a deficit in 2024 and will run a deficit in 2025 as well, debt continues to rise which can also be seen in an increase in debt compared to GDP. The model predicts government debt will pass the EU limit of 60% in 2032, meaning potential geopolitical consequences in case the government will not keep its budget in check more. It will decrease again after 2046 due to productivity increases catching up to government spending. Debt/GDP will be 69% in 2050, still above the 60% threshold.

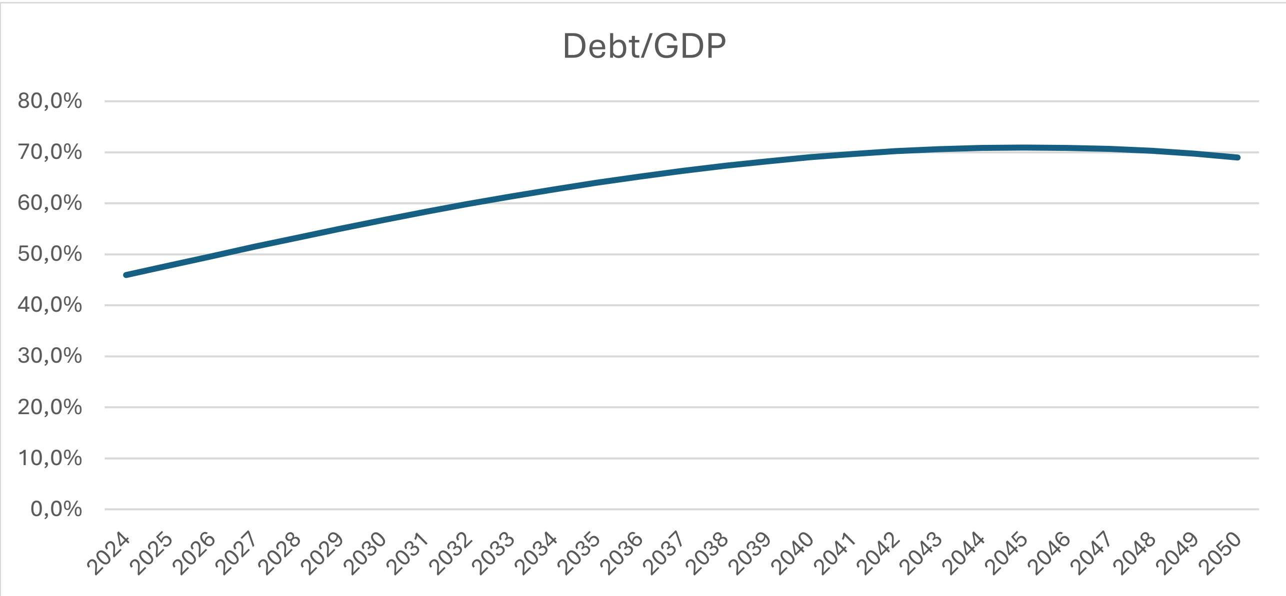

Figure 16: Government debt to GDP base scenario

6.3.2 Green growth policy

As the base scenario would not result in enough investments to have net zero emissions in 2050, green growth policy could be used with both the government and the private sector doing more green investments. To reach climate neutrality in 2050, the public and private sectors would have to do 2.2 times as many green investments starting in 2026. This means the green investments factor for companies increases from 2.4% to 5.4% of their total investments. This would be an increase of 7 billion euros. Government green investments would have to increase from 3.6 billion to 8 billion euros per year, then increased by inflation. This comes down to an increase of about 4.5 billion euros. In total, extra investments would come down to about 11 billion euros per year, then increased by inflation. As a consequence, real GDP rises to 1420.5 billion euros in 2050, slightly higher than the base scenario due to the increased government expenditure.

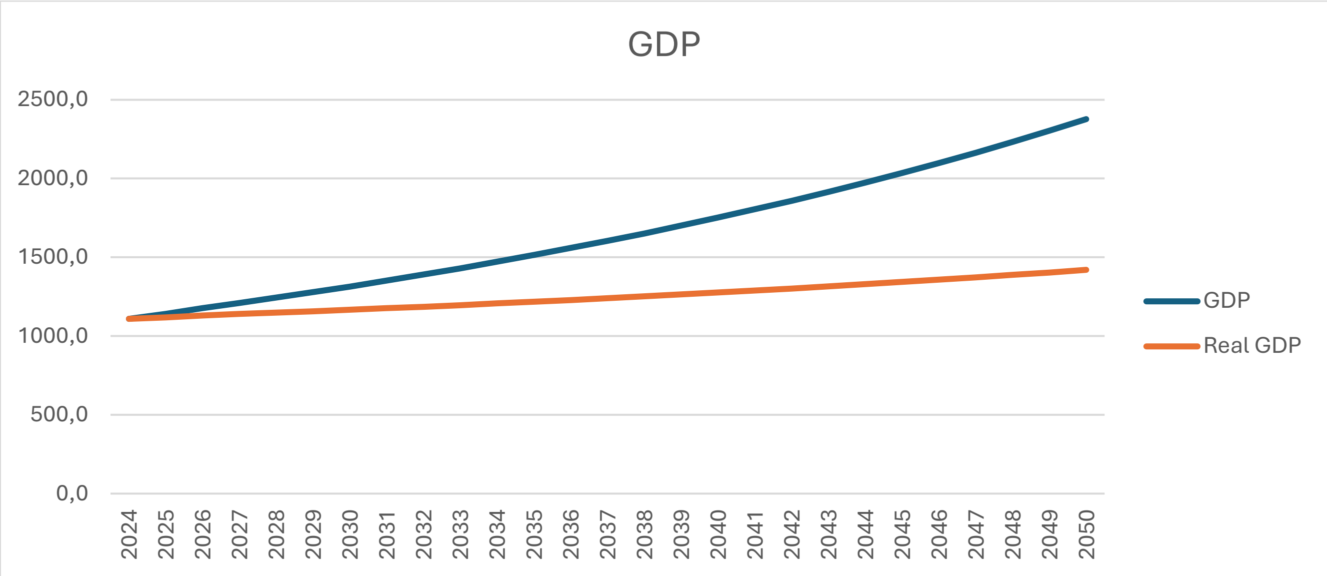

Figure 17: GDP and real GDP green growth policy

As can be seen in figure 18, green energy investments in 2026 have a delayed effect but then result in a relatively linear increase, due to investments going up with the linearly defined inflation. Green energy reaches 100.6% of total energy consumption, meaning the Netherlands could export more excess energy to surrounding countries. Green growth would likely decrease near the 100% point due to decreasing investments as the energy has been almost completed and it could be relatively difficult to change the last processes from grey to green. Nevertheless, carbon capture storage could also cause the relative amount of green energy to outgrow demand for energy and undo parts of the effects of industrialisation, helping to bring back carbon levels to before the industrial revolution.

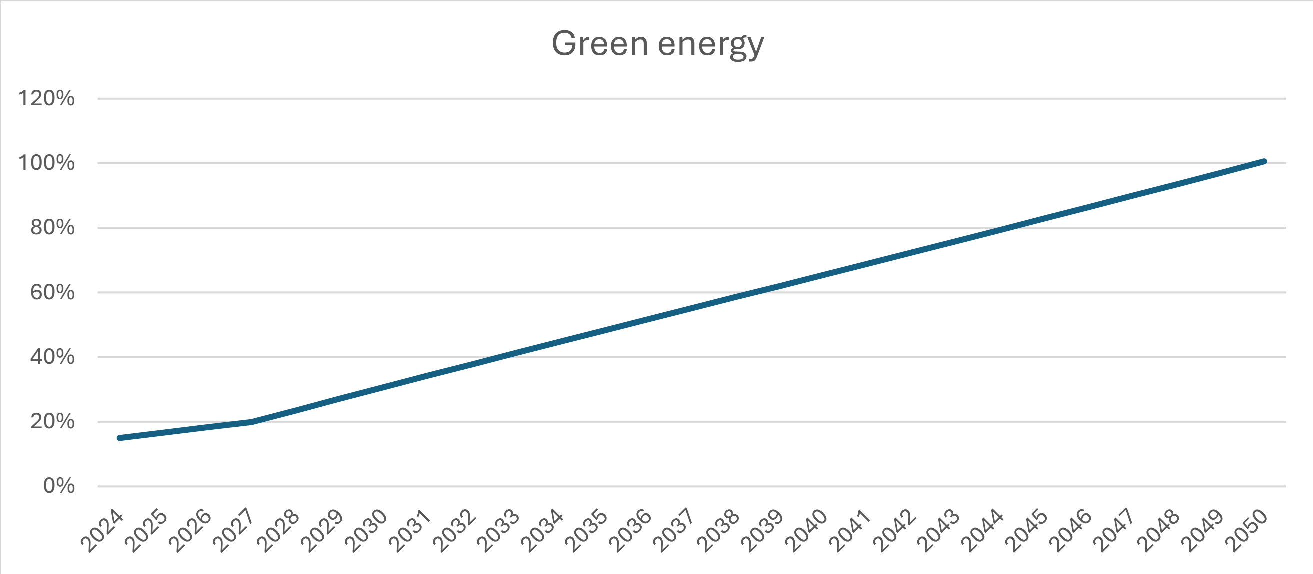

Figure 18: Green energy green growth policy

The increased investments in green energy do come at a cost for the government, with government debt/GDP increasing compared to the base scenario ending at 72.9% of GDP in 2050, 4 percentage points higher. This might not seem that much, but it could cause the Netherlands to potentially lose its triple A credit rating, meaning interest rates could potentially rise. The government could mitigate this through austerity policies in other sectors, although these could face potential public backlash as well. Nevertheless, the increase in debt/GDP is manageable and would allow the Netherlands to become climate neutral, increasing the geopolitical image and therefore leverage the country has, especially when the country can export its excess green energy.

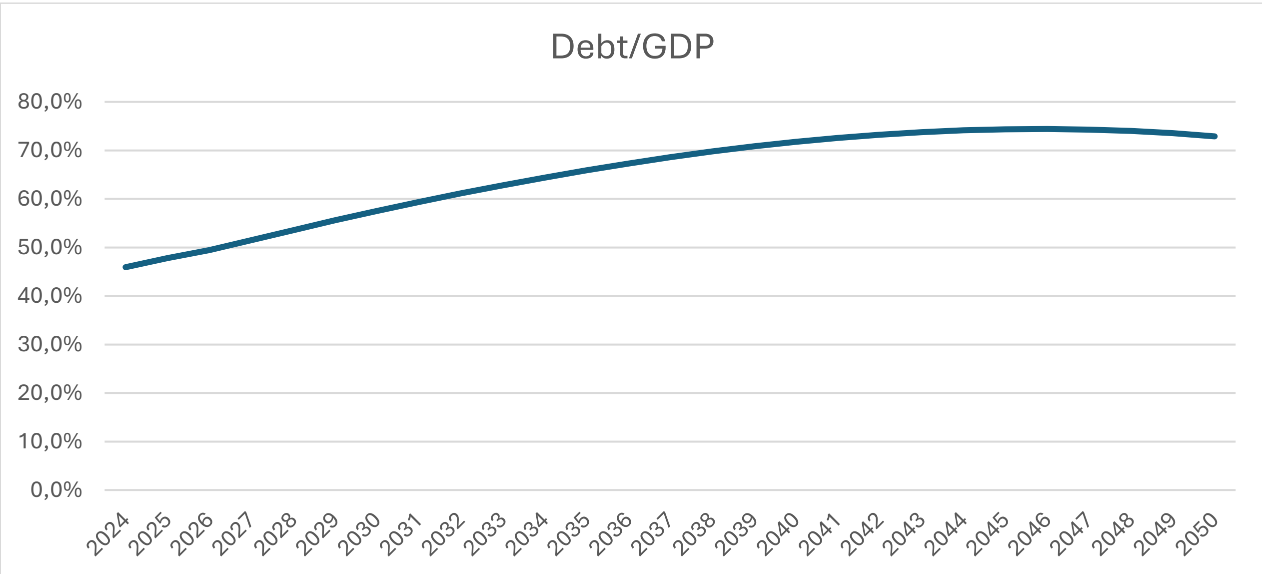

Figure 19: Government debt to GDP green growth policy

6.3.3 Degrowth policy

Alternatively to green growth policy, consumption could decrease with degrowth policy allowing an alternative path towards reaching climate neutrality in 2050. Assuming investments stay the same as the base scenario, the consumption factor would have to decrease by about 3% per year or a decrease of about 50% of consumption to reach climate neutrality in 2050. Adjusting for population growth would mean real per capita consumption has to decrease by 55% in 2050 compared to real per capita consumption today. Such a large decrease would likely result in public resistance and might not be feasible at all to implement. Nevertheless, it is important to look at the effects such a degrowth policy has on the economy.

While GDP still rises due to the 2% inflation per year, real GDP decreases from 1109.5 billion in 2024 to 1096.7 billion euros in 2035. Real GDP increases again afterwards due to the increases in productivity catching up with the decreases in consumption. GDP grows to 1149.1 billion euros in 2050, slightly higher than the level of 2024. This is a growth of 3.6%. This could therefore be seen as an a-growth policy, as real GDP remains stable. Despite the downturn in consumption, companies could still generate enough revenue to pay for the same amounts of income, materials, and investments as in the base scenario, increasing their overall equity from 152.2 billion euros in 2024 to 923.3 billion euros in 2050.

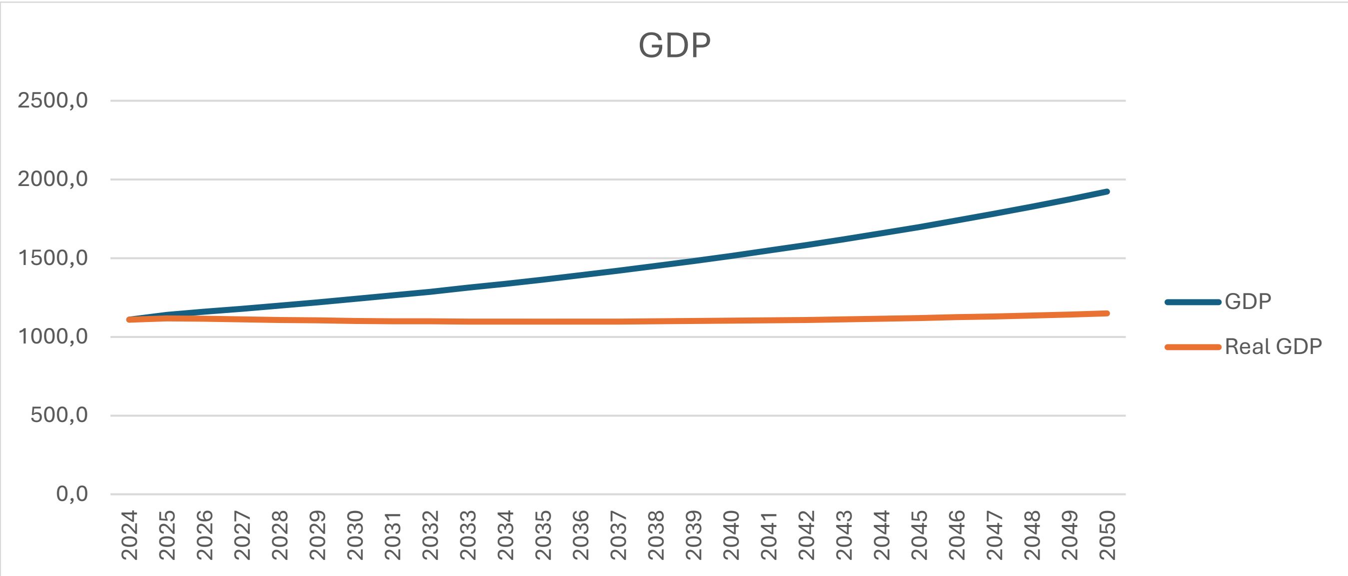

Figure 20: GDP and real GDP degrowth policy

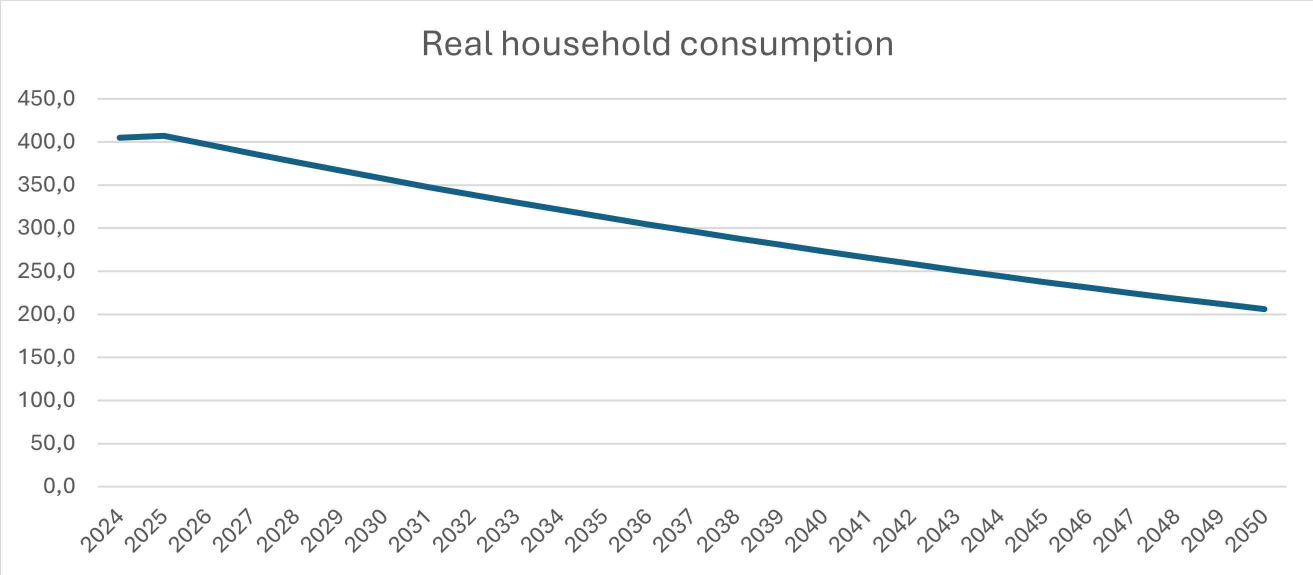

Figure 21: Real household consumption degrowth policy

Unlike the green growth scenario where the percentage of green energy increases relatively linear, it increases more exponentially in the degrowth scenario due to the percentual decrease in consumption. If the model would run further than 2050, green energy growth would slow down again, due to the decreases in consumption slowing down over time. This would then result in an S-curve. Green energy is 102.4% of total energy consumption in 2050. This could result in more geopolitical leverage as well, if the government can manage its debt/GDP which could be a large problem in a degrowth scenario.

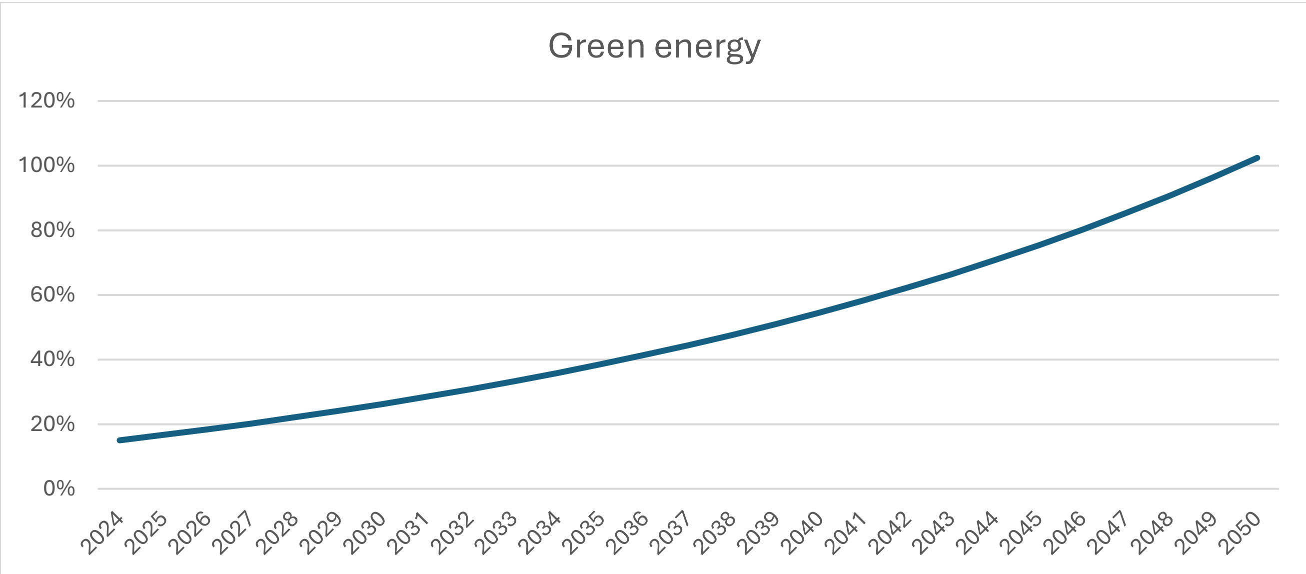

Figure 22: Green energy degrowth policy

Aside from the large downturn in consumption required in the degrowth scenario, the government faces severe problems with its debt in the degrowth scenario, with debt/GDP increasing to 199.8% of GDP in 2050. Out of all the countries in the world, only Sudan and Japan currently have a larger debt compared to GDP (IMF, 2025). Government debt/GDP increases exponentially in the first years until about 2036 when the increases in productivity cause it to increase more linearly instead. This debt/GDP could be mitigated if the reductions in consumption would come from for example higher levels of consumption taxes, as in the model households save a lot of money due to their income staying the same as in the base scenario while their expenses decrease.

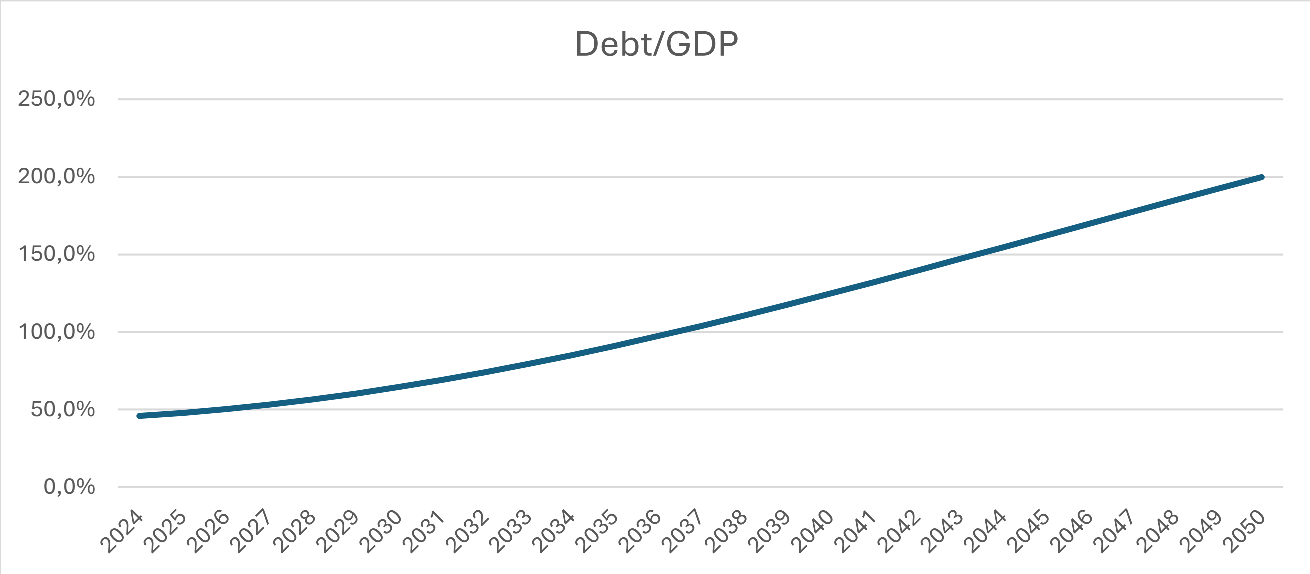

Figure 23: Government debt to GDP degrowth policy

6.3.4 Comparison

Comparing the three policies shows both similarities and differences in the trend. For green energy both green growth and degrowth have a linear trend, as they are based on linear (increasing with inflation) investments. In the degrowth scenario, real consumption is assumed to decrease with 3.6% per year from 2026, showing an exponential curve in the green energy graph. The largest difference can be seen in debt/GDP where the base and green growth scenarios are decently similar and the degrowth scenario skyrockets compared to them. The government could mitigate this through enacting the degrowth scenario through higher consumption taxes, but this could face an elevated level of public backlash. Real GDP grows in all scenarios but the least in degrowth which is logical as it is anti-growth policy.

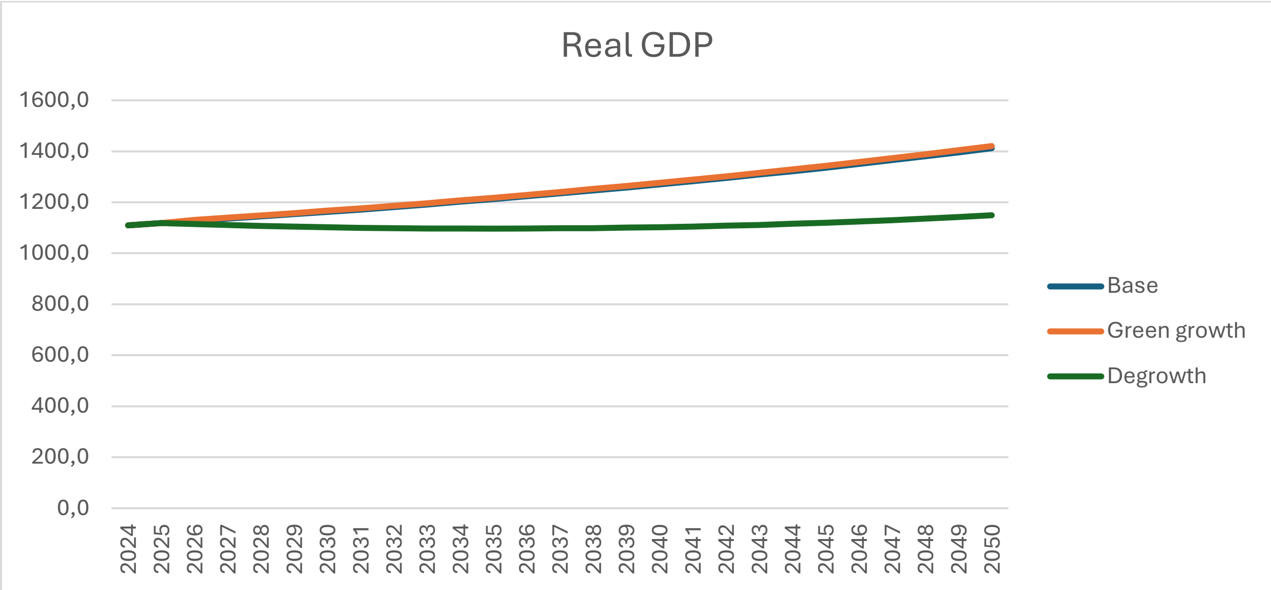

Figure 24: Real GDP policy comparison

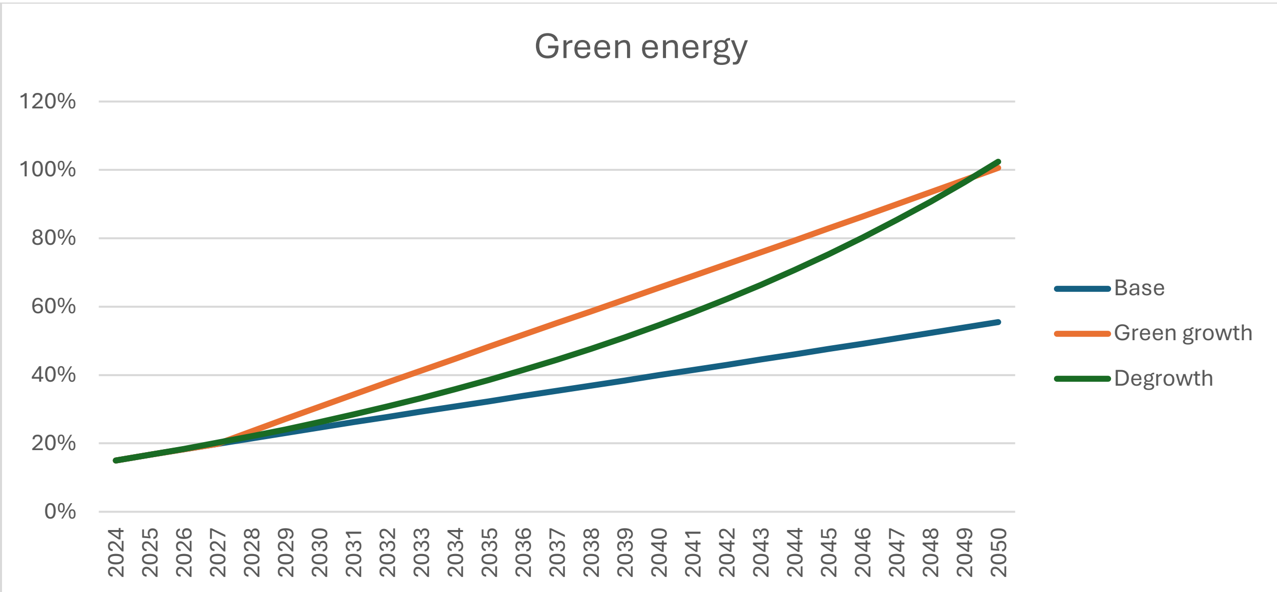

Figure 25: Green energy policy comparison

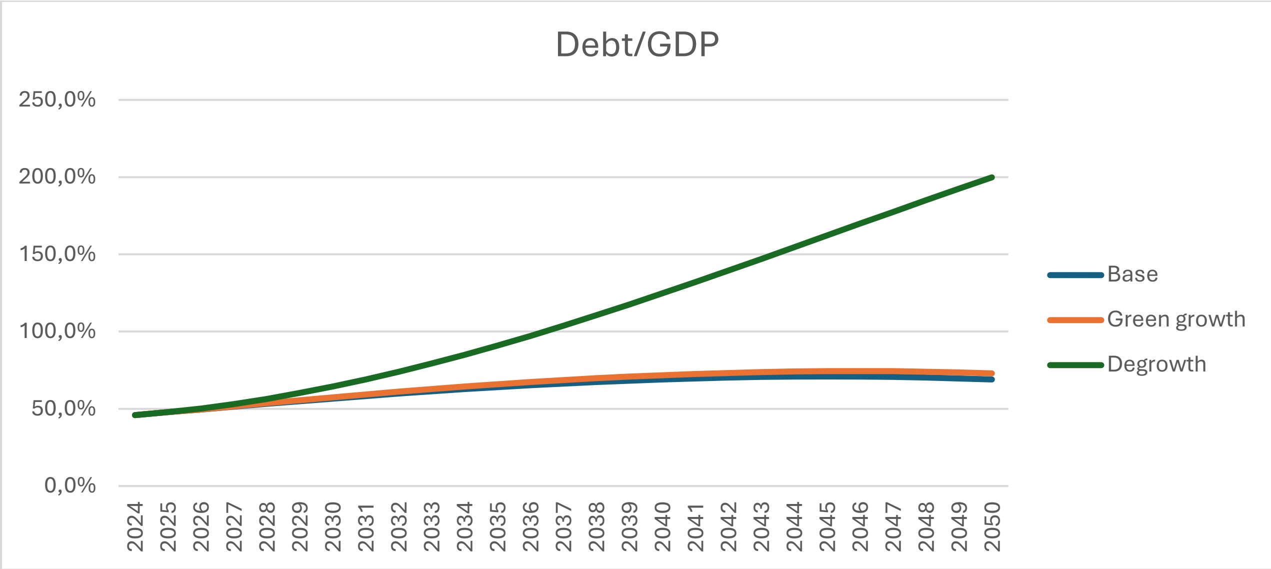

Figure 26: Debt to GDP policy comparison

6.4 Model scenarios

Now that the base scenario with an adjustment for green growth and degrowth policy has been shown, the scenarios as explained in chapter 5.3 can be adapted in the model to see what their impact would be on the economy and the energy transition. The scenarios will first be translated into model variables to do this.

6.4.1 Scenario 1: Long-lasting trade war

This scenario, as mentioned in chapter 5.3, assumes the trade war with the US which really started on the 2nd of April 2025, will be quite drawn out. Instead of ending in 2028 like in the base scenario, the trade war will continue until 2034. This influences Dutch exports which will decrease from 98% in the base scenario to 96% in this scenario. The Dutch government will also implement higher tariffs as a response to US protectionism, increasing the average tariff rate from 0.55% to 2%. The EU will see the increased hostile attitude from the US as a threat to its geopolitical stability and therefore invest more into research & development to protect their citizens and values and again strengthen their position on the world stage (European Commission, sd). The assumed effect on innovation will be an increase from 102% in the base scenario to 104% in this scenario.

In this scenario the real GDP will grow to 1479.2 billion euros in 2050, which is slightly higher than the base scenario. This is due to the increased innovation, which increases productivity as well. The increase is low while the trade war is going on until 2034, increasing quicker afterwards. The trade war will therefore only have a small impact on the Dutch economy in the model, as its influence quickly disappears in the last 15 years, while the increased innovation remains.

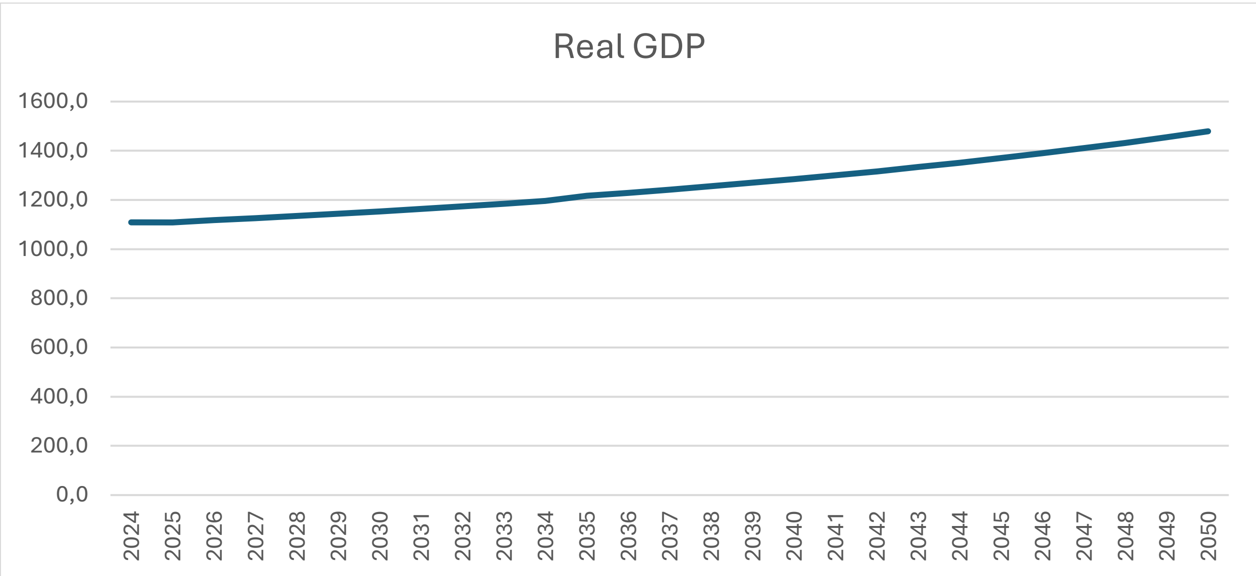

Figure 27: Real GDP scenario 1: Long-lasting trade war

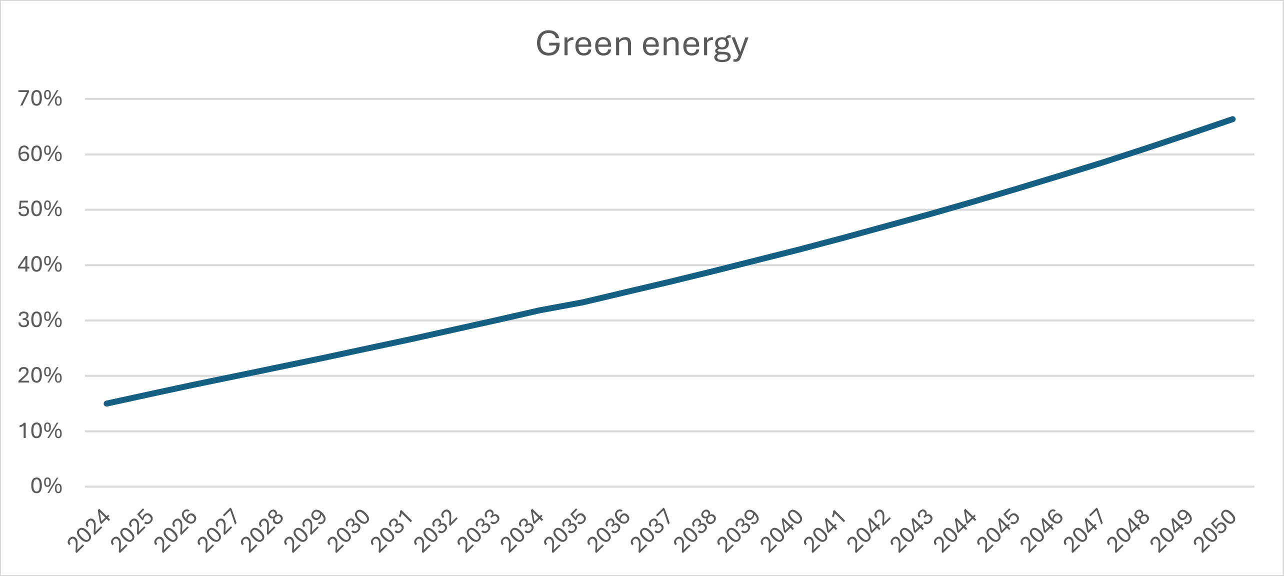

Figure 28: Green energy scenario 1: Long-lasting trade war

This scenario has a much larger impact on the energy transition than the economy, as the doubling of innovation starting in 2026 causes energy transition investments to be a lot more effective than the base scenario with 66.3% green energy in 2050. This is still not close to climate neutrality, which highlights the need for more investments as well. This scenario also assumes the EU invests a lot in the energy infrastructure, which will require quite a large shift in EU investments from fossil fuels to green energy.

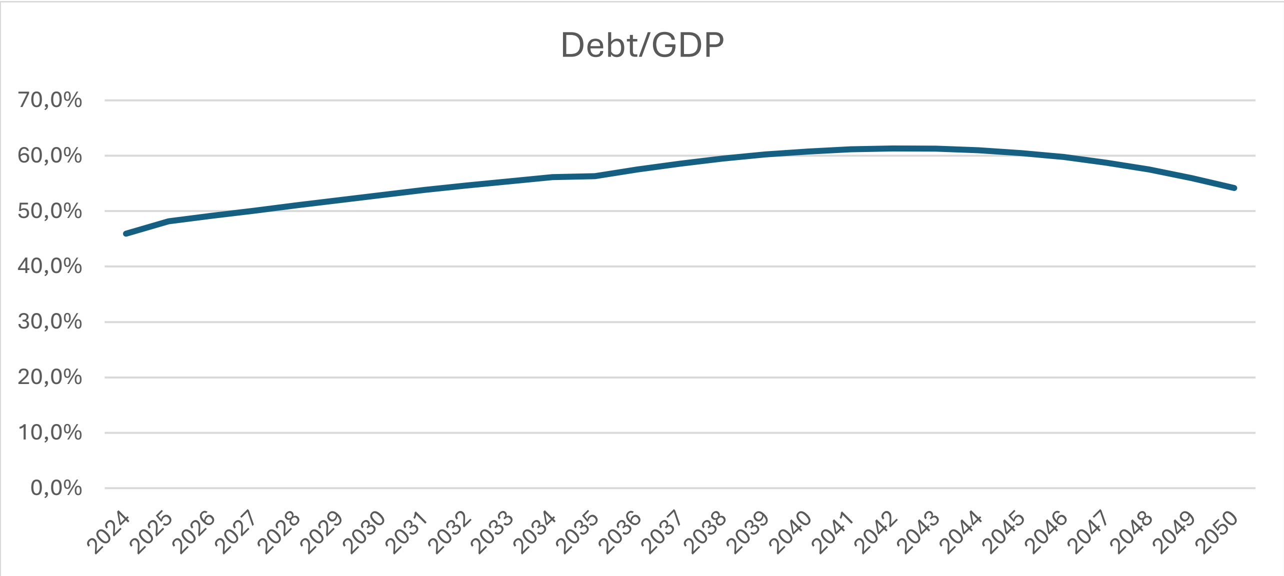

Figure 29: Debt to GDP scenario 1: Long-lasting trade war

Debt to GDP is slowly rising until 2034, slower than the base scenario due to increased government revenue from tariffs. After the tariffs are removed debt/GDP rises a bit quicker and then decreases below the 60% threshold again, with 54.2% government debt to GDP in 2050. Government debt is much lower because of the tariffs but the negative consequence is decreased purchasing power for consumers and companies. This is mitigated through the increases in productivity caused by inflation, meaning households and companies get more income, therefore slightly increasing their purchasing power compared to the base scenario.

6.4.2 Scenario 2: Chinese invasion of Taiwan

The consequences of a Chinese invasion of Taiwan would be drastic. The invasion would not only result in the deaths of thousands of people but also result in worldwide economic shocks as the world depends on the Chinese economy and the microchips and semiconductor industry of Taiwan (McCoy, 2023). As semiconductors are part of all sorts of current day electrical devices, innovation will come to a halt. This is implemented in the model by stopping innovation growth from 2026 until 2034 when the collapsed industry could have recovered. Business investments will also be curbed due to global financial uncertainty and lack of critical materials for investment, decreasing by 2% per year until 2034, compared to the base scenario. While the Dutch government could theoretically increase tariffs as a response, China is too economically powerful, making this unfeasible and likely result in a lot more losses than profits.

The impact on real GDP caused by the lower innovation and investments can be clearly seen in figure 30, as growth is much lower in the period 2026-2034 than after this period. This results in real GDP being 1326.9 billion euros in 2050 in this scenario, almost 100 billion euros lower than in the base scenario.

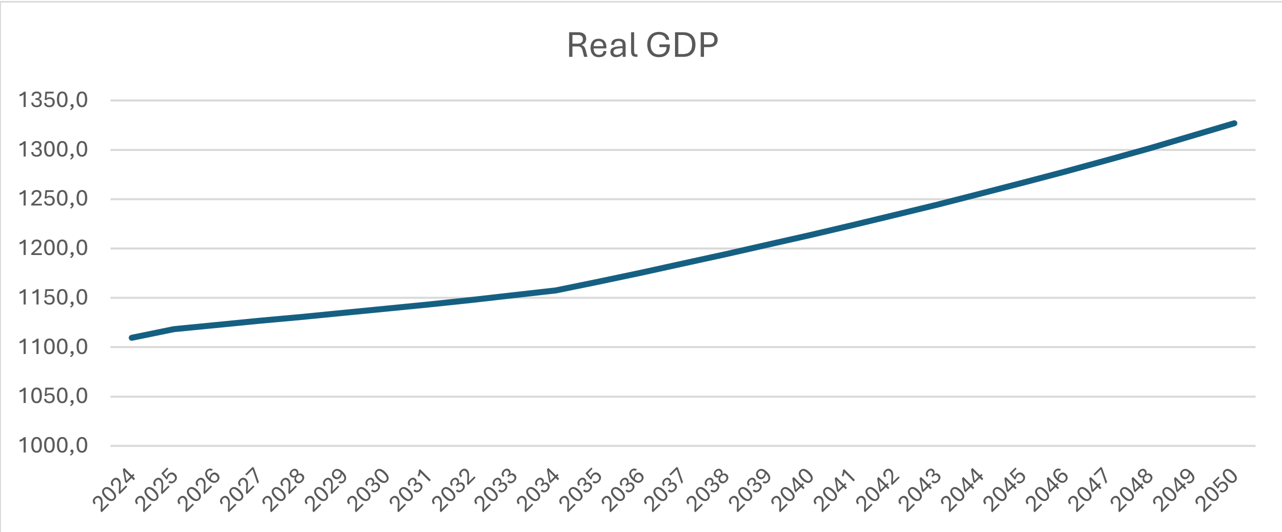

Figure 30: Real GDP scenario 2: Chinese invasion of Taiwan

Green energy is also heavily hit by the Chinese invasion of Taiwan, as the lack of microchips means innovation and investments come to a halt. In 2050 47.4% of the energy demand will be met by green energy, much lower than the 55.5% in the base scenario. This means even more investments or less consumption is needed to become climate neutral in 2050.

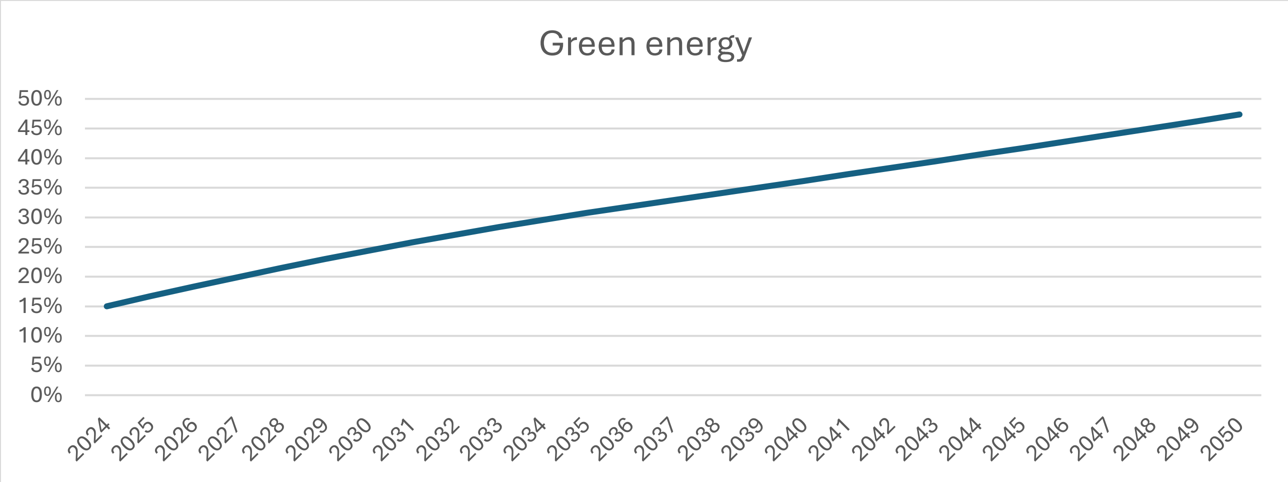

Figure 31: Green energy scenario 2: Chinese invasion of Taiwan

Finally, government debt to GDP increases compared to the base scenario due to the lack of investments and productivity increases. Debt to GDP rises sharply until about 2034, after which it gradually slows down with the increases from 2048-2050 being less than one percentage point, showing economic recovery after the invasion of Taiwan. It is difficult to mitigate the government debt in this scenario, as China is too economically powerful to put up sanctions such as tariffs against. The EU would need to come together and start producing more critical materials themselves to mitigate the economic damage caused. While this protectionist approach could decrease geopolitical leverage, it would increase energy independence of the continent and eventually increase leverage through becoming climate neutral earlier.

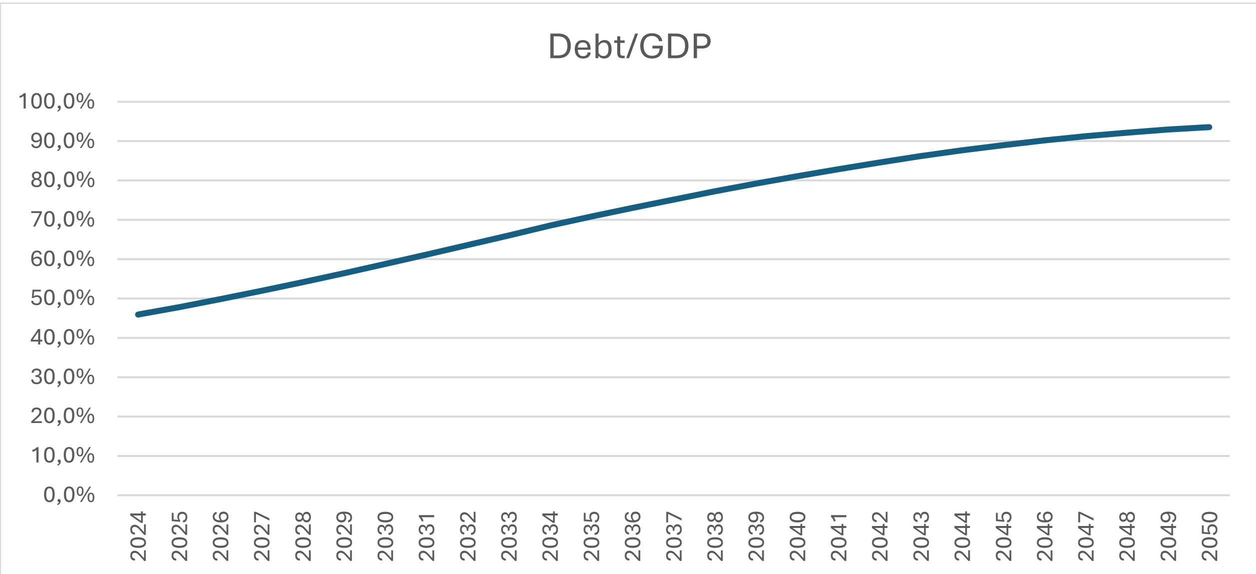

Figure 32: Debt to GDP scenario 2: Chinese invasion of Taiwan

6.4.3 Scenario 3: Business as usual

This scenario assumes the trade war with the US will only last for a short while, with international tensions fading away afterwards, returning to business as usual. As international tensions fade away, businesses will have more trust in the economy and are therefore willing to spend a larger amount on investments than they would in the base scenario. Business investments will therefore increase by 1% per year starting 2026, compared to the base scenario. Major breakthroughs in innovation do not happen however, with the innovation factor staying the same as in the base scenario.

Real GDP increases steadily from 1109.5 billion euros in 2024 to 1504 billion euros in 2050, being higher than the base scenario due to the increased investments. Investments increase slightly exponentially, which can be seen in the real GDP curve being slightly exponential as well.

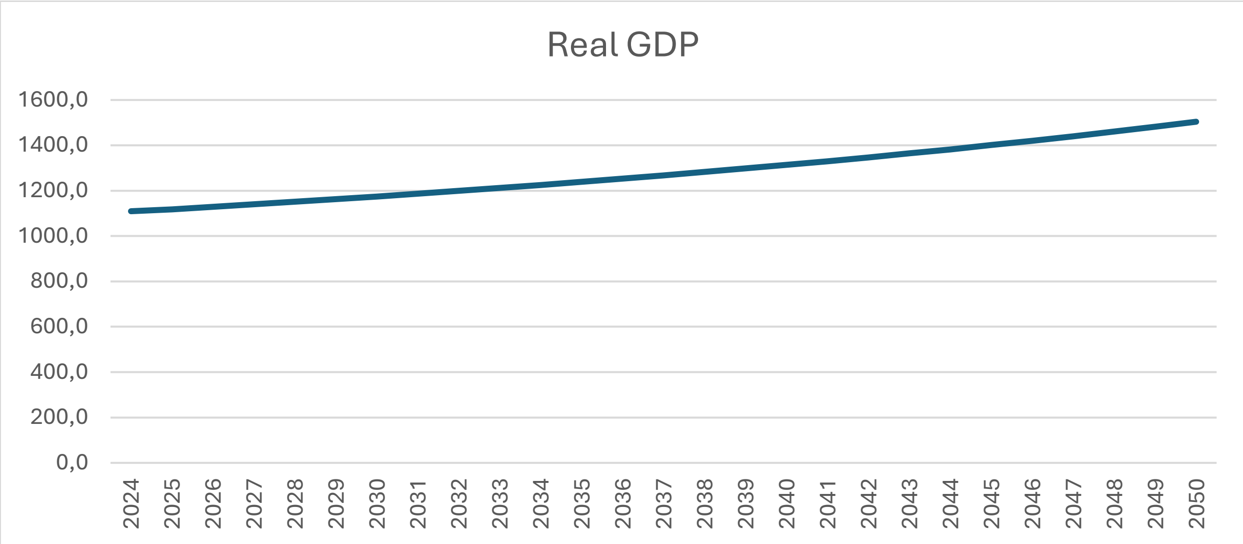

Figure 33: Real GDP scenario 3: Business as usual

The energy transition outlook is also more positive in this scenario compared to the base scenario. Despite energy innovation not increasing, additional business investments result in additional green investments, increasing the green energy mix from 55.5% to 58.9% in 2050. This is a positive increase but still shows a large need for more green investments or less consumption.

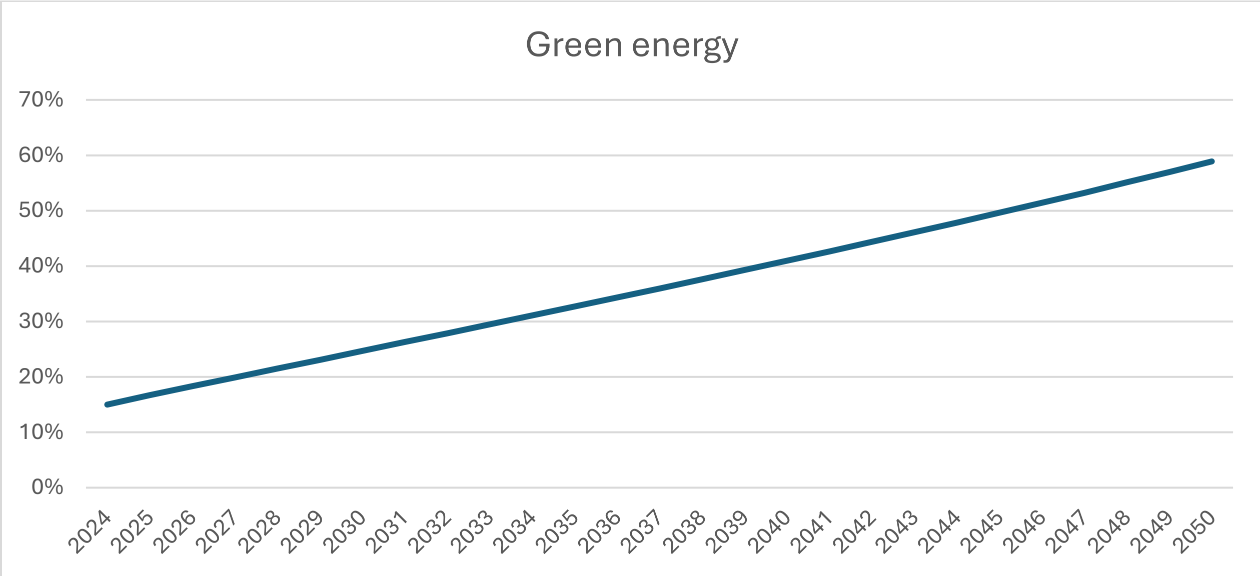

Figure 34: Energy scenario 3: Business as usual

Debt to GDP follows a similar curve as in the base scenario, although it only barely goes over the 60% threshold in this scenario, decreasing to 51% in 2050. This means the government has more financial space to invest in the energy transition, without risking losing its triple A rating.

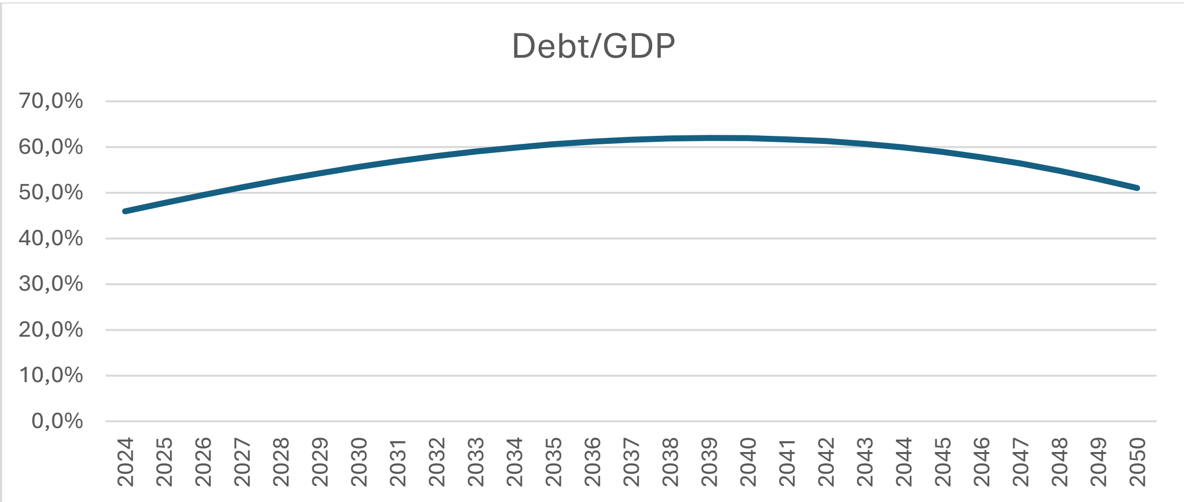

Figure 35: Debt to GDP scenario 3: Business as usual

6.4.4 Scenario 4: Fourth industrial revolution

Another scenario is the rapid expansion of AI, augmented reality and the internet of things causing a fourth industrial revolution (Ross & Maynard, 2020). The US trade war will end quickly and geopolitical cooperation and innovation skyrockets. This causes trust in the economy to rise quickly, resulting in a substantial increase in business investments. These will increase by 2% every year compared to the base scenario. Innovation will be a 5% increase per year due to AI breakthroughs, instead of a 2% increase in the base scenario. This innovation will cause increases in productivity and a quicker energy transition. Overall, the outlook of this scenario is the most optimistic out of the five scenarios.

Real GDP increases sharply in this scenario from 1109.5 billion euros to 1773.1 billion euros due to the extra investments and higher productivity. This is an increase of about 60%. Such an increase in real GDP would be seen in countries across the world due to the high global level of innovation. Overall, the economic outlook is very positive due to the large geopolitical cooperation and high innovation, giving even more room to invest into the energy transition.

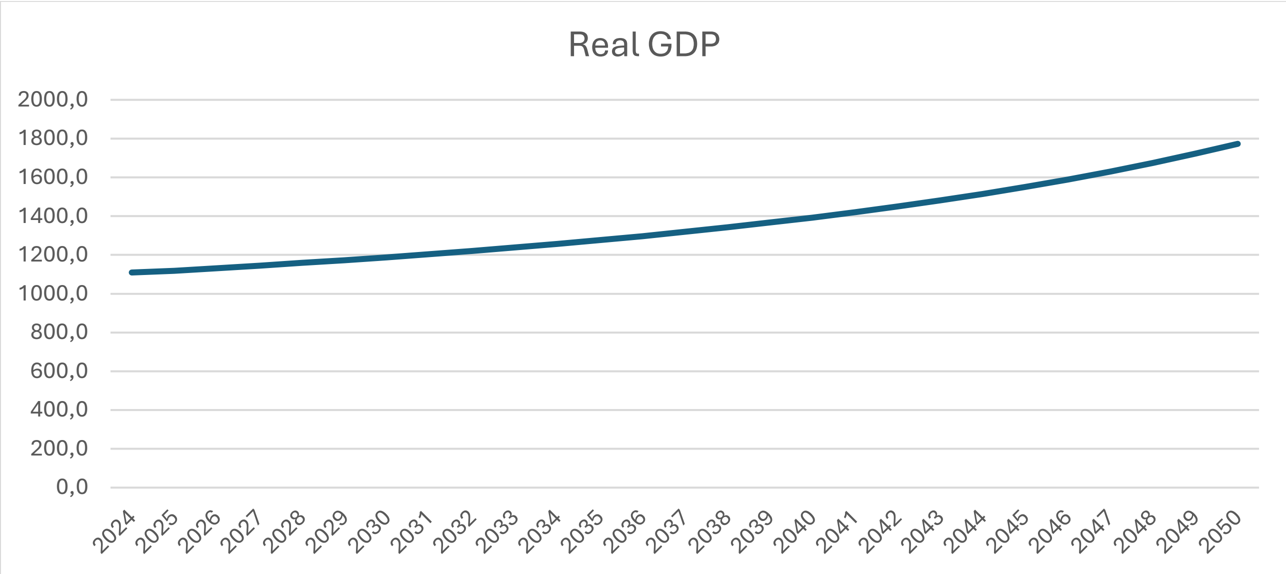

Figure 36: Real GDP scenario 4: Fourth industrial revolution

Green energy in this scenario already comes close to climate neutrality, reaching 85.1% green energy in 2050, due to the high levels of innovation and investment. This means the booming economy would only require people to consume somewhat less than before or invest somewhat more than current policy. Still, the chance of this scenario happening is rather low so it should not be expected the energy transition will be completed that easily. A degrowth, green growth or mixed path would still have to be chosen.

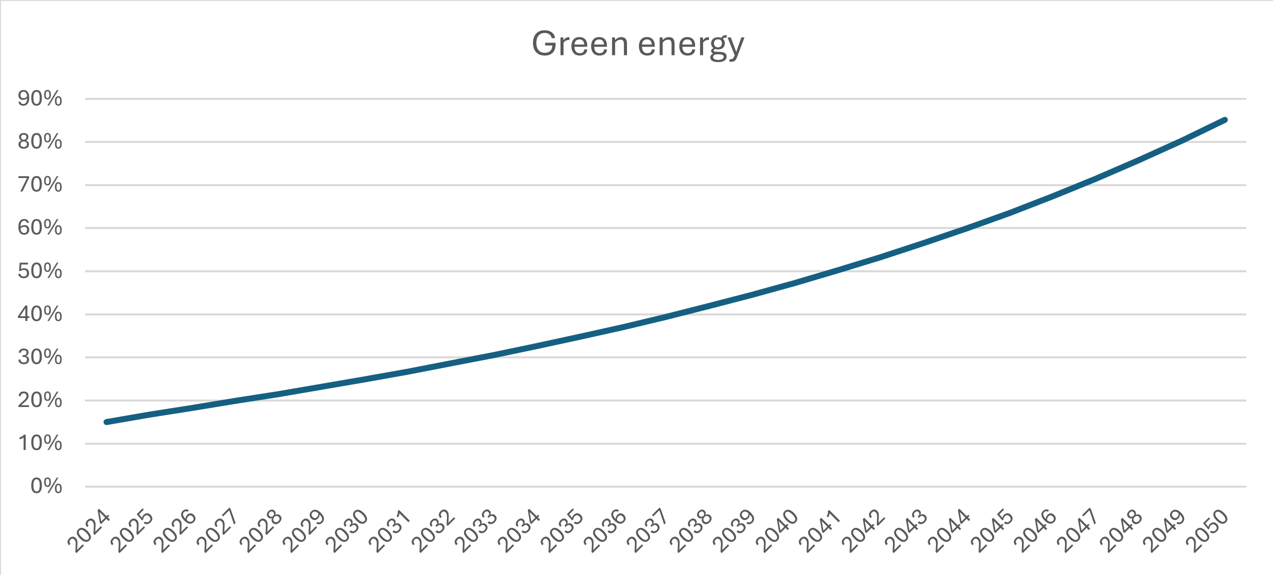

Figure 37: Green energy scenario 4: Fourth industrial revolution

Debt to GDP increases to 56.4% in 2034 in this scenario before heavily decreasing to 17.9% of GDP in 2050. This is mainly caused by the higher tax income the government receives due to the higher productivity as well as the higher levels of GDP this scenario has compared to the base scenario. The government starts having a surplus from 2041 onwards in this scenario. The low government debt to GDP shows the government has the necessary financial space to complete the energy transition through their own investments. The private sector already invests more due to the elevated levels of innovation and geopolitical cooperation.

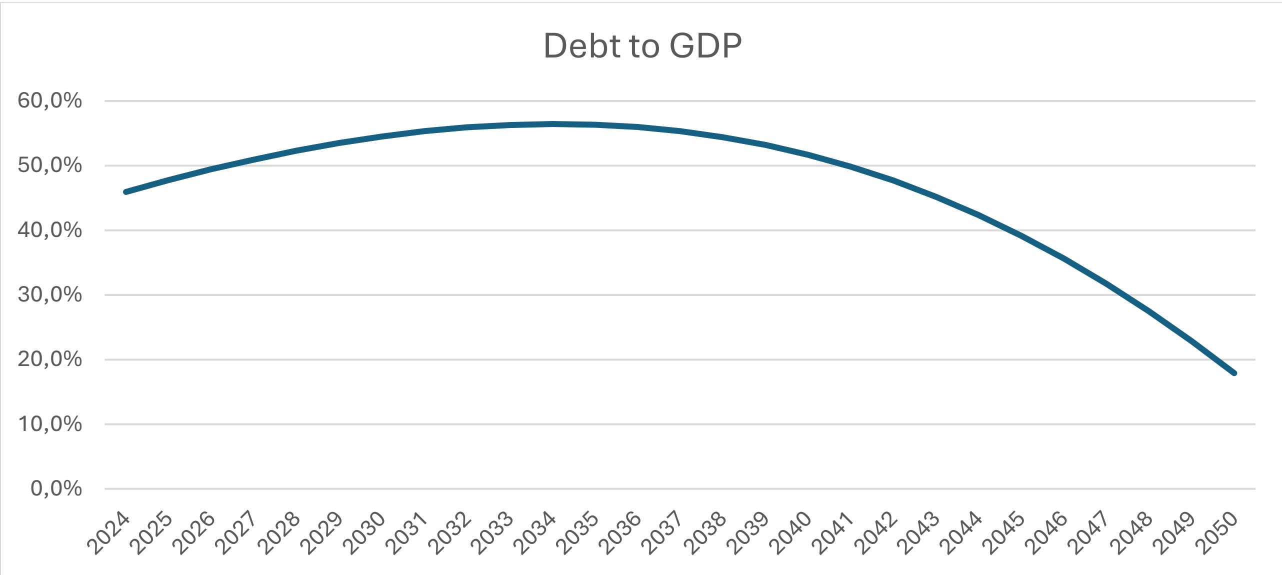

Figure 38: Debt to GDP scenario 4: Fourth industrial revolution

6.4.5 Scenario 5: Extended war in Europe

This scenario is the most extreme out of the five scenarios but is still realistically possible to happen. In this scenario, the Russo-Ukrainian war will extend beyond Russia and Ukraine with Russia invading the Baltic states as well (Clarke, 2025). The European Union, NATO and consequently the Netherlands, will be involved in a large-scale war which could result in a third world war. The Netherlands will transform their economy into a war economy, increasing government spending but resulting in a decrease in the private green investments. This green investments factor will decrease from 2.4% to 1.5%. Defence spending, showcased in 'Other government spending' will increase, with 10% per year from 2026-2030 indicating extra defence spending due to the war. After the war defence spendings decrease by 20% before going back to normal. Tariffs will increase to 5%, while the export factor will decrease to 95% from 2026 until the end of the war in 2030. Innovation will increase by 4% per year starting in 2026 due to the war effort requiring innovative technology. These also include energy innovations, which help to guarantee European energy security and work towards the energy transition. Consumption before taxes will decrease with 5% per year for the first three years of the war, due to the uncertain times, and then 1% for the last two years of the war as the thought of being in a war normalises. After the war in 2031 consumption will experience an increase of 5% before returning to the normal again.

Real GDP will only slowly rise during the war, due to the decreased levels of consumption caused by the uncertainty of to the war. Main increases in real GDP during this period are caused by increased levels of productivity due to extra innovation, as well as the much higher levels of government spending. Real GDP decreases in 2031 due to the government severely reducing its defence spending after the war has passed. Following 2031, real GDP increases again due to the recovered levels of consumption as well as extra productivity, resulting in a real GDP of 1557.4 billion euros in 2050, much higher than real GDP in the base scenario but much lower than the fourth industrial revolution scenario.

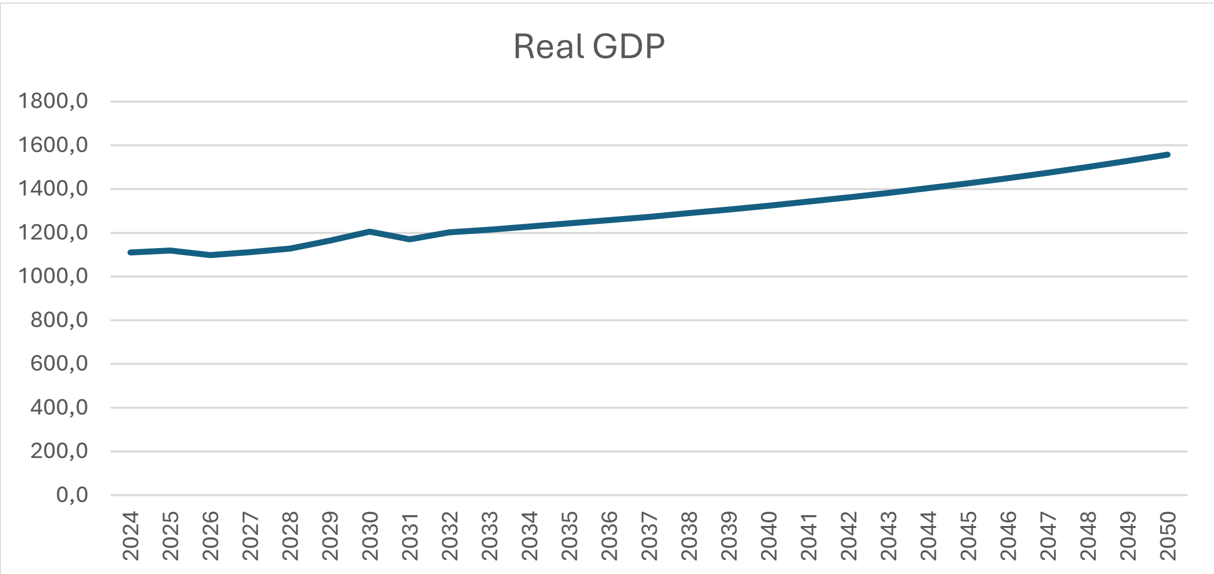

Figure 39: Real GDP scenario 5: Extended war in Europe

Green energy rises slowly in the first years of the war due to decreased levels of green investments by the private sector, but lower levels of consumption help mitigate the decrease in green investments during these years. When consumption levels return to normal in 2031, the graph flatlines somewhat before returning to a sharper increase as green investments catch up again. Green energy will make up 71.8% of total energy consumption in 2050, being much higher than the base scenario. This is due to a much higher level of innovation and a somewhat lower level of consumption.

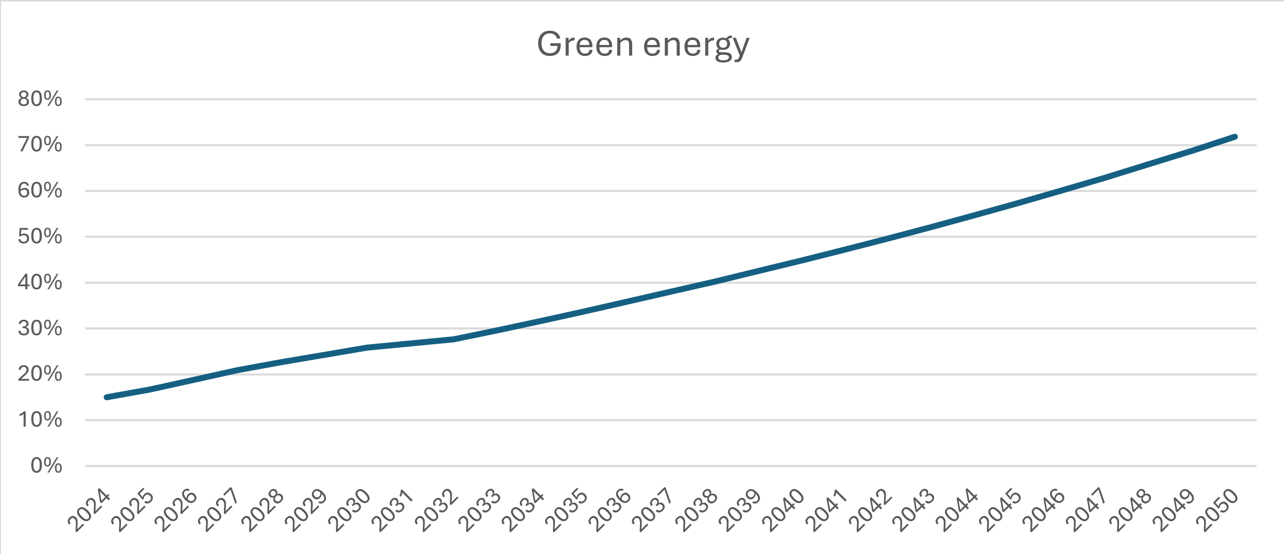

Figure 40: Green energy scenario 5: Extended war in Europe

Government finances are among the variables which are most impacted by the war effort, as government debt to GDP sharply rises. While the increases do not seem that high during the years of the war, they are already much higher than the base scenario. The sharp increase between 2030 and 2031 can be explained by austerity policy of the government decreasing GDP in that year, while the debt levels stay high. Debt to GDP does slow down as time goes on, reaching a peak of 142.1% in 2048 before going slightly down to 141.8% in 2050. Such a high government debt would cause the government to lose its triple A status, meaning interest payments would be higher than in the model. This also means the government does not have the financial means to invest in the energy transition to make up the remaining 28% of green energy needed. In this case the government will have to call upon the private sector to increase investments or increase taxes to mitigate its debt.

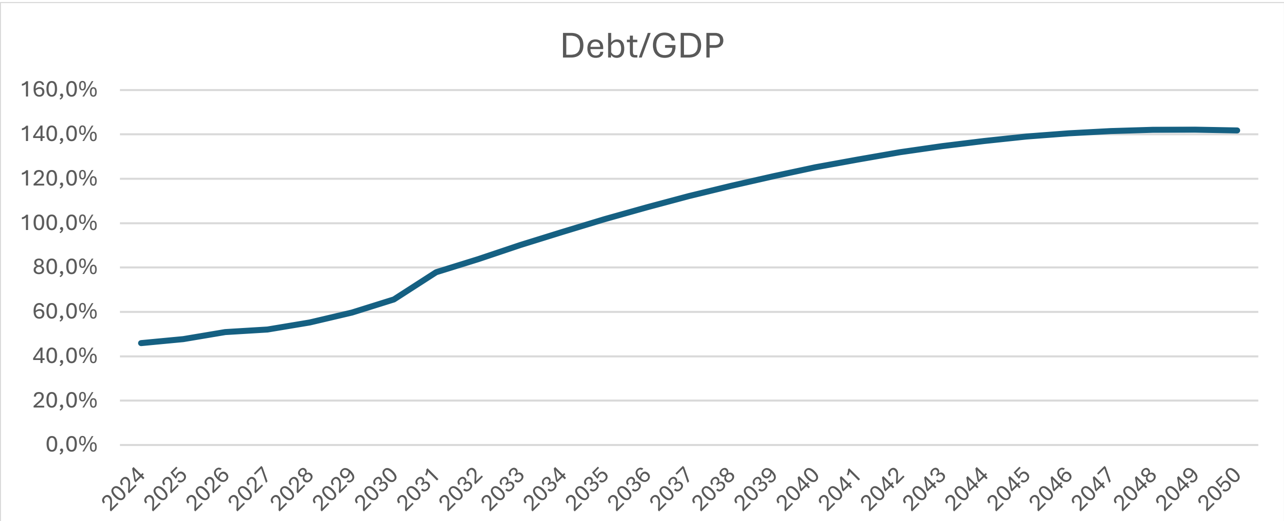

Figure 41: Government debt to GDP scenario 5: Extended war in Europe

6.3.4 Comparison

Comparing the five scenarios with the base scenario, it can be seen the fourth industrial revolution is the most positive scenario, resulting in the highest amount of green energy, lowest debt to GDP and highest real GDP. This scenario is also the only one in which debt to GDP decreases a lot. The highest debt to GDP can be seen in the extended war in Europe scenario, as the government will have to pay a lot to finance the war and subsequently pay interest on the war debt. If the government would decide to decrease spending here, green investments could be hit despite them not being very high, delaying the energy transition even more. The business as usual scenario is similar to the base scenario but slightly better in all three factors. The same goes for the long-lasting trade war scenario but innovation is higher here, resulting in a higher amount of green energy. Finally, the Chinese invasion of Taiwan scenario shows the lowest increase in green energy due to the large disruption of crucial energy transition supply chains. Debt to GDP is also the second worst in this scenario.

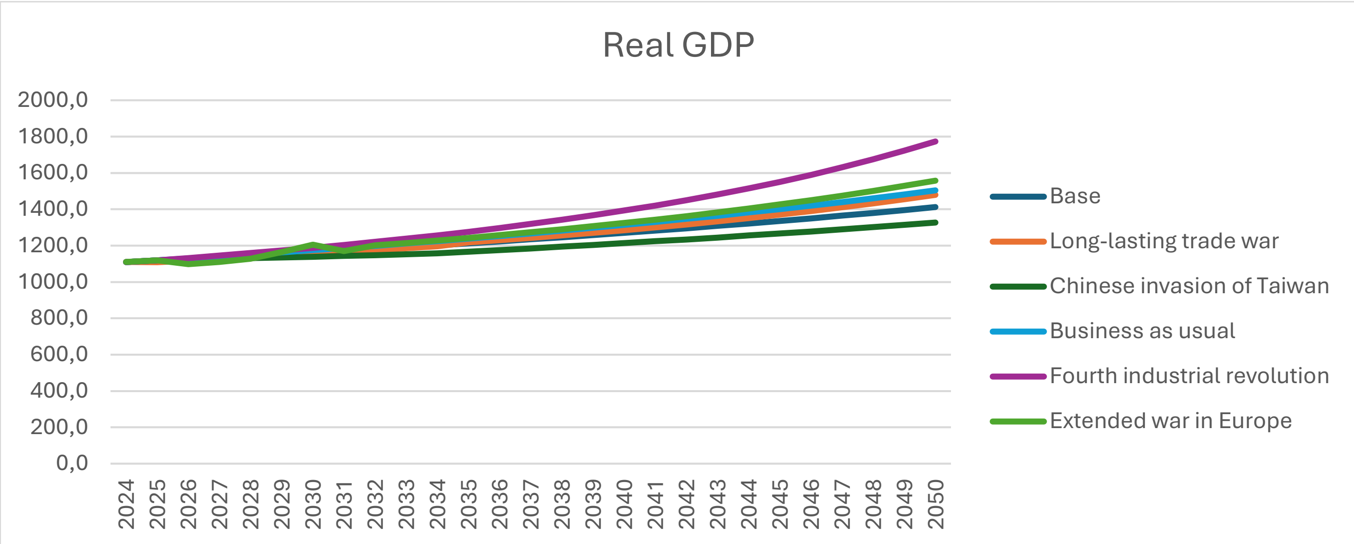

Figure 42: Real GDP scenario comparison

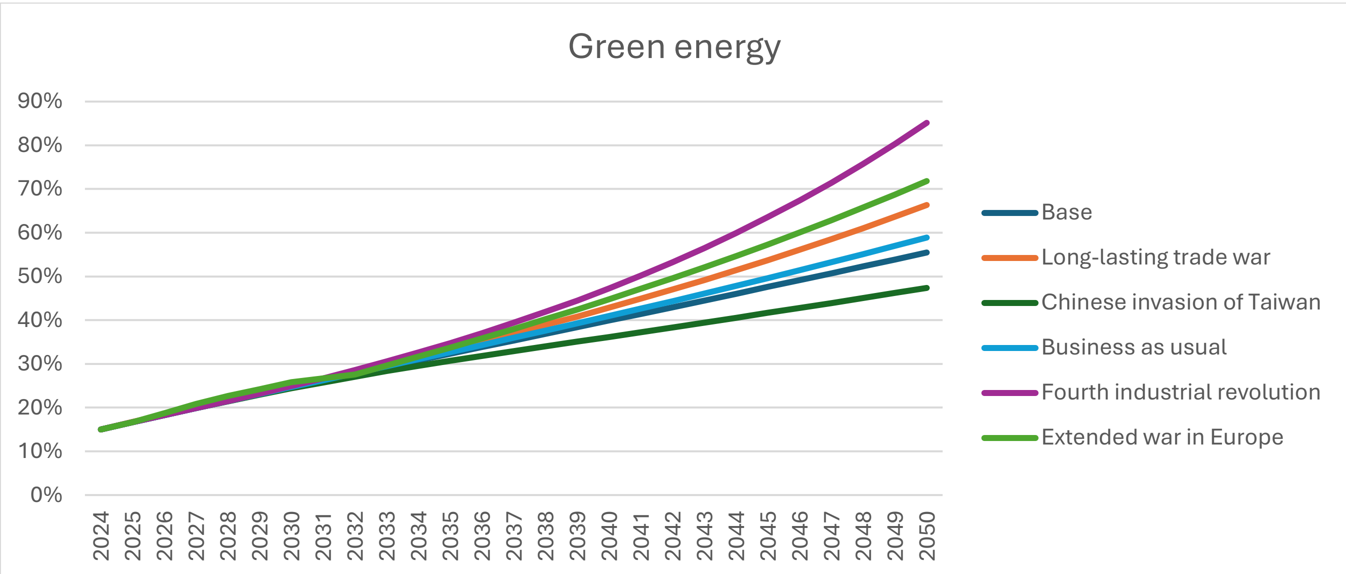

Figure 43: Green energy scenario comparison

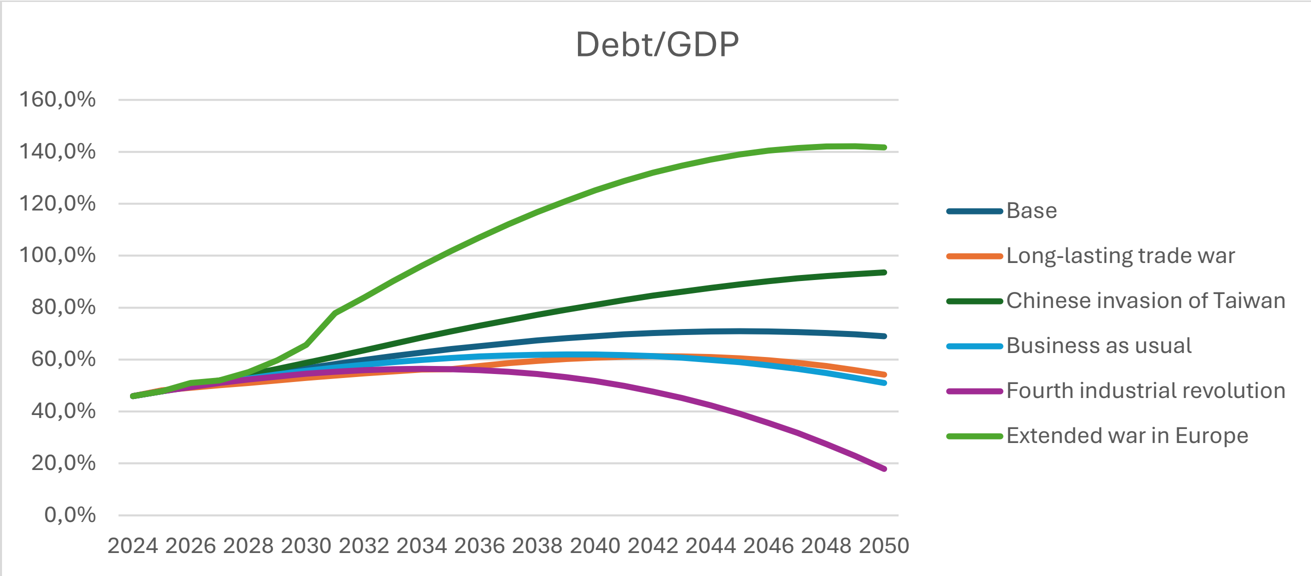

Figure 44: Debt to GDP scenario comparison

6.5 Conclusion

The results of the macroeconomic model show that both degrowth as well as green growth could be a viable strategy in reducing carbon emissions and reaching climate neutrality. Four out of five scenarios show much more investments or much lower consumption is needed to reach climate neutrality. The fourth industrial revolution scenario is quite optimistic and expects substantial amounts of innovation. This is paired with a natural increase in corporate investments which will result in much less investments needed or degrowth needed to reach climate neutrality in 2050. Assuming the most optimistic path would come true is however a bad policy decision to make. Therefore, the Netherlands will have to consider how much they want to decrease consumption and how much they want to incentivise corporate investments, as well as increase government investments. The problem of more government investments is the creeping government debt to GDP, which even in the base scenario already hits the 60% threshold.

Increasing green private investments seems to be the best strategy economically and energy transition wise but might be difficult for the government to realise, without delivering an extensive energy transition plan and committing to more green investments itself as well. Reducing real consumption helps the energy transition a lot as well but decreases projected GDP a lot, if consumption reductions are very high. A high quality of life could be maintained with much lower increases in GDP, due to for example fewer working hours. However, the international market still uses debt/GDP as a measure of economic performance and therefore their willingness to lend money to a countries' government. Overall, the right middle ground must be found between consumption reductions, as well as private and public sector green investments.

Comparing the economic model to the research by the CPB mentioned in paragraph 4.1.1 shows the starting GDP of 1130 billion euros (CPB, 2024) being similar to the model GDP of 1109.5 billion euros. In their scenarios the GDP in 2050 will be 10-72% larger than 2024 but the CPB does not mention whether this is real GDP or not. The 10% scenario which the CPB calls 'autonomous' already assumes a degrowth strategy. This is similar to the degrowth policy in the model with a real GDP growth of 3.6%. The 'market' scenario which experiences grey growth has a 72% increase in real GDP (CPB, 2024) which is relatively similar to the 60% increase in the fourth industrial revolution scenario, although this assumes a green growth strategy. Overall, the increases in GDP stated by the model seem realistic compared to projections made by the CPB.

7 Impact of green growth and degrowth on the energy transition

This chapter will analyse the impact of green growth and degrowth on the energy transition, how different actors affect this transition and how they in turn are affected by this transition. The chapter will end with several alternatives the Dutch government could implement to help reach climate neutrality in 2050. Some of these alternatives are based on green growth measures, other degrowth measures with some alternatives combining the two as well.

7.1 Actor analysis

An important part towards determining the impact of green growth and degrowth on the energy transition is looking at the important actors involved in the energy transition. Through getting a clear overview of the influential and important actors, policy in the energy transition can be improved to find a way to have as many actors as possible collaborate in achieving climate goals.

7.1.1 Dutch government

The main actor or problem owner regarding the energy transition in the Netherlands could be determined to be the Dutch government, as the government has the means to directly influence the energy transition. The goal of the government is to reach climate neutrality in 2050, thereby following the Paris agreement (Rijksoverheid, 2023b). The government wants to achieve this by doing sustainable investments and thus achieving green growth (Rijksoverheid, sd). The main dilemma for the government is whether sustainable investments alone are enough to achieve the climate goals while maintaining a healthy economy. The government must balance this with a plethora of other expenses such as healthcare, social security as well as defence meaning it might be difficult to invest adequate amounts into the energy transition while keeping a healthy budget. This is also important for keeping a triple A credit rating, so government interest rates stay low. If the government can successfully get the private sector on board with doing more energy transition investments, it would be much easier to achieve the climate goals while maintaining a healthy budget.

7.1.2 European Union

Next to the Dutch government, the European Union is an important actor within the energy transition. Similar to the Dutch government, the goal of the EU is to reach climate neutrality in 2050. The EU also wants to achieve 55% CO2 reductions compared to 1990 by 2030 (European Parliament, 2023). Similar to the Dutch government, this comes down to a green growth approach by decoupling resource usage from economic growth (European Commission, 2024b). While the EU is not as influential as the Dutch government regarding the Dutch energy transition, they are important as an actor checking whether the Dutch government follows European energy transition agreements. The same goes for checking whether the budget stays within a 3% yearly deficit and a maximum of 60% debt to GDP (European Council, 2025)

7.1.3 Local governments

While the European Union mainly does oversight but also attributes part of the budget from the Green Deal to the national energy transition, local governments are the ones who often need to put energy transition policy into practice. Local governments such as the province of Utrecht follow the goals of reaching 55% reduction in 2030 and 100% in 2050 (Provincie Utrecht, 2024). The same goes for the water management boards which also work on the energy transition (Unie van Waterschappen, 2021). While local governments have less influence than the Dutch government and European Union, they still have a lot of interest into national energy transition policy and how feasible that policy will be. If the Dutch government wishes to fluently work towards climate neutrality, collaboration with local governments is crucial.

7.1.4 TenneT

TenneT is the largest grid operator in the Netherlands, operating both in the Netherlands and parts of Germany (TenneT, sd). One of the important tasks of TenneT, aside from transporting electricity, is keeping the electricity grid and therefore the balance between supply and demand stable (TenneT, sd). As an increasing amount of solar and wind energy will form the supply of the electricity grid, this balance will become increasingly difficult, showcasing the need for batteries or other types of electricity storage. TenneT is also responsible for available grid capacity and therefore has a considerable influence on the feasibility of the energy transition. Without the required infrastructure it will be difficult to complete the transition in time.

7.1.5 Vattenfall

Vattenfall is one of the largest energy suppliers of the Netherlands with 1.9 million customers, while also being one of the largest energy producers of the country with several gas power plants as well as solar and wind parks (Vattenfall, 2025). As large energy supplier and producer, Vattenfall wishes to realise climate neutrality in 2040 by compensating any potential emissions they might have at that time with carbon capture storage (Vattenfall, 2024). Similar to the grid operators, large energy suppliers will mainly influence the energy transition through large green investments.

7.1.6 MKB Nederland

The small and middle-sized companies (MKB) in the Netherlands are for 90% represented by the organisation MKB Nederland (MKB Nederland, 2025a). MKB Nederland wants to work together with the Dutch government on the energy transition to reach the climate goals in time but sees potential problems in permits blocking the path to become more sustainable (MKB Nederland, 2025b). MKB Nederland also mentions an often discussed point regarding fossil subsidies, as they agree on decreasing these subsidies in time, but warn they should not be decreased too fast, when there are not enough alternatives for fossil energy or necessary infrastructure yet (MKB Nederland, 2025c). They also want these subsidies to be decreased in accordance with other countries, by making worldwide, or at least European agreements, to stop subsidising fossil energy. Else industry would likely move to other countries, with emissions being moved from the Netherlands to other countries. Through representing such a large part of the small and middle-sized companies in the Netherlands, the Dutch government would have to really consider the interests of MKB Nederland to maintain a healthy economy and reach climate neutrality by 2050.

7.1.7 Shell

While small and middle-sized companies have bundled their influence through MKB Nederland, multinationals are generally large enough to be influential on their own. There are several multinationals which are important towards the energy transition but one of the most important ones is probably Shell. Shell has the same goal as the other actors to reach climate neutrality by 2050 and is projected to invest 10-15 billion euros worldwide into the energy transition including investments in the Netherlands such as Holland Hydrogen which produces green hydrogen (Shell, 2024). Shell does expect national governments to design policy in such a way that consumers will slowly choose for more renewable options. Shell also shifts some of the responsibility to consumers stating they are eventually the ones who need to choose which products they buy, sustainable or not sustainable (Shell, 2024). Many gas companies see hydrogen as a potential future as it uses similar infrastructure. Nevertheless, it would be in the interest of Shell to slowly shift from fossil fuels to hydrogen, so they have enough time to transition at a relatively low cost.

7.1.8 Greenpeace

One of the important environmental organisations within the Dutch energy transition is Greenpeace. Greenpeace wants the Netherlands to be climate neutral quicker in 2040, as they think 2050 will be too late to decrease the effects of climate change far enough (Greenpeace Nederland, 2025). Greenpeace would prefer the government to do this through a degrowth scenario by decreasing the amount of consumption and moving some of the industry out of the Netherlands (Greenpeace Nederland, 2025). Greenpeace is also actively participating against large polluters such as Shell, by for example occupying oil platforms in which they recently settled a lawsuit with Shell regarding the North Sea oil platforms (Greenpeace International, 2024).

7.1.9 Extinction Rebellion

Another important environmental organisation is Extinction Rebellion, which unlike Greenpeace wants the energy transition to be completed in 2025 as they say 2050 would result in much more than 1.5 degrees global warming (Extinction Rebellion, 2021) (Extinction Rebellion, 2025). The only way to realise this would be through drastic degrowth by stopping entire industries. Extinction Rebellion wants to achieve this through public protests through what they call peaceful rebellion but does not want to use eco sabotage as measure to achieve their goals (Extinction Rebellion, 2023). As the actions of Extinction Rebellion often reach the news, their main effect on the energy transition is influencing public opinion and pressuring companies and politicians.

7.1.10 Vereniging Eigen Huis

Representing the interests of current and future homeowners is Vereniging Eigen Huis. Vereniging Eigen Huis has a few goals they work towards regarding the energy transition, namely allowing all homeowners to own solar panels, be able to heat their homes in a sustainable way, as well as be able to afford their energy costs (Vereniging Eigen Huis, sd). Homeowners are an important actor here, as without them it would be much more difficult to complete the energy transition in time. Vereniging Eigen Huis also has lobbying power they use to convince politicians and companies of the causes of homeowners. Therefore, they have relatively high influence and interest in the energy transition.

7.1.11 Citizens

While solutions of the climate crisis are often seen through the lens of what the government and companies must do, citizens hold a responsibility towards the climate crisis as well. This includes their own levels of consumption as well as whether the products they buy come from sustainable sources. Another aspect is voting in which citizens change the makeup of parliament and therefore how the government will handle the energy transition. Citizens might not have much influence in the energy transition, but small individual actions can lead to large consequences.

7.2 Power-interest grid

A power-interest grid is a method to divide different actors into four quadrants based on their power and interest. The most important actors are those in the quadrant with the most power and interest, often called the players. It is also important to take actors into account which have relatively high power although lower interest, as well as actors with higher interest although lower power.

In this power-interest grid regarding the Dutch energy transition, the Dutch government has the most power and most interest, as it is the main actor responsible for the course of the energy transition. Local governments also hold a high interest but have less decision-making power. TenneT has quite a lot of power and interest in the energy transition as the largest grid operator, as they are responsible for most of the electricity infrastructure and the balancing of the electricity grid. Vattenfall also has a lot of power, but they have somewhat less due to being one of the many producers and suppliers of electricity. Shell can influence the government due to their economic importance through lobbying and is actively interested in the energy transition due to it directly affecting their business model. The European Union is less interested in the Dutch energy transition specifically but has the power to intervene if the Netherlands does not complete energy transition goals in time. Vereniging Eigen Huis has less power and influence but still quite a lot, as the cooperation of homeowners is crucial towards speeding up the energy transition.

Extinction Rebellion and Greenpeace are both environmental organisations, who therefore have a very high interest in the energy transition, while having less power to influence it. Extinction Rebellion has more power here due to their actions reaching the national news more often. Citizens have a moderate interest in the energy transition, as some citizens care a lot about it while others focus on different issues. Their individual power is low, but their collective power would put them near actors such as the government and the EU. The last actor MKB Nederland still is interested in the energy transition, but it is not their focus. As representative of 90% of small and middle-sized companies in the Netherlands they do however have major economic importance and therefore lobbying power to influence the course of the energy transition.

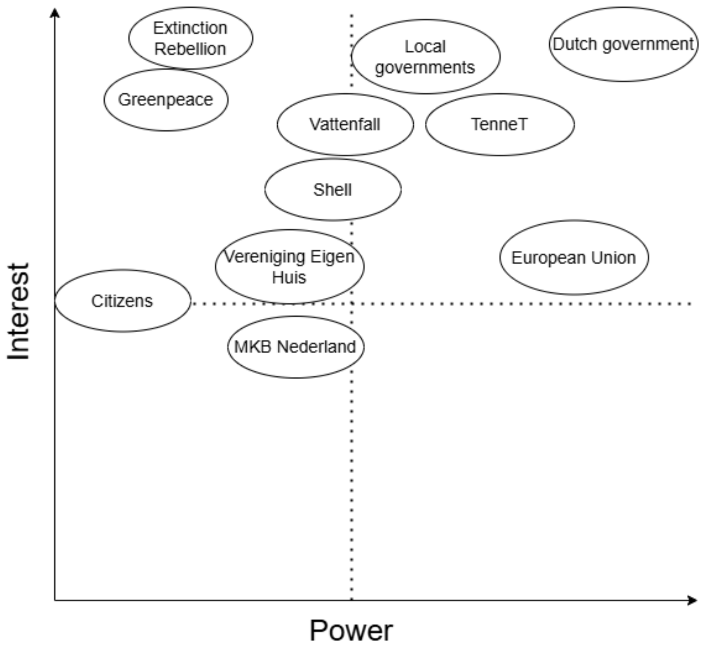

Figure 45: Power-interest grid Dutch energy transition

7.3 Causal-relation diagram

To consider all the interests of the actors it is important to put their goals in a causal-relation diagram as criteria. The general criteria in this research are economic growth measured by GDP, carbon emissions and quality of life. These are mentioned in the main research question and the fifth sub question 'What strategies are the most effective in tackling the energy transition while maintaining the quality of life of Dutch citizens?'. All actors think the energy transition is important, but their level of importance is quite different, as well as the decisions they make. For example, Extinction Rebellion wants to reach net zero emissions almost immediately, while Shell wants to reach it much more gradually. Actors such as MKB Nederland and Shell also put a much higher importance on economic growth than Extinction Rebellion and Greenpeace. The three criteria GDP, carbon emissions and quality of life therefore showcase different priorities of the actors and the choices which must be made between them. It is difficult to achieve a high GDP, net zero carbon emissions in 2050 and a good quality of life all at the same time. This dilemma also showcases the difference between a green growth and degrowth approach.

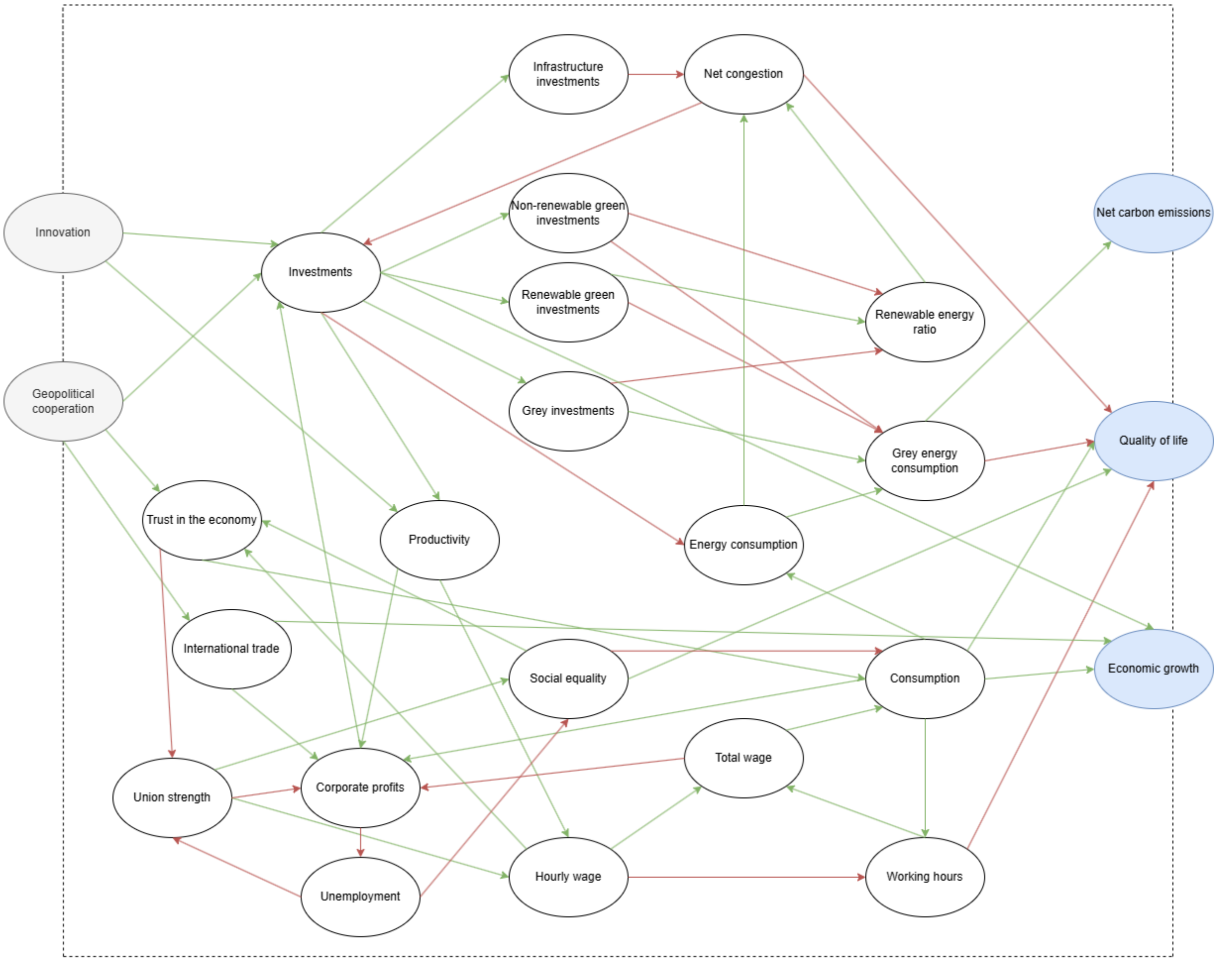

Figure 46: Causal-relation diagram energy transition (corrected for inflation)

The causal-relation diagram shows various relationships within the green growth and degrowth discussion. Firstly, investments can be divided in several categories, both within the energy sector, as well as outside the energy sector. Investments outside the energy sector will result in productivity increases, which in turn cause more corporate profits. These investments will also directly contribute to economic growth. Within the energy sector, investments can be split in several subdivisions. For simplicity, these have been split in four categories, infrastructure, non-renewable green energy, renewable green energy and grey energy. Infrastructure needs to be developed to handle increasing amounts of energy consumption, as well as an increasing ratio of renewable energy within the electricity grid.

Outside of the electricity sector, a lack of storage could also result in congestion in periods with low amounts of wind and solar energy available, while there is a high energy demand. Less investments in infrastructure would have to be made with a lower amount of renewable energy, compared to non-renewable energy. However, investments in for example nuclear energy are more expensive and more biofuels have the downside of much more land usage being needed. Net congestion itself is bad for investments, as the grid is full, and quality of life due to people not having enough energy at certain moments for their daily energy needs. Quality of life in turn is influenced by consumption, as well as social equality and the number of working hours. As people consume more, more of their needs tend to get fulfilled and if social equality increases, people tend to be happier overall (Kallis, et al., 2018). The same goes for less working hours, which offers people more time for leisure or volunteer work, increasing overall quality of life (Kallis, et al., 2018).

The relationship between social equality and consumption is more difficult. However, when income inequality is large, people tend to consume more to appear as if they have a higher status than they actually have (Pybus, Power, Pickett, & Wilkinson, 2022). Finally, there are the relations around unions. If trust in the economy goes up, less people are inclined to join unions as they tend to already have a good life. Unions in turn help to improve wages and social equality at the cost of corporate profits. If corporate profits decrease too much, this results in higher levels of unemployment, which would negatively impact union strength. Unemployment also negatively impacts social equality. There are many of these feedback loops in the causal-relation diagram, indicating a lot of the energy transition and economic situation of the Netherlands is a balancing act.

7.4 Alternatives

To work towards improving the criteria of the causal-relation diagram, the government has several alternatives it can use. Different alternatives could be used in combination with each other to achieve the best results for the energy transition.

7.4.1 Possible alternatives

A0: The zero option

This is the standard option, in which the government decides not to change the status quo of the energy transition.

A1: Higher government infrastructure investments

In this alternative, the ministry of climate and green growth will invest much more in the energy transition than it currently does. Instead of 3.6 billion euros, it will spend 10 billion euros per year which is increased with an average inflation of 2%. These extra investments will be done in infrastructure, helping grid operators such as TenneT reduce net congestion, in turn stimulating actors such as Vattenfall and Shell to invest more into green energy. This alternative will result in a higher government debt to GDP however, as discussed in the model results in chapter 6.3.2.

A2: Government owned power plants

This alternative assumes the government invests money into building its own power plants, including nuclear power plants or wind farms at sea, to reach net zero carbon emissions more quickly, while recovering the investment costs over time. The government will have to look out whether their ownership threatens private actors in the market however, as indicated by European rules regarding energy liberalisation. The costs will be assumed to be 10 billion euros per year, meaning large expenditures in the first years but return on investments after the power plants have been built.

A3: Stimulate business investments in green energy

The government could also try to influence businesses to invest more into green energy by organising targeted campaigns at businesses and promoting a green sentiment within the population. The government creates a clear plan with energy transition goals in the coming years, which should incentivise business investments, due to offering more stability. The question remains to what level this strategy would stimulate business investments, as the government only creates a plan and sets up campaigns here. It does not invest more into the energy transition itself or offer subsidies in this alternative.

A4: Subsidise green energy

This alternative could be combined with alternative 3 to further stimulate business investments in the energy transition. By making green energy cheaper, businesses could invest much more, while also offering lower prices for consumers, making it cheaper for them to switch from grey alternatives to green alternatives as well. This alternative has a similar problem to alternative A1 however, as green energy subsidies could get quite expensive overall. Actors including Vattenfall, MKB Nederland and Shell would likely support this alternative.

A5: Reduce fossil subsidies

Fossil energy is currently still being subsidised, and environmental organisations such as Greenpeace and Extinction Rebellion want to see these subsidies being removed as quickly as possible, while organisations including MKB Nederland want to decrease fossil subsidies albeit at a much lower pace. This alternative seeks a compromise between actors by slowly decreasing fossil subsidies, so infrastructure and green investments can be gradually done before grey energy becomes a lot more expensive and companies miss a lot of income. This also saves government costs and can therefore be combined with alternative 4 to keep the energy price stable.

A6: Implement Universal Basic Income

To decrease the number of working hours and increase social equality, the government could implement Universal Basic Income (UBI) to allow everyone to earn at least a living wage. This would increase social equality, while reducing consumption and therefore grey energy consumption. Assuming every Dutch citizen would get 1000 euros per month through UBI the total costs for this would be 216 billion euros per year however, which is already half the current government budget and twice the current expenditures for social welfare. Without a lot of tax increases for the highest incomes or a lot of automation from the fourth industrial revolution scenario, this would quickly result in a very high government deficit.

A7: Reduce the standard work week to 32 hours

By reducing the work week to a standard 32 hours, the government could incentivise a shift from working a lot for a high income to consume, to focusing on free time and using this for leisure, social contact and personal development. This could increase the quality of life of Dutch citizens without costing a lot of money for the government to implement. Through the decreased consumption caused by the lower working hours, energy consumption will decrease causing lower carbon emissions. However, it will also lower investments, as less consumption means fewer corporate profits and therefore less investments. However, the decrease in energy consumption should still help move towards climate neutrality, despite lower green investments.

A8: Consumption reduction campaign

By setting up a campaign with tips to help reduce consumption, the required investments to become carbon neutral severely decrease, which helps the energy transition. This campaign could include a to-do list or a sort of bingo card with actions people could undertake to reduce their consumption or energy consumption specifically. It could also include options to switch consumption to more sustainable goods, nudging consumers in the right direction by giving positive feedback.

A9: Household energy transition subsidies

To get households and housing corporations onboard and cooperate with actors including Vereniging Eigen Huis, the government could decide to introduce more solar energy subsidies. This will help reverse the solar market decline caused by the removal of the salderingsregeling, as mentioned in chapter 4.2. Aside from solar energy, these subsidies could also include subsidies for buying a heat pump, household energy storage or just insulating people's homes to reduce energy consumption. While costing more than an energy reduction campaign, this alternative could get lower income households onboard with the energy transition as well.

A10: Higher carbon taxes

To decrease carbon emissions even further, the Dutch government could decide to increase the carbon taxes beyond the current level established within the European Union. Alternatively, the government could try to increase carbon taxes on a European level to decrease the chance of companies moving to other countries. This would further decrease emissions in the Netherlands, while earning the government more money which can be invested into the energy transition. These carbon taxes will be partially worked through to consumers, decreasing their purchasing power. The effect of this alternative would be relatively similar to the alternative of gradually decreasing fossil subsidies.

A11: Circular economy laws

Another method to decrease resource usage and therefore carbon emissions, is by making products more durable and incentivising recycling, creating a circular economy. To achieve this, the government could set up more regulation regarding goods and services, which is more effective if done on the European level. Therefore, the government will have to convince the EU to establish more regulation as it is not feasible for the Netherlands to make substantial changes to product requirements on its own.

A12: Higher luxury consumption taxes

Another way to limit consumption, and therefore further the energy transition through degrowth policy, is introducing higher luxury consumption taxes. Current consumption taxes are 21% for most products and 9% for food and some other goods such as books. The government could instead tax luxury products a higher amount, for example 30-40% while decreasing consumption taxes for food and other basic goods. By compensating an increase in luxury consumption taxes with a decrease in basic consumption taxes the feasibility could be higher, while also ensuring the quality of life of lower income citizens does not decrease. Consumption can be decreased through this policy and social equality increased, working towards the energy transition while maintaining quality of life.

A13: More progressive taxation

Instead of focusing on changing the amount of tax, the government could redistribute the tax system by making higher incomes pay a relatively higher share than lower incomes. A more progressive tax system would also include higher dividend taxes or taxes on the profit people make with shares, as these taxes mainly influence the richest share of the population. Changing the tax burden could increase social equality and therefore limit consumption of status goods. This would impact government debt to GDP however, increasing quite a lot.

7.5 Conclusion

This chapter showcased several dilemmas within the energy transition and how strategies such as green growth and degrowth are affected by the important actors operating in the Netherlands as well as how these strategies affect them. The Dutch government has a plethora of options to choose from to help reach climate neutrality, but these options all have dilemmas such as increasing government debt, decreasing purchasing power of consumers, potentially causing companies to move out of the Netherlands or conflicts between actors which could make an alternative difficult to implement.

If the government focuses on green growth through increasing renewable investments, this could result in more net congestion showcasing additional need for infrastructure investments. Less energy consumption caused by degrowth policy, would result in less infrastructure investments needed but could also be difficult to implement. The government will have to consider how these relations impact the energy transition as well as economic growth, quality of life of citizens and the government budget itself. The alternatives all have positive and negative consequences as well as different actors who would support them, increasing or decreasing feasibility through societal support and resistance. A balance between green growth and degrowth policy could cause additional support from actors, helping in speeding up the energy transition while overcoming excesses caused by a purely degrowth or green growth policy.

The next chapter will rank the alternatives and screen the alternatives based on feasibility and efficacy on the energy transition, both degrowth and green growth alternatives. This chapter will then formulate suggestions based on how these alternatives impact the criteria, through using a score and SMART card.

8 Multi-criteria analysis

This chapter will use the alternatives discussed in the previous chapter and rank them based on feasibility and effect on the energy transition, using a mix of green growth and degrowth alternatives. These alternatives will be included in a problem diagram and then compared in a multi-criteria analysis, using a score card and SMART card to rank them in detail. This will help answer the last sub question, showcasing which strategies are most effective in tackling the energy transition, while maintaining the quality of life of Dutch citizens.

8.1 Alternatives screening

The alternatives discussed in chapter 7.4 will be screened by giving them a score in feasibility and efficacy in completing the energy transition. Alternative 0 won't be screened as other alternatives will be compared to the base scenario, to show which effect they have compared to the status quo.

Alternative	**Efficacy**	**Feasibility**	**Total**
A1: Higher government infrastructure investments	8	7	15
A2: Government owned power plants	7	6	13
A3: Stimulate business investments in green energy	4	10	14
A4: Subsidise green energy	7	7	14
A5: Reduce fossil subsidies	5	8	13
A6: Implement Universal Basic Income	3	3	6
A7: Reduce the standard work week to 32 hours	5	7	12
A8: Consumption reduction campaign	4	10	14
A9: Household energy transition subsidies	8	8	16
A10: Higher carbon taxes	5	7	12
A11: Circular economy laws	6	6	12
A12: Higher luxury consumption taxes	8	7	15
A13: More progressive taxation	6	8	14

Table 7: Alternatives screening

The feasibility of alternative 3 and alternative 8 are the highest, due to it being relatively easy for the government to set up a promotion campaign and the costs being relatively low (Ministerie van Algemene Zaken, 2025). Offering more household energy transition subsidies has a high feasibility, due to many parties likely supporting this as it will increase the purchasing power of households. Implementing Universal Basic Income is the most difficult alternative to implement, as it costs a lot of money and requires changing the entire welfare system. This alternative is also not highly effective at reducing carbon emissions, as it does not focus on carbon reduction but redistribution of wealth. Alternatives 10 and 11 depend on whether the government can lobby these ideas to the European Parliament, as the efficacy is very low if the Netherlands would be the only country to implement higher carbon taxes or circular economy laws. The EU also already has a circular economy action (European Commission, 2025c), meaning it is better for the Dutch government to not put forward its separate plan as well. Eventually, alternative 1: Higher government infrastructure investments, alternative 9: Household energy transition subsidies and alternative 12: Higher luxury consumption taxes will be taken into consideration, having the highest total points. Alternative 13, more progressive taxation will also be taken into consideration to consider two degrowth related alternatives and two green growth-related alternatives.

8.2 Problem diagram

The problem diagram adds the four chosen alternatives and shows how they influence the causal-relation diagram of chapter 7.3. Most of these influence two variables and all of them eventually have an impact on the three criteria in the problem diagram. Household energy transition subsidies influence both energy consumption, through increased insulation of houses and installation of heat pumps, and renewable green investments through extra solar panels. Higher infrastructure investments cause increased investments through reducing net congestion, helping the energy transition and increasing economic growth and quality of life. Household energy subsidies help households directly, increasing both their purchasing power while furthering the energy transition, positively influencing net carbon emissions and quality of life, while having a smaller effect on economic growth. A consumption reduction campaign reduces economic growth but increases quality of life through less net congestion and less working hours. Higher luxury consumption taxes increase social equality while decreasing consumption, ensuring quality of life can be maintained, while net carbon emissions and economic growth decrease.

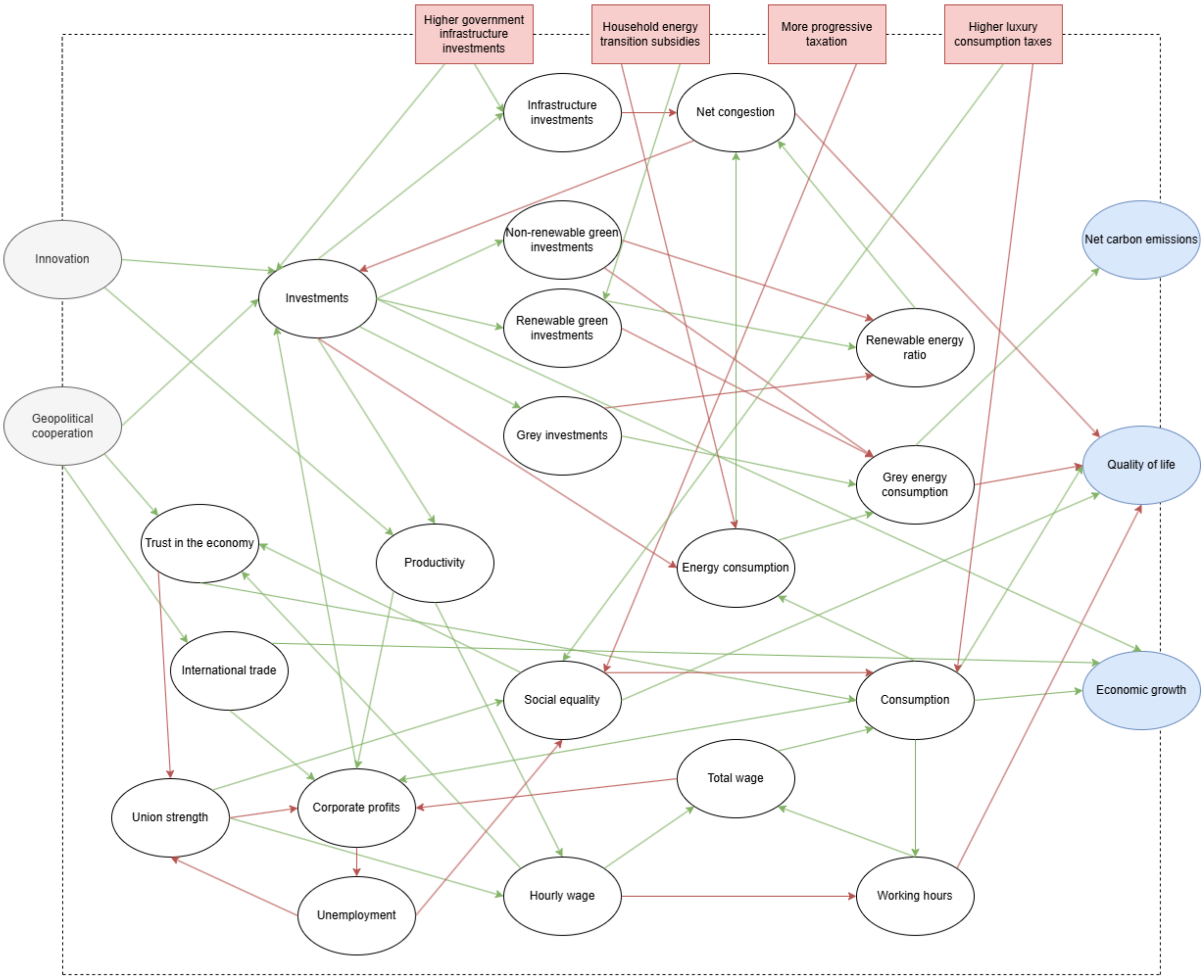

Figure 47: Problem diagram energy transition (real values)

8.3 Score card

The different alternatives can then be ranked through a score card. Most of these are ranked by using the macroeconomic model, except for the factor quality of life. Quality of life will be given a score of 5.5/10 in the base scenario, with a lower value indicating a decrease in quality of life and vice versa. First it is important to define how the alternatives affect the different criteria.

Higher government infrastructure investments will cost 10 billion euros per year extra for the government starting 2026, then increased by inflation. The private sector will invest an extra amount of 5 billion euros per year into the energy transition, due to the trust gained through the government's commitment to the transition. Household energy transition subsidies will cost the government 5 billion euros a year and will lower energy consumption due to increased insulation of homes as well as through heat pumps. Energy consumption is expected to decrease by a factor of 1% per year in this scenario. Companies will invest 3 billion euros per year more, as the government shows consistent investment into the energy transition. Higher luxury consumption taxes will increase the average consumption tax rate from 16.3% to 25%, causing an overall decrease in consumption. More progressive taxation will instead hit income and dividend taxes. Income taxes will decrease from 34.3% to 33%, while dividend taxes which mainly affect richer households with a tax rate increase from 15% to 25%. This will cause an estimated decrease in consumption of 0.5% per year compared to the base scenario due to more social equality.

Quality of life in the scenario higher government infrastructure could be defined in the following way. Following the problem diagram, the infrastructure investments lead to lower levels of net congestion, in turn leading to a higher quality of life. The lower level of net congestion also leads to more investments, which can be seen in business investments increasing. This is also because of the government taking a leading role in the energy transition. Extra investments include extra investments in green energy which will help lower grey energy consumption and decrease energy poverty, although not as much as directly subsiding households' energy transition. Extra investments also lead to higher levels of productivity, causing people to earn a higher wage having to potentially work less hours increasing quality of life. This policy will therefore improve quality of life much compared to the zero option, increasing it to 7.

Household energy transition subsidies directly help alleviate energy poverty and work towards the energy transition. The commitment of the government will lead to higher levels of private investments as well although lower than government investments in infrastructure due to net congestion still being a concern. Due to directly helping households instead of indirectly, this policy will be scored slightly higher than infrastructure investments with a 7.5.

Higher luxury consumption taxes will instead of increase quality of life decrease it, as households cannot buy all the goods they want to buy anymore. Social equality is slightly increased in this scenario but the overall decrease in consumption levels do not make up for this increase in quality of life. People are also not able to work less in this scenario as goods become more expensive due to increased taxes. Therefore, quality of life will decrease from 5.5 to 4.5.

More progressive taxation will mainly affect the richest part of the population through higher dividend taxes but will also lower income taxes for a majority of the population, increasing their quality of life as they will have to work less to meet their needs. The higher social equality will also lead to a lower level of status good purchases and an overall increase in quality of life. Quality of life is likely still lower than through direct investments and the average decrease in income taxes is small, leading to a score of a 6.

Alternatives→ Criteria ↓	A0 Zero option	A1 Higher government infrastructure investments	A9 Household energy transition subsidies	A12 Higher luxury consumption taxes	A13 More progressive taxation
Net carbon emissions [Mton CO2]	40.7	-32.8	8.7	32.6	31.5
Quality of life [1-10]	5.5	7	7.5	5.5	6
Real GDP [bln euros]	1412	1431	1422	1343	1354
Government debt to GDP [%]	69	77.9	73.5	19.6	94.2

Table 8: Score card base scenario

As can be seen in the score card for the base scenario, real GDP would grow the quickest in the scenario of higher government infrastructure investments as both the government and private sector would invest a lot into the energy transition. Net carbon emissions would be negative in this scenario, reaching climate neutrality in 2043 already due to the high investments. The main downside is the higher government debt to GDP, increasing by 9 percentage points. Household energy transition subsidies have a lower government debt to GDP and a higher quality of life, although net carbon emissions are still slightly positive in this policy scenario. Government debt to GDP is by far the lowest in alternative 12 as the higher luxury consumption taxes generate a lot of income for the government. The effect on the energy transition is relatively low however and quality of life also decreases compared to the base scenario. Finally, alternative 13 More progressive taxation would result in similar net carbon emissions as alternative 12 and has a much higher quality of life but faces the problem of high government debt to GDP due to the reduced levels of consumption.

Alternatives→ Criteria ↓	A0 Zero option	A1 Higher government infrastructure investments	A9 Household energy transition subsidies	A12 Higher luxury consumption taxes	A13 More progressive taxation
Net carbon emissions [Mton CO2]	19.3	-40.2	-3.4	14.2	13.6
Quality of life [1-10]	6	7.5	8	6	6.5
Real GDP [bln euros]	1479	1500	1490	1407	1419
Government debt to GDP [%]	54.2	62.6	58.4	6.7	78.1

Table 9: Score card scenario 1: Long-lasting trade war

Alternatives→ Criteria ↓	A0 Zero option	A1 Higher government infrastructure investments	A9 Household energy transition subsidies	A12 Higher luxury consumption taxes	A13 More progressive taxation
Net carbon emissions [Mton CO2]	57.5	-13.2	22.4	47.8	46.5
Quality of life [1-10]	5	6.5	7	5	5.5
Real GDP [bln euros]	1327	1345	1336	1260	1271
Government debt to GDP [%]	93.6	102.9	98.3	41.8	121.1

Table 10: Score card scenario 2: Chinese invasion of Taiwan

Alternatives→ Criteria ↓	A0 Zero option	A1 Higher government infrastructure investments	A9 Household energy transition subsidies	A12 Higher luxury consumption taxes	A13 More progressive taxation
Net carbon emissions [Mton CO2]	37.6	-41.2	5	29.5	28.4
Quality of life [1-10]	6	7.5	8	6	6.5
Real GDP [bln euros]	1504	1523	1514	1434	1445
Government debt to GDP [%]	51	59.5	55.3	4	74

Table 11: Score card scenario 3: Business as usual

Alternatives→ Criteria ↓	A0 Zero option	A1 Higher government infrastructure investments	A9 Household energy transition subsidies	A12 Higher luxury consumption taxes	A13 More progressive taxation
Net carbon emissions [Mton CO2]	6.8	-55.9	-13.5	2.7	2.2
Quality of life [1-10]	6.5	8	8.5	6.5	7
Real GDP [bln euros]	1773	1797	1785	1696	1708
Government debt to GDP [%]	17.9	25.1	21.5	-22.6	36.9

Table 12: Score card scenario 4: Fourth industrial revolution

Alternatives→ Criteria ↓	A0 Zero option	A1 Higher government infrastructure investments	A9 Household energy transition subsidies	A12 Higher luxury consumption taxes	A13 More progressive taxation
Net carbon emissions [Mton CO2]	14.1	-45.4	-7.5	9.7	7.6
Quality of life [1-10]	4.5	6	6.5	4.5	5
Real GDP [bln euros]	1557	1579	1568	1493	1487
Government debt to GDP [%]	141.8	148.1	145.1	106.8	175.2

Table 13: Score card scenario 5: Extended war in Europe

Some important observations after seeing the scores of the alternatives for every scenario are for example higher infrastructure investments reaching the net zero goals for 2050 in every scenario, while household energy transition subsidies reach the net zero goals in three out of the six scenarios (five scenarios plus the base scenario). Higher luxury consumption taxes and more progressive taxation come close to net zero emissions in some scenarios such as scenario 4: Fourth industrial revolution but never reach it entirely. Government debt to GDP would also become positive in this scenario for higher luxury consumption taxes, meaning the government stops running a deficit. Ultimately, the government could compensate the increases in debt to GDP in alternative 1 and 9 with the higher luxury consumption taxes in alternative 12, having both a positive effect on the government budget as well as a reduction in overall consumption making the energy transition smoother. This would also compensate a decrease in quality of life caused by higher levels of taxation. More progressive taxation has the worst impact on government finances overall, due to the government not increasing taxes but instead redistributing them, while GDP decreases due to lower consumption and investments. This could be more effective through European wide policy, stopping leakage of investments.

8.4 SMART card

A SMART card standardises the scores of the score card and gives the different criteria a weight factor, depending on their importance. The standardised scores will be between 0 and 1, with a 0 given to the alternative having the least desired value on that criterium, while giving a 1 to the alternative having the most desired value. Net carbon emissions will be given the highest weight of 5, as this criterium shows how far the energy transition has come and whether the Netherlands undertakes extra action to remove CO2 from the atmosphere, or export excess green energy to other countries. Quality of life and Government debt to GDP will both be given a weight of 4, as quality of life is an important measure for social acceptance of the energy transition, and government debt to GDP for financial acceptance of the energy transition. Real GDP is given a weight of 2 as the importance of this factor depends on whether someone wants to grow the economy or does not prioritise this.

Alternatives→ Criteria ↓	Weight	A0 Zero option	A1 Higher government infrastructure investments	A9 Household energy transition subsidies	A12 Higher luxury consumption taxes	A13 More progressive taxation
Net carbon emissions [Mton CO2]	5	0	1	0.44	0.11	0.13
Quality of life [1-10]	4	0	0.75	1	0	0.25
Real GDP [bln euros]	2	0.78	1	0.89	0	0.12
Government debt to GDP [%]	4	0.34	0.22	0.28	1	0
Total		2.92	10.88	9.1	4.55	1.89
Rank		4	1	2	3	5

Table 14: SMART card base scenario

The SMART card shows alternative 1 scores the highest on two of the four criteria, net carbon emissions and real GDP, while scoring high on quality of life as well. It only scores relatively low on government debt to GDP, as alternative 12 decreases debt to GDP by a major amount. Alternative 9 scores good as well but the decreased amount of government investments and subsequent lower impact on carbon emissions makes this less good in comparison. While alternative 12 and 13 score much lower, this does not mean these alternatives should not be considered at all. The government can still decide to use these alternatives in combination with other alternatives to speed up the energy transition and keep their finances in check.

Ultimately, the green growth alternatives score better than the degrowth alternatives which can be attributed to cascading effects by investments. Initial investments, such as the government improving infrastructure, will most likely lead to more business investments, which means more productivity and an even quicker energy transition. The increased levels of productivity will offer people the opportunity to work a lower number of hours and increase their standard of living. Nonetheless, it should be considered that there are limits to growth. The Earth only has so many resources, which will eventually be depleted if societies around the world do not switch to a more circular economy. However, a circular economy could still experience growth due to increased levels of innovation, allowing for increased levels of consumption, as consumption becomes more efficient. A similar effect could be seen in Dutch energy consumption, as discussed in chapter 4 and appendix A. Decreasing energy consumption is more effective than decreasing overall consumption, which would still result in a green growth scenario, as money not spent on energy can be used in other areas, so overall consumption stays the same.

8.5 Conclusion

This chapter looked at the different alternatives discussed in chapter 7 and how they impact the energy transition. Four alternatives were chosen which scored the highest in a combination of feasibility to implement and efficacy. Two alternatives followed a degrowth strategy while the other two alternatives followed a green growth strategy. The green growth alternatives, higher infrastructure investments and household energy transition subsidies have a high impact on the energy transition due to more than doubling current and future green investments. This result in net zero or even negative carbon emissions in all scenarios for higher infrastructure investments and net zero or negative carbon emissions in half the scenarios for household energy transition subsidies.

The degrowth alternatives also decreased the total amount of carbon emissions but by a lower amount than the green growth alternatives. This is due to these alternatives focusing on overall consumption instead of specifically focusing on energy consumption or green investments as the green growth alternatives do. Implementing degrowth alternatives can also be more difficult, as decreased consumption leads to a higher government debt to GDP except if compensated by higher levels of taxation. If higher levels of taxation were to be implemented however, this would result a lower quality of life.

Eventually, the government as well as the different actors within the energy transition have a lot of options to choose from to go forward in the energy transition. It is relatively difficult to measure the exact efficacy of each measure, but action taken right now would make the road towards climate neutrality easier. Actions from one actor can also pave the road for other actors to follow them, as for example companies would be more likely to invest more into the energy transition if the government shows a clear commitment towards the transition as well.

9 Discussion

The findings of this research show several paths the Netherlands could take to complete the energy transition in 2050, through a degrowth and green growth policy, depending on multiple scenarios. Green growth would require additional investments ranging from about 5 billion euros to 15 billion euros per year until 2050, corrected for inflation. Degrowth would require real consumption reductions up to 50% in 2050. This has been mainly determined through macroeconomic modelling using the cost estimation by Kerkhoven & Hanemaaijer (2025) while adjusting these numbers for higher infrastructure investments needed (Nillesen, de Lange, & van Heugten, 2024) (Ekker, 2025).

This research used a macro-economic model to determine the economic consequences of green growth and degrowth. The real GDP in this model is similar to the GDP in 2050 determined by other studies such as the one by CPB (2024), accounting for their different scenarios. The starting value of 1130 billion euros in the CPB model is also similar to the 1109.5 billion euros in the model used in this research. Unlike this research which used several scenarios based on external factors, the CPB opted to use policy scenarios. This already showcases a difference in methods making the two models more difficult to compare. Nevertheless, the CPB scenario 'sustainable' is comparable to degrowth policy while the scenario 'market' is comparable to green growth. The effect of both scenarios on GDP is similar as well, with a maximum increase of 72% in real GDP compared to the maximum increase of 60% in this research.

A limitation of the macroeconomic model used in this study is the behaviour of some variables being linearly defined, while in reality these would form an S-curve. This can be seen through the increasing green energy mix which does not to slow down once production reaches 100% of consumption, resulting in a less realistic conclusion near the end of the timespan of the model. While production could in theory increase and be used for exports, phasing out the last fossil fuels will likely face problems such as sustainable aviation which is very unlikely to become sustainable before 2050. Another limitation is the way inflation has been defined, which is now constant in both degrowth and green growth policy, although this could be lower with degrowth due to the lower consumption.

There is also a question about definitions. As mentioned in chapter 3, different definitions are used for green growth and degrowth with degrowth especially being defined differently, as Van den Bergh (2011) also mentioned. The Ministry of Climate and Green Growth also had no clear definition of green growth. The lack of concrete definitions can make it more difficult to compare different research as well as measure people's opinions about the two policies, as the person filling in a survey might think of it differently than the person who created the survey. This study used a more concrete definition of degrowth and green growth which can be different from the definition used by other studies but should make it easier to determine where the differences lie.

The same can be said for the criterium 'quality of life' used in chapter 7 and 8, as what exactly constitutes quality of life is difficult to say. Quality of life here has been used in a more economic term (available consumption, number of hours of free time) but quality of life also depends on personal factors which can be difficult to determine. It is therefore difficult to argue whether green growth or degrowth would improve people's quality of life. An example of this is additional consumption potentially improving people's quality of life, while consuming less and being happy with what you have, also being positive for quality of life.

Regarding the literature review, several studies such as Hickel & Kallis (2019) argued a green growth approach would not be enough to become climate neutral in 2050, as innovative technologies will not cause a decoupling of economic growth and increasing sustainability. The paper by Van Vuuren et al (2017) argued sustainable development or a green growth approach can be beneficial in ensuring public support for taking climate action. The study by Hao et al (2020) finds a green growth strategy is possible and potentially more viable to be implemented than a degrowth strategy. Based on the literature research and economic modelling this study finds green growth would be a more viable alternative than degrowth due to much lower costs (a maximum of 15 billion euros extra per year real investments or about 1% of GDP, compared to degrowth which requires up to 50% real consumption reduction). Continuing to grow the economy, while reaching sustainability goals therefore seems possible. However, this study did not focus on specific sectors in the model. Sectors which would have high difficulty with the transition, such as the aviation sector, could therefore not be suitable for green growth. Degrowth could be the answer for those specific sectors which can otherwise not become climate neutral in 2050, reducing the amount of carbon capture storage needed to mitigate the carbon emissions of those sectors.

10 Conclusion, further research and reflection

10.1 Conclusion

The energy transition is considered to be one of the biggest challenges of the current day. An important aspect of this transition is what approach society should take to become climate neutral. One of these approaches, green growth, assumes economic growth can be sustainable through innovation and investments. The other approach, degrowth, assumes innovation and investments will not be enough and society needs to massively decrease their consumption. This thesis researched the influence of green growth and degrowth on the Netherlands through the main research question:

'What is the influence of green growth and degrowth on the Dutch economy and energy transition in the Netherlands?'

This main research question has been answered through five sub-questions, using those conclusions together to form an answer to the main research question.

Firstly, the state of the Dutch economy and energy transition was researched. The economic outlook of the Netherlands is quite positive with low levels of unemployment and a low government debt to GDP between 40% and 45%, although inflation is still higher than the required level of 2%. This showcases enough financial space to invest in the energy transition, but these investments should be smart, not to cause higher levels of inflation. The outlook on the energy transition is somewhat worse, as while more than half of electricity consumption is currently being supplied by renewable energy, only 15% of total energy consumption is supplied by green energy. Half of this is through biomass, which in large quantities is often produced in unsustainable ways. This shows quite a challenge in reaching climate neutrality in 2050.

Secondly, external factors such as innovation and geopolitics could influence the energy transition considerably. Development of new types of batteries such as redox-flow, solid-state and metal-air batteries, as well as improvements in currently used batteries such as lithium-ion, could increase further development of renewable energy without causing infrastructure problems such as net congestion. Efficiency of solar panels and wind turbines is also expected to increase, while new innovations such as Small Modular Reactors could offer more stable small-scale production of nuclear energy. Innovations such as nuclear fusion or sustainable aviation are however unlikely to be implemented before 2050, meaning sufficient carbon capture storage will be needed to complete the energy transition in sectors which cannot become fully sustainable.

Geopolitics is very important due to how interconnected the world is, both in its energy infrastructure as well as its economy. If the trade war with the US continues for a long time or China would decide to invade Taiwan, this could disrupt supply chains and potentially delay the energy transition. Conversely, it could also cause more protectionist policies, with countries choosing renewables to become more energy independent. The choice for a degrowth or green growth policy could influence geopolitics, as a degrowth policy could lead the Netherlands to become more dependent on other countries and cause a larger debt to GDP, decreasing geopolitical leverage. Green growth policy could increase energy independence and lead to the Netherlands producing more green energy than it consumes, allowing exports and therefore increasing leverage. This could in turn influence other countries to achieve climate neutrality faster as well.

With this information, the third and fourth sub-questions were researched, which analysed the impact of green growth and degrowth policy on the economy and energy transition. Five scenarios were analysed based on the external factors innovation and geopolitical cooperation. These five scenarios were: 'long-lasting trade war', 'Chinese invasion of Taiwan', 'Business as usual', 'Fourth industrial revolution' and 'Extended war in Europe'. Four of these scenarios, together with the base scenario, showed major investments or major degrowth needed to reach climate neutrality in 2050. The only scenario which did not require large changes was the fourth industrial revolution scenario. While increasing private green investments would be the cheapest option for the government, this would also be very difficult to realise. Alternatively, the government could increase green investments itself, although this results in an increasing government debt to GDP, which already becomes higher than 60% in the base scenario. The government stimulating a decrease in consumption would be possible but would also result in higher levels of debt to GDP due to GDP growth coming to a halt while government expenses maintain a high level. Degrowth policy to reach climate neutrality would not result in true degrowth but 'a-growth', as real economic growth comes to a halt but does not decrease. While green growth policy results in the expected economic growth, it is unclear whether society accepts to invest much more in the energy transition.

For the energy transition itself, green growth policy would have to be balanced as investments in for example the renewable energy sector would also require additional investments in energy infrastructure to mitigate net congestion. Degrowth policy would require less investments into energy infrastructure but could be more difficult to implement due to a lack of public support. While there are a lot of alternatives the government could use to speed up the energy transition through degrowth or green growth, these alternatives require the cooperation of several societal actors. Some of these alternatives would also require international cooperation with other countries in the European Union, such as building a circular economy, as many laws would have to be changed. It also would not be effective to implement alternatives such as these as the Netherlands specifically, as companies could move to other countries, meaning the energy transition comes to a halt again. A balance between green growth and degrowth policy could cause more actors to cooperate with the government and lead to a smoother and quicker energy transition.

The fifth and last sub-question researched the most effective strategies to tackle the Dutch energy transition while maintaining the quality of life of Dutch citizens. Two green growth alternatives were analysed which the government could implement: higher government infrastructure investments and household energy transition subsidies, as well as two degrowth alternatives: higher luxury consumption taxes and more progressive taxation. Additional real government infrastructure investments of 10 billion euros per year, combined with an additional real 5 billion euros private investments into green energy would result in the energy transition being completed in every scenario, with much higher production of green energy than consumption. These extra green investments would come down to about 0.5% to 1.5% of GDP. If total real additional investments were 8 billion euros instead, like in the household energy subsidies alternative, climate neutrality would be reached in half the scenarios. Quality of life would also increase with these alternatives due to less energy poverty and less net congestion.

The two degrowth alternatives would result in working towards climate neutrality but only come close to reaching it in the fourth industrial revolution scenario. Higher luxury consumption taxes would result in a higher level of government income and therefore lower debt. However, it would result in quality of life stagnating, as the lower basic consumption taxes do not fully make up for the decrease in purchasing power for luxury goods. More progressive taxation would slightly help quality of life by making it more equally distributed. A downside to this alternative is the lower consumption and therefore lower GDP causing a higher debt to GDP. In total, real consumption would have to decrease by up to 50% in 2050 compared to 2024 to reach climate neutrality, depending on the scenario.

In conclusion, this research finds green growth has a more positive impact on the Dutch energy transition and economy than degrowth has. However, a combination policy where energy consumption decreases while green investments are considerably higher is still very helpful to reach the energy transition goals even more smoothly. Whichever strategy is chosen; it is clear the Dutch government will have to take much more action to reach climate neutrality in 2050.

10.2 Further research

To validate the findings of this research, future research could include a larger, more detailed macroeconomic model than the one used here, to more precisely determine the impact of a degrowth strategy compared to a green growth strategy. Such a macroeconomic model could for example look at different income groups and how much people in each group consume. This could help create more detailed degrowth and green growth policy. It could also look at how inflation is impacted by degrowth an green growth. These aspects could help the government more accurately decide which combination of strategies to implement, while leaving enough budget for the many other expenses the government has.

Another aspect which has not been focused on in this research is societal support for degrowth and green growth in the Netherlands. While green growth and degrowth are economically feasible, although they both have a certain cost, implementing them would require sufficient societal support. Further research could focus on polls and interviews to more accurately determine the opinions of the different actors involved in the energy transition. It could also look at political movements and political parties in the Netherlands and how these influence support for green growth and degrowth.

More research could also be done into the total costs of the energy transition as well. This study used the cost estimation by Kerkhoven & Hanemaaijer (2025) and adjusted it upwards, due to extra infrastructure investments needed. If the costs of the energy transition were determined to be lower than expected, degrowth might become more feasible as the up to 50% reduction in real consumption found here does not seem feasible due to the lack of public support such a policy would likely experience.

Finally, geopolitics is an important factor in the energy transition. Green growth and degrowth can both influence the geopolitical leverage the Netherlands has to convince other countries to take more climate action as well. Other countries can however also influence the Netherlands to take a green growth or degrowth approach if they have a lot of leverage over the Netherlands. The energy transition choices taken by the Dutch government could influence the choices of other governments and vice versa, but this exact effect is still unknown.

10.3 Reflection

Before doing this research, I had a relatively neutral opinion about degrowth and green growth, being unsure which strategy would be more feasible to implement. With the initial literature review as well as further literature research regarding this topic, the division between proponents of green growth and degrowth seems quite large. A lot of arguments come down to either green growth being insufficient to achieve climate neutrality while also keeping the current illusion of constant growth, or degrowth being economically unfeasible or lacking public support. Through the course of this research, my own opinion has shifted somewhat towards the green growth side, as the macroeconomic model used shows the needed investments for green growth are a lot lower than the required consumption reduction in green growth. Economically, degrowth does not seem feasible as long as we use a capitalist economic system. Changing the current system could be possible, but this requires so many systematic changes that economic effects would likely fall outside of the scope of what can be realistically determined.

Aside from the economic argument, there is also the public support element of green growth and degrowth. While there are organisations such as Extinction Rebellion which explicitly plead for degrowth, public resistance for their actions seems to increase. This is combined with voting tendencies shifting to parties which do not find climate change important enough and want to focus on other issues instead. I therefore think the public support argument for degrowth, while potentially being true in some countries, would not work in the Netherlands. A question which remains however is what definition of green growth and degrowth are used by people and organisations. As discussed in chapter 3 these definitions are not clearly agreed upon. If a much less strict definition of degrowth were then used, it might be a lot more feasible than degrowth as it is defined in this report but might then not be able to reach the climate goals before 2050.

With this research, I hope to contribute to the degrowth vs green growth discussion, providing more data which can be used to further energy transition policy. As the macroeconomic model used in this research is quite simple, a larger model would be needed to more accurately reflect the costs of a green growth or degrowth approach. Unfortunately, this was not possible within the scope of this research, which was done from March 2025 until June 2025, as well as the resources of a single student. Nevertheless, the overall conclusions of this research, as well as the overview of the entire Dutch energy transition and economic situation can be used within further research and for helping the Dutch government decide on which energy transition policy to take. I find it important that the scientific community continues research regarding this topic, to find the most feasible solutions for the energy transition and ensure enough public support can be realised to stop climate change in time.

Disclaimer

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Appendix

Appendix A: Model values

General economic indicators

GDP in 2024 until 2026 is expected to be respectively 1130.8, 1182.8 and 1228 billion euros (European Commission, 2024a). National savings are expected to be respectively 345, 359.9 and 371.5 billion euros (European Commission, 2024a). These are private savings and public savings together. Total consumption including government expenditure is 772.4, 808.6 and 842 billion euros (European Commission, 2024a). Subtracting national savings, consumption and government expenditure from GDP then results in 1130.8-166.6-772.4 = 191.8 billion euros in 2024, 1182.8-174.5-808.6 = 199.7 billion euros in 2025 and 1228-179.6-842 = 206.4 billion euros in 2026. As total investments are equal to national savings plus foreign savings, and foreign savings are equal to exports-imports, foreign savings should be 191.8/2 = 95.9 billion euros in 2024, 199.7/2 = 99.85 billion euros in 2025 and 206.4/2 = 103.2 billion euros in 2026. This means total investments are 95.9 + 166.6 = 162.5 billion euros in 2024, 99.85 + 174.5 = 274.35 billion euros in 2025 and 103.2 + 179.6 = 282.8 billion euros in 2026.

Population and consumption

The input variable population will use the population as predicted by the Dutch population pyramid (CBS, 2025m). This pyramid starts with 17.9 million inhabitants in 2024 and ends with 19.7 million inhabitants in 2050. In 2024 about 9.8 million people were working (CBS, 2024e) which is about 54.6% of the population. This percentage is used to calculate the amount of working people in the Netherlands with the rising population. The average gross income of people in the Netherlands in 2022 was 48100 euros per year with 10.1 million people getting a primary income (CBS, 2024f). This is similar to the 9.8 million people working in the Netherlands in 2024, although slightly different which could be explained by some people earning two primary incomes. Assuming wages went up with 2% per year, wages would be about 50,000 euros in 2024. 50,000 x 9.797 = 489,8 billion euros total wages.

According to the Miljoenennota of 2024, the state should receive 90.8 billion euros through income taxes as well as 77.1 billion through insurances financed through income tax (Rijksoverheid, 2023e). That means the total income tax is 167.9 billion euros or an average of 167.9/489,8 = 34,3% of people's income which seems realistic compared to the income tax in box 1 and 2 of respectively 35.82 and 36.97%, with people with low incomes paying almost no income taxes (Rijksoverheid, 2025). The total amount of welfare expenditures from the government are 110.9 billion euros in 2024 (Rijksoverheid, 2023e) which is provided to non-working people in the model so 110900/(17.943-9.797) = 13614 euros per person. The total amount of healthcare taxes is 56 billion euros (Rijksoverheid, 2023e) or 56000/17.943 = 3121 euros per person. The total amount of healthcare expenditure is 111.3 billion euros or 111300/17.943 = 6203 euros per person. Lastly, consumers receive income through dividends. The dividend tax rate is 15% (Belastingdienst, sd) and dividend tax income was 6.5 billion euros (Rijksoverheid, 2023e). This means total dividends before taxes were 43.3 billion euros and after taxes 36.8 billion euros.

Consumption taxes

For consumption taxes, the BTW amounts of 21% for general consumption and 9% for basic goods consumption, while some products are exempt from taxes (Belastingdienst, sd). Total consumption before tax was 488 billion euros in 2024 (27200 euros consumption per inhabitant (European Commission, 2024a)* 17.943 million inhabitants). Total consumption tax income in 2024 was 79.5 billion (Rijksoverheid, 2023e). Therefore, total consumption after tax was 408.5 billion euros with an average consumption tax rate of 79.5/488 = 16.3%. This seems realistic, as it falls between the 21% and 9% consumption tax rates on most goods and services. The current savings and debt of households can be calculated by adding the savings, deposits, portfolios and other shares, while subtracting short term and long-term debts such as mortgages. The total amount is then 559.72 (savings and deposits) – 0.142 (short-term debts) – 4.283 (long-term debts) – 0.085 (short-term loans) – 12.042 (long-term loans) – 5.120 (mortgages outside of those with financial institutions) + 19.079 (own shares) + 72.993 (shares in investment funds) = 634.728 billion euros (CBS, 2024g).

Investments

Total investments in 2022 were 208.818 billion euros (CBS, 2025p). Inflation was relatively high in this period, and it was a period of economic recovery after Covid. Therefore, it can be assumed investments went up with 4% per year, which would result in 225.9 billion euros investments in 2024. Assuming these investments went up with 2% per year instead, this would mean total investments in 2024 were 217.254 billion euros. Of these investments a part will be green investments. Green investments in the period 2024-2030 are expected to be 33 billion euros in total or 5.5 billion euros per year, while a total of 39 billion euros or 6.5 billion euros per year would need to be invested in order to meet the 2030 energy transition goals (ESG, 2024). Therefore, there is an investment gap of 6 billion euros in the coming years with current policy.

Corporate taxes

The main type of taxes corporations must pay are profit taxes. Other taxes include excise duties, transference and environment taxes. For simplification, these taxes are also included in corporate taxes making for a total of 46.2 (profit taxes) + 3 (gifts and inheritance taxes) + 1 (gambling taxes) + 13.9 (excise duties) + 8.2 (environment taxes) + 7.6 (transference taxes) + 4.9 (vehicle taxes) + 1.5 (bpm taxes) + 0.5 (bank taxes) + 1.3 (other taxes) = 88.1 billion in corporate taxes (Rijksoverheid, 2023e). Corporate revenue is assumed to be the same as GDP, so 1130.8 billion euros as starting value, later adjusted in the model. Gross profit is calculated through corporate revenue minus wages, dividends and material expenses. In the first quarter of 2024 companies made 91.1 billion euros profit, 84.4 billion in the second quarter, 100.2 billion in the third quarter and 97.6 billion in the fourth quarter for a total of 373.3 billion euros gross profit (CBS, 2024j) (CBS, 2024k) (CBS, 2024l) (CBS, 2025q). This means the average corporate tax rate is 88.1/373.3 = 23.6%. Then there are also company savings and debt which are 308.232 (savings and deposits) – 0.162 (short-term debts) – 1.857 (long-term debts) – 73.073 (short-term loans) – 122.430 (long-term loans) – 4.508 (mortgages) + 43.918 (own shares) + 2.129 (shares in investment funds) = 152.249 billion euros savings (CBS, 2024g). These are used as the starting value for equity in the model.

Government expenditure

Government expenditure mainly depends on the amount of tax income, but the government can also decide to run a to boost the economy and/or energy transition. The government spends money on the energy transition, which is for simplification, assumed to be the amount of money going to the Ministry of Climate and Green Growth of 3.6 billion euros in 2025 (Rijksoverheid, 2024e). 7.8 billion euros go to interest payments on government debts (Rijksoverheid, 2023e). Healthcare and welfare expenses were already included in the model in the consumption. Other expenses in 2024 were projected to be 50 + 10.8 + 11.6 + 21.3 + 19.8 + 3.1 + 2.7 + 7.9 – 3.6 + 14.4 + 14.5 + 47.5 = 200 billion euros (Rijksoverheid, 2023e). These government expenditures are expected to rise based on inflation and population growth. Total government debt in 2023 was 481 billion euros which was 45.1% of GDP (CBS, 2024h). This means GDP was 1067 billion euros in 2023. Using the Miljoenennota of 2023, the interest payments on government debt were 5 billion euros (Rijksoverheid, 2022a) meaning the government paid an interest rate of roughly (5/481) * 100% = 1.04%. The government debt would have risen with 395-366.4 = 28.6 billion euros (Rijksoverheid, 2022a) for a total of 481+28.6 = 509.6 billion euros government debt in 2024. Over this amount the government had to pay 7.8 billion euros interest or (7.8/509.6) * 100%= 1.53% with debt rising with 433.6-402.9 = 30.7 billion euros in 2024 (Rijksoverheid, 2023e). Therefore, the interest rate of government debt will be assumed to be 1.5%.

Imports and exports

Imports and exports are the last economic factors. Total exports of goods were 686.6 billion euros in 2023 compared to total imports of goods of 614.9 billion euros (CBS, 2024i). Total exports of services in 2023 were 290.8 billion dollars and total imports of services 273.3 billion dollars (CBS, 2024i). This means the total trade surplus was 686.6-614.9+290.8-273.3 = 89.2 billion euros. Assuming imports and exports of goods have risen with an average inflation of 2%, this results in 700.3 billion euros exports of goods, 627.2 billion euros imports of goods, 296.6 billion euros exports of services and 278.8 billion euros imports of services in 2024. This would result in a total trade surplus of 700.3-627.2+296.6-278.8= 90.9 billion euros in 2024. Total (import) tariffs in 2024 were expected to result in 5 billion euros in tax income (Rijksoverheid, 2023e). Total imports were 627.2 + 278.8 = 906 billion euros in 2024. It is assumed 75% of the tariffs are paid by consumers and 25% by companies. The tariff rate is roughly 5/906 = 0.55% which is relatively low but can be explained through most of the trade in the Netherlands being Schengen area trade and the tariff rates not being that high (Douane, sd). The export factor is assumed to be 99% from 2025 until 2028 due to the trade war with the US reducing exports in those years, returning to 100% afterwards.

Energy transition

As for the impact on the energy transition, the total costs of the energy transition are assumed to be 20% higher than predicted by the report by (Kerkhoven & Hanemaaijer, 2025) as discussed in chapter 4. This chapter showed investment costs seemed on the low end of what is required, as for example infrastructure investments needed are much larger than what is stated in the report. This means total investment would need to be 514 * 1.2 = 616.8 billion euros. With an average inflation of 2% that would be 616.8 * 1.02^10 = 752 billion euros by 2050 or 616.8 * (1 / 1.02^16) = 449.3 billion euros in 2024. The amount in 2050 would be higher, as the population increases. Chapter 4 also showed the current amount of green energy being 15% of total consumption. It can be assumed that investments in the energy transition will directly add to this percentage, based on cumulative investment/total investment needed. The percentage is also influenced by the innovation, as total energy consumption shows a declining trend (CBS, 2024d). Total energy consumption in 2023 was 1090.2 PJ (CBS, 2024d) or 302.8 TWh. The carbon intensity of energy production in 2023 was 0.22 kg/kWh (CBS, 2024m) which would be 0.22 Mtons/TWh. Total CO2 emissions in 2023 were 118.67 Mtons (Ritchie & Roser, 2024). Using this, a carbon intensity of consumption can be determined of 118.67 / 302.8 = 0.39 Mtons/TWh.

Appendix B: Model formulas

Variable	Unit	Equation	Assumption/Note
Nominal GDP	Bln €	= C + I + G + X - M	Keynesian demand-based GDP.
Consumption (C)	Bln €	=Total consumption + Material expenses	
Total investments (I)	Bln €	= National savings + foreign savings	Private savings + Public savings + Foreign savings make up total investments.
Government expenditure (G)	Bln €	=Total government spending – Healthcare - Welfare	Welfare and Healthcare already included in consumption before tax.
Exports (X)	Bln €	=Exported goods + exported services	
Imports (M)	Bln €	=Imported goods + imported services	
Debt/GDP	%	= government debt/nominal GDP	
GDP at constant prices	Bln € (2024)	= nominal GDP/Accumulated inflation	
National savings	Bln €	=Private savings + public savings	
Private savings	Bln €	=Investments + Household savings + Corporate savings	
Public savings	Bln €	=Government surplus	
Foreign savings	Bln €	=Imported goods + Imported services – Exported goods – Exported services	
Population	Mpeople	(Given)	Based on CBS predictions.
Employment	Mpeople	=Population * Employment factor	
Employment factor	%	(Given)-0.02	Based on CBS data, assumed to decrease with 0.2% every year.
Not employed	Mpeople	=Population-Employment	
Productivity	%	= (previous value) + last year (Cumulative Innovation *	Assumes productivity goes up depending on cumulative

		(Investments + Other government spending + Green government spending)/100000	innovation and investments (outside of welfare and healthcare spending)
Negotiating power	%	= (previous value) * 0.99	Negotiating power of workers and unions slowly declines with 1% per year.
Inflation	%	(Constant)	Constant 2% inflation per year (ECB goal).
Accumulated inflation	%	= (previous value) * Inflation	
Wage share	%	= (previous value) + 0.5 * (Productivity this year- Productivity last year)	Assumes wage share goes up with half of productivity every year.
Income	€/person	= (2024 value) * Accumulated inflation * Productivity * Negotiating power	Income rises with inflation and productivity adjusted for negotiating power.
Total income	Bln €	= (Gross income per person * Employment) / 1000	
Welfare per person	Bln €	= (previous value) * Inflation	Welfare rises with inflation.
Welfare	Bln €	= (Welfare per person * Not employed) / 1000	All not employed people get welfare, no employed person gets welfare.
Income tax%	%	(Constant)	
Income tax	Bln €	= Total income * Income tax%	
Healthcare tax per person	€/person	= (previous value) * Inflation	Healthcare tax rises with inflation.
Healthcare tax	Bln €	= (Healthcare tax * Population) / 1000	
Healthcare per person	€/person	= (previous value) * inflation	Healthcare rises with inflation.
Healthcare	Bln €	= (Healthcare * Population) / 1000	
Dividends	Bln €	= (previous value) * Inflation	Investors want dividends to go up with inflation.
Dividend tax%	%	(Constant)	
Dividend tax	Bln €	= Dividends * Dividend tax%	

Disposable income	Bln €	= Income – Income tax + Welfare – Healthcare tax + Healthcare + Dividends – Dividend tax	
Total household savings	Bln €	= ((previous value) + Household savings) * Interest rate	
Interest rate	%	(Constant)	Set at 1% per year, lower than inflation.
Household savings	Bln €	= Disposable income – Total consumption before tax	
Household consumption before tax	Bln €	= (previous value) * Population increases * Inflation	Consumption rises with population increases and inflation
Consumption tax%	%	(Constant)	
Consumption tax	Bln €	= Consumption before tax * Consumption tax%	
Household consumption	Bln €	= Total consumption before tax – Consumption tax – 0.75 * Tariffs	
Real household consumption	Bln € (2024)	= Total consumption / Accumulated inflation	
Corporate revenue	Bln €	= (Total consumption + Material expenses + Total government spending – Healthcare – Welfare + Investments) * Productivity	
Material expenses	Bln €	= (previous value) * inflation	
Gross profit	Bln €	= Corporate revenue – Income – Material expenses	Income-costs.
Corporate tax%	%	(Constant)	Includes a variety of different taxes.
Corporate tax	Bln €	= Gross profit * Corporate tax%	
Net profit	Bln €	= Gross profit – Corporate tax – Dividends – Tariffs * 0.25	

Equity	Bln €	= ((previous value) + Corporate surplus) * Interest rate	
Investments	Bln €	= (previous value) * Inflation	Assumes investments go up with inflation
Green investments factor	%	(Constant)	
Green investments	Bln €	= Investments * Green investments factor	
Corporate surplus	Bln €	= Net profit – Dividends – Corporate investments	
Export goods	Bln €	= (previous value) * Export factor * Inflation	
Import goods	Bln €	= (previous value) * (1-Tariffs%) * Inflation	
Export services	Bln €	= (previous value) * Export factor * Inflation	
Import services	Bln €	= (previous value) * (1-Tariffs%) * Inflation	
Export factor	%	(given)	Export factor is 100% normally but 98% in 2025-2028 due to the trade war with the US
Tariffs%	%	(Constant)	
Tariffs	Bln €	= (Import goods + Import services) * Tariffs%	
Government green investments	Bln €	(previous value) * Inflation	
Other government spending	Bln €	= (previous value) * Inflation * Population increases	Government spending goes up with inflation and population increases.
Total government spending	Bln €	= Healthcare + Welfare + Government green investments + Other government spending + Interest payments	
Total government income	Bln €	= Income tax + Healthcare tax +	

		Consumption tax + Corporate tax + Tariffs + Dividend tax	
Government surplus	Bln €	= Total government spending – Total government income	
Government debt	Bln €	= (previous value) – Government surplus	Interest payments are already included in Total government spending.
Interest on debt%	%	(Constant)	
Interest payments	Bln €	= Government debt * Interest on debt%	
Innovation	%	(Constant)	Innovation is 2% per year in the base scenario
Accumulated innovation	%	= (previous value) * Innovation	
Total green investments	Bln €	= (Green investments + Government green investments) * Cumulative Innovation	Corporate and government green investments are multiplied by the cumulative innovation.
Cumulative green investments	Bln €	= (previous value) + Total green investments	
Required investments	Bln €	= (previous value) * Real consumption change * Inflation	Required investments go up with inflation, as the value of money shrinks. Higher real consumption means more investments needed.
Green energy mix	%	= 2024 value + Cumulative green investments * Required investments	Assumes all energy transition investments directly contribute to more green energy in the mix.
Carbon intensity	Mton CO2/TWh	= 0.46 – Green energy mix * 0.46	
Energy consumption	TWh	= (previous value) * Real consumption change / Energy Innovation	Assumes energy consumption grows with real consumption but follows the overall trend of decreasing over time due to innovation

Total carbon emissions	Mton CO2	= Carbon intensity * Energy consumption	
Cumulative carbon emissions	Mton CO2	= (previous value) + Total carbon emissions	

Table 15: Macroeconomic model formulas with units and assumptions