Rotterdam School of Management
Erasmus University

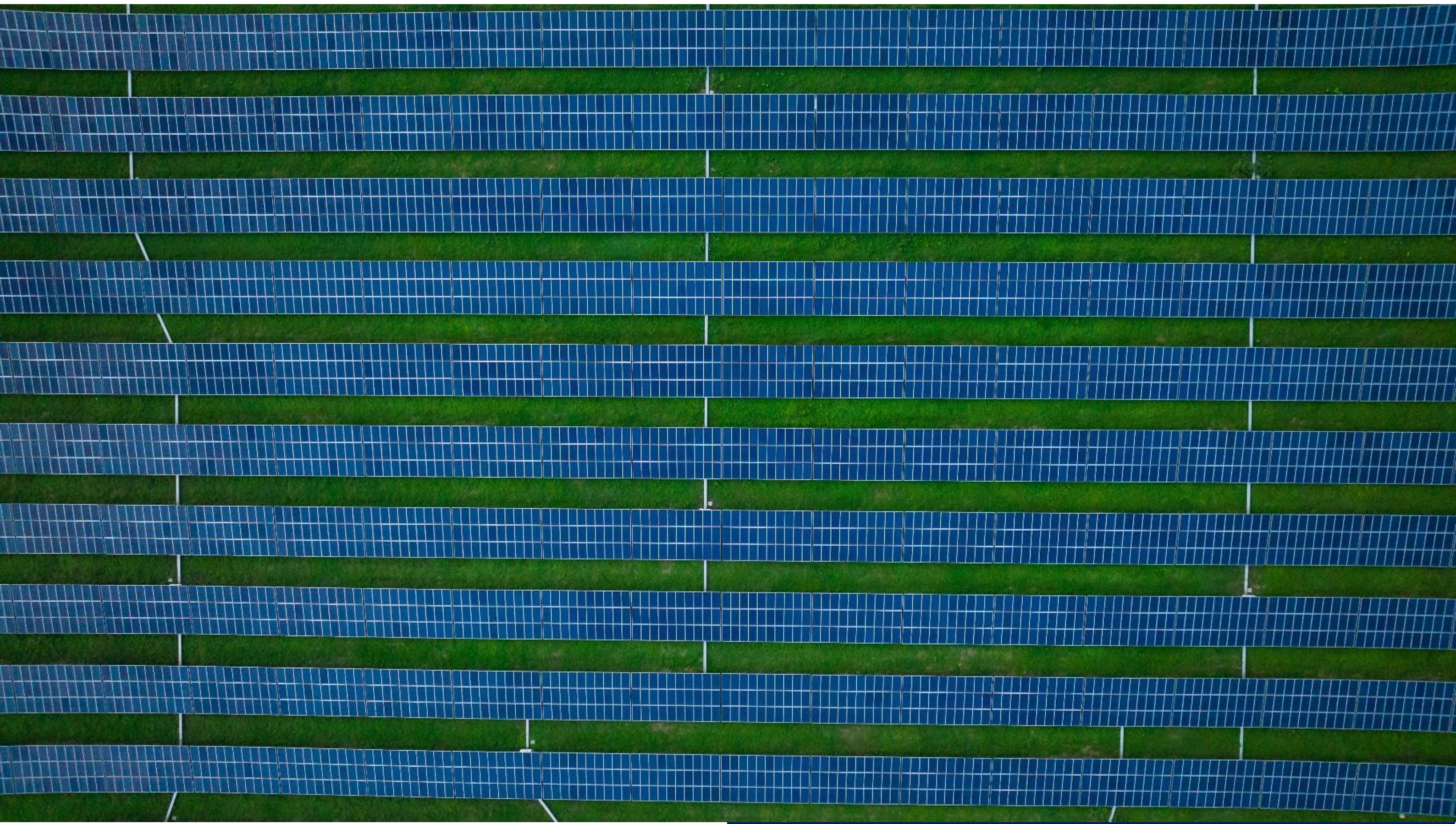
Erasmus Platform for Sustainable Value Creation

Working paper

Free!?* energy transition

*Including the monetised value of climate, health, energy security and macroeconomic effects in the Netherlands

Hesse McKechnie
Arjan Udding



RSM Erasmus

Working paper

Free!?* energy transition

September 2026

Hesse McKechnie

Fellow, Erasmus Platform for Sustainable Value Creation / Associate, Sustainable Finance Lab

Arjan Udding

Deputy Director NewForesight / Founder Valuence

In cooperation with Kennisprogramma EIK (Energietransitie Integraal Kostenbeeld) (link)

We would like to thank our sparring partners and reviewers of drafts of this document: Reinier de Adelhart Toorop, Moutaz Altaghlibi, Amanda Bachaus, Diala Beinke, Myrthe van Dalen, Simon Davies, Pietro Galgani, Roland van Keeken, Philipp Kollenda, Aart Kooiman, Jonathan Krakow, Frank Lenzmann, Nienke Maas, Sacha de Nijs, Eva Rood, Sander Oosterloo, Florian Reuter, Frederik Schlosser, Johannes Schuurink, Dirk Schoenmaker, Mark Sturton, Eric de Weerdt, Geoff West

Management summary

Net zero scenarios outperform our current energy system on economic value once the prudent monetisation of climate, health, security and macroeconomic effects is included. The energy transition effectively pays for itself over the transition period (2026 – 2050).

In 2025, the Netherlands spent €76BN to meet its energy needs. Half of this cost, €38BN was spent on energy carriers, predominantly fossil fuels, while the energy system emitted 157 megatonnes of CO2. Under EU Climate Law, the Netherlands is committed to achieving net-zero by 2050. The economic debate therefore matters: how much does the transition cost the Netherlands, and what value does it create elsewhere in the economy?

Across much of the public discourse, there is a perception that the energy transition is too expensive for us to afford. Especially now that we live in times of geopolitical uncertainty and pressure on European competitiveness. This paper demonstrates the need to update this outdated perspective by taking a more holistic approach to calculating economic value.

The starting point for this paper is *'Energietransitie Integraal Kostenbeeld'* (EIK, 2026). This programme has been set up, with support of the Dutch Ministry of Economic Affairs and Climate, to develop integral financial cost overviews for different scenarios of the Dutch energy transition. Based on EIK data, if the Netherlands were to continue to grow its economy with its current energy mix without any transition towards net-zero (No Transition or NT), it would have to foot an average annual bill of €95BN to meet its energy needs over the period 2026 – 2050. Under the KEV scenario, which is essentially the best extrapolation of the Netherlands' current policies scenario and which achieves a partial energy transition, the annual production costs are €99BN. EIK has also modelled two transition scenarios that lead to net-zero in 2050: TRANSFORM and ADAPT. Both scenarios have higher production costs than no transition, €108 – 113 BN (14% - 19%) respectively.

However, production costs are only part of the economic picture and the energy transition has more going for it. This paper places four additional economy-wide effects alongside the OPERA cost comparison: climate, health, energy security and the macroeconomic effect of increased domestic expenditure. These effects are deliberately limited in scope and are calculated at the level of the Dutch economy.

The purpose of this paper is to determine whether the prudent monetisation of economic benefits changes the overall assessment that our political leaders will have to make when making investment decisions about the energy transition. It has not sought to be comprehensive and should be seen as a 'proof of concept'. Benefits are calculated at the level of the overall Dutch economy, rather than at the level of individual stakeholders.

The energy transition improves energy security as it reduces dependence on energy imports and produces more (clean) energy at home. It will reduce the Netherlands' carbon footprint which in turn reduces the cost of compensating for environmental harm. Reductions in air pollution that are the result of a fossil fuel dependent economy reduce the days of lost work and the cost of national health expenditures on respiratory and other diseases. The transition will also have broader macroeconomic impacts. The structural increase in capital expenditure will increase aggregate demand domestically, creating high-paying jobs in the Netherlands which boost consumption and tax receipts.

The inclusion of these effects changes the comparison between the four scenarios materially. Under the central assumptions, annual economy-wide costs are €134BN for NT, €116BN for KEV, €122BN for ADAPT and €113BN for TRANSFORM. No transition is the worst performer, incurring around €39BN a year in climate, health and security costs, which add ~40% to production costs. The current policies projection roughly halves these costs, while the net-zero scenarios reduce them by around three quarters. Positive macroeconomic impacts of increased aggregate demand compared with no transition varies between €2 - 5BN annually across scenarios.

The net zero scenarios (ADAPT and TRANSFORM) achieve near parity with the current policy trajectory (KEV). Not much should be read into the exact ordering of KEV, ADAPT and TRANSFORM as there is less than 8% difference between them. The key conclusion from this analysis is that the energy transition effectively pays for itself over the transition period (2026 – 2050). The intentionally headline grabbing title of this paper 'free energy transition' is derived from this insight. However, parity should not suggest indifference. ADAPT and TRANSFORM scenarios have deliberately incurred costs up front to achieve net zero; costs which in KEV still must be made beyond 2050. Were the cost benefit analysis to be extended beyond 2050, the net zero scenarios would compare even more favourably.

Investment to accelerate the energy transition is economically justified because it raises the Netherlands' expected economic output. This understanding should shift our political debate. The pathways differ in timing, technology choices, risk and the various stakeholders who ultimately carry the costs. Rather than focussing simply on affordability, the Netherlands needs to have a broader discussion on risk, resilience and incentives. Policy makers should work to align the individual decisions made by households, companies, financiers, network operators and public bodies with the economy-wide value of the transition.

With money on the table, we have good reason to figure out how.

Contents

Contents 1
1. Introduction 2
2. The scenarios 4
  2.1. EIK / OPERA framework 4
  2.2. What the paper takes from EIK / OPERA (and what not) 5
  2.3. Treatment of subsidies and taxes 7
  2.4. The four scenarios (NT, KEV, ADAPT, TRANSFORM) 8
3. From ‘production cost’ to ‘expected economic value’ 12
  3.1. Scope clarification: expected economic value, conservatively defined 13
  3.2. Monetising four economy-wide effects 15
4. The economy-wide effects of the energy transition 18
  4.1. Economic value of climate 18
  4.2. Economic value of health 21
  4.3. Economic value of energy security 23
  4.4. Economic effect of increased aggregate demand 25
5. The economic case for the energy transition 28
6. Sensitivity Analysis 32
7. Risk and resilience 35
8. From macro insight to micro action 39
9. Further research 41
10. Conclusion 43
11. Annexes 44
  11.1. General assumptions 44
  11.2. Calculations: economic value of climate 45
  11.3. Calculations: economic value of health 47
  11.4. Calculations: economic value of security 53
  11.5. Calculations: Economic value of increased aggregate demand 57
  11.6. Reconciliation with EIK figures 66
Glossary 67
References 70

1. Introduction

EIK has sharpened the evidence on energy-system costs; this paper asks what changes when wider economic effects are added.

It is easy to get confused when following public discourse on the affordability of the energy transition. We are bombarded with contradictory information. Moreover, the discussion is often conflated with the attainment of climate goals, which although related, ignores other system dynamics of the energy transition.

Ten years after Paris, the 'hype' around sustainability has subsided. Now that there is no credible pathway to the 1.5°C climate goal (UNEP, 2024), we hear about the need for a more 'realistic' approach towards net zero. Many argue that in times of geopolitical challenge and European focus on competitiveness the necessary investment to achieve net-zero can't be prioritised. This shift in priorities can be seen in the figures. Global investment in fossil fuel has been going up since 2024, reversing the declines of previous years (Banking on Climate Chaos, 2026).

What is easy to miss amidst the noise is the fact that the pace of innovation and development of clean technology has continued unabated in the ten years since Paris and continues to do so. For example, the Levelised Cost of Electricity (LCOE) generated by Solar PV has decreased by 67% in the decade since Paris (NEA, 2026). In Spain, it is estimated that a 20% rise in the renewable energy share from 2021 to 2024, reduced Spain's wholesale electricity prices by nearly 20% (BBVA, 2025). The cost of battery storage has fallen even faster, by 75% since Paris (IEA, 2025b).

The question we should be asking ourselves in the Netherlands is whether we can afford to spend a projected ~€850 BN on predominantly fossil fuel imports from now until 2050.[1] That is a lot of money to be spending on a volatile energy source that we are looking to phase out. This is money we could use instead to invest in our future energy system.

The Dutch energy transition is often assessed through the cost of the energy system itself: investment, operating expenditure and energy carriers. These costs matter but national energy choices also affect healthcare expenditure, labour productivity, exposure to international energy shocks and the economic value attached to greenhouse-gas emissions.

[1] OPERA output for the KEV scenario from 2025 – 2050.

The '*Energietransitie Integraal Kostenbeeld*' (EIK – energy transition holistic cost overview) programme has substantially improved the evidence base on the production costs of different Dutch energy pathways. Its work shows a shift from a fuel-intensive system towards a more capital-intensive system as the Netherlands decarbonises. It has calculated the financial costs of several transition scenarios and shows that the cost of achieving net zero is now within touching distance of business as usual.

The aim of this paper is to challenge our own prejudices that the energy transition is '*good for the world*' but unaffordable. This paper adds a further layer to the EIK comparison. It places selected climate, health, energy-security and macroeconomic effects alongside the production costs for the same scenario pathways and asks whether their inclusion materially changes the economic case for reaching net zero. The analysis is deliberately narrow: it does not attempt to monetise every social or environmental consequence but focuses on four effects that can be linked to the scenario pathways and valued using existing evidence. This leads to the question behind the title of the paper: how much of the apparent cost premium of the energy transition remains once these wider economic effects are included?

We ask the question whether we can have our cake and eat it too: can the energy transition be had for free?

Section 2 of this study helps the reader understand the scenarios and input assumptions this study is based on. Section 3 outlines the methodology used to derive economic value. Section 4 describes how four economy-wide effects, climate, health, security and investment, impact the broader economy. Section 5 brings it together to show the economic value across scenarios. Section 6 discusses the sensitivity of the model to several input variables. Section 7 argues that we should move the political debate on from affordability towards a discussion of resilience and the different types of risks we have to manage as a country. Section 8 suggests three actions policy makers could take away to act on the insights in this paper. Section 9 provides an overview with recommendations for further work to be carried out. Section 10 concludes.

2. The scenarios

This paper builds on the scenario framework developed by the 'Energietransitie Integraal Kostenbeeld' (EIK – energy transition holistic cost overview) programme.[2]

Their model provides the analytical backbone for the economic-value calculations in this paper. The EIK scenarios align demand, supply, infrastructure needs and policy constraints over 2025–2050, providing coherent long-run pathways within which Dutch policy choices can be compared.

2.1. EIK / OPERA framework

The analysis has been carried out on two net-zero scenarios and two reference scenarios (current policies and no transition).

The EIK scenarios are generated with OPERA, an optimisation model of the Dutch energy system (TNO, 2020). OPERA represents supply, conversion, infrastructure and demand options in detail, and finds cost-minimising system configurations under constraints such as emissions targets, technology availability, and policy assumptions. This makes the scenario set well suited as a consistent "engineering–economic" baseline for comparing pathways and quantifying system-level changes over time.

This paper builds on two net-zero scenarios: ADAPT and TRANSFORM (TNO, 2022). OPERA has been used to cost these scenarios. OPERA has also been used to cost the 'current policies' scenario KEV (*Klimaat- en Energieverkenning* / Climate and Energy Exploration) (TNO, 2023). KEV is essentially a partial energy transition as it does not achieve net-zero.

In addition, this paper has constructed a 'no transition' (NT) reference scenario which is an extrapolation of OPERA output of the year 2025 only. The exact energy mix of the Netherlands is maintained for the entire period 2025 – 2050. The only change is the

[2] The knowledge programme 'Energietransitie Integraal Kostenbeeld' (EIK) consists of a coalition of knowledge partners which include: Rijksdienst voor Ondernemend Nederland (RVO), Nederlandse Organisatie voor Toegepast Natuurwetenschappelijk Onderzoek (TNO), Central Bureau of Statistics (CBS), Centraal Planbureau (CPB), and Planbureau voor de Leefomgeving (PBL)

growth in energy consumption in line with GDP (1.5%) to allow for comparability with the other scenarios.

These scenarios have been periodically updated based on the latest available data. The data used in this paper has been supplied by EIK and is based on the OPERA output from January 2026.

2.2. What the paper takes from EIK / OPERA (and what not)

The wider economic effects are calculated from scenario-consistent OPERA outputs supplied through EIK.

This paper builds on the OPERA output. It takes the scenario-consistent system outputs needed to compare pathways on a like-for-like basis: energy demand and supply by carrier, the deployment and timing of major technologies and infrastructures, the system cost structure (CAPEX, OPEX, and fuel and import components), and energy-related GHG emission trajectories.

This paper departs from the EIK methodology in the treatment of the discount rate. EIK uses the OPERA output for calculating CAPEX with a social discount rate of 2.8% (OPERA, 2026). This is the official discount rate for the purposes of conducting public cost benefit analyses (Rijksoverheid, 2025). This paper uses the OPERA output based on commercial financing assumptions for its headline production-cost comparison. These assumptions are an 8% discount rate for corporates and 4% for households.[3] The rationale for this approach is that most investment decisions will be made by private sector actors. The commercial discount rate reflects more closely the real-world financing conditions that private actors face.[4] This decision regarding methodology trades-off potentially undercounting the public benefit at the macro level to more realistically reflect the private cost at the micro level. The aim of this more conservative approach of showing costs is to avoid criticism of the approach focussing on an argument about discount rates.

---

[3] More specifically. The 8% discount rate applies to market-exposed ETS1 sectors, and the 4% discount rate applies to all other sectors

[4] Noting that this is still an approximation as private sector actors may add a ‘risk premium’ to any investment decisions which will result in a higher discount factor than dictated by borrowing costs alone.

The analysis for this paper then layers on top additional impact data that allows for the quantification of economy-wide effects consistent with the OPERA output.

2.3. Treatment of subsidies and taxes

The effect of taxes and subsidies are included in the analysis but not in the overall value of the business case for the transition as their effects are distributive and do not affect the size of the economy as a whole.

Taxes and subsidies affect energy prices, investment decisions and the distribution of costs between households, companies and government. At the aggregate level of the Dutch economy, many of these payments are transfers between actors rather than additional economic costs or benefits. A tax paid by a company is a cost to that company but revenue to government. A subsidy has the reverse effect.

For this reason, taxes and subsidies are not added to the headline economic costs as separate effects. Doing so could result in double counting where their effect is already reflected in fuel prices, investment costs or government revenues included elsewhere in the analysis.

This treatment does not mean that taxes and subsidies are economically irrelevant. They directly shape the private business case of technologies. Tax exemptions, reduced rates and other forms of fossil support can keep fossil consumption or investment more attractive than it would be under a neutral fiscal system.

The same distinction applies to the EU Emissions Trading System. The purchase of an emission permit is a financial cost to the buyer and a receipt to government or another permit holder. It is therefore not treated as a separate loss to national economic welfare. The underlying climate effect is valued independently through the climate shadow price applied in section 4.1.

Taxes, subsidies and carbon pricing are therefore treated primarily as distributional and behavioural instruments. Their role in investment decisions is addressed in the policy recommendations, while their direct budgetary effect remains outside the headline estimate.

2.4. The four scenarios (NT, KEV, ADAPT, TRANSFORM)

No Transition (NT)

No transition is the baseline scenario for this analysis which keeps the 2025 energy production mix and increases energy consumption in line with 1.5% GDP growth.

NT is a hypothetical counterfactual constructed for this study rather than an EIK scenario. It holds the 2025 energy system—including its cost structure, fossil-asset base, fuel mix and emissions—constant through 2050, apart from energy-demand growth in line with GDP. It therefore provides the fixed reference against which current-policy and transition pathways are compared.

In economic terms, NT is a commodity-based system: the Netherlands pays for energy by purchasing fossil fuels on international markets, with no domestic technology base to fall back on. The result is a system that remains 89% dependent on imported energy in 2050, with no meaningful expansion of offshore wind, no hydrogen economy, and no electrification of buildings or industry. The gas network remains intact and fully operational. NT is not a forecast but a counterfactual that enables comparison of costs and benefits with our current policy trajectory as well as transition scenarios.

Klimaat- en Energieverkenning (KEV)

KEV is the best estimate of the Netherlands current policy trajectory at any point in time.

The Climate and Energy Exploration *(Klimaat- en Energieverkenning*, KEV) is the best available forecast currently of what will happen in the Netherlands based on current policies (PBL, 2025e). It is based on existing policy commitments as described in the national plan for the energy system (*Nationaal Plan Energiesysteem,* NPE) of 2023. The KEV is recalibrated annually to include actual investment plans extended forward. The NPE will also be updated in 2026 based on new EU and Dutch coalition government targets. The result of KEV is a hybrid system: substantially more renewable than NT, but without the fossil infrastructure being dismantled. It sees emissions reduce from 157 to 68 $MtCO_2$ (a reduction of 57%) but fails to achieve net-zero.

ADAPT

ADAPT is a 2050 climate neutral energy transition that leaves the Netherlands' industrial structure and living patterns largely intact.

ADAPT is a net-zero 2050 scenario constructed for the Dutch economy (TNO, 2023). ADAPT reaches near net-zero in 2050 while leaving the Netherlands' industrial structure and living patterns largely intact. It is the scenario of pragmatic acceleration: more electrification, faster scaling of low-carbon infrastructure, and targeted use of Carbon Capture and Storage (CCS) in hard-to-abate sectors, but without requiring radical behavioural change.

The energy system that emerges in 2050 is fundamentally different from today's. The gas distribution network is largely decommissioned. Most homes are no longer connected to the gas grid, heated instead by ground-source heat pumps, air heat pumps, and district heating networks. Offshore wind expands to 40 GW, backed by a dedicated offshore electricity grid costing approximately €5.9bn per year. Green hydrogen electrolysis reaches 12.6 GW, serving the industrial sector. CCS is deployed selectively in genuinely hard-to-abate applications: refineries, ammonia production, and waste incineration. There is also investment in nuclear energy: 3 GW of European Pressurized Reactor (EPR) capacity.

TRANSFORM

TRANSFORM is a 2050 climate neutral energy transition achieved through significant energy demand reduction and implementation of innovative technologies.

TRANSFORM is another net-zero 2050 scenario constructed for the Dutch economy (TNO, 2023). It takes a different approach from ADAPT. There is significant energy demand reduction and greater renewable deployment. It also relies to a greater extent on technologies that are still scaling up today, and for which the business case can only be made viable through new government policy and incentives.

Energy demand falls to 2,695 PJ by 2050, 13% below ADAPT, driven both by efficiency gains and changed consumption patterns. The industrial system is transformed. Transport is largely electrified or switched to hydrogen. Almost all buildings have left the gas network.

There is greater renewable energy investment than in ADAPT. Offshore wind is nearly double ADAPT. Solar thermal is deployed at scale for utilities, residential, and for district heating. Green hydrogen electrolysis reaches significant capacity. The most distinctive, and risky, element is Power-to-Liquids (P2L) at 240 PJ capacity: synthetic fuels produced via high-temperature electrolysis, direct air capture, and Fischer-Tropsch synthesis. This scale of P2L does not exist anywhere in the world today.

TRANSFORM achieves the lowest import dependency of all scenarios (44%). However, it is reliant on several forecasts and projections to materialise. It requires that cost curves will fall as projected. It requires a 13% demand reduction through policy and behavioural interventions.

Comparing the energy systems across scenarios

The scenarios can be compared in terms of total energy system costs to supply a Dutch economy growing at 1.5% GDP per year over the period 2026 – 2050.

Except for KEV, the four scenarios are not forecasts. In this study, the scenarios are used to test the same economic valuation logic under different plausible system designs: pathways that differ in ambition, speed, and technology mix but can be compared on a like-for-like basis.[5] Table 1 summarises the four scenarios across key differentiating metrics.

[5] To achieve comparability this paper has made some adjustments to public figures (PBL, 2025e) (TNO, 2023). KEV, which is a forecast, differs from ADAPT and TRANSFORMS which are scenarios. The treatment of bunker fuels used for energy consumption of Dutch nationals abroad (aviation and shipping) differs in the public figures and have had to be corrected to achieve like-for-like comparability

Table 1: Key system characteristics by scenario, 2050

Scenario	NT	KEV	ADAPT	TRANSFORM
Energy consumption (PJ)	4,280[6]	2,930[7]	3,107[8]	2,695[9]
Import dependency[10]	89%	63%	65%	44%
Offshore wind (GW)[11]	~0	~18	40	70
Nuclear (GW)[12]	0	0	3.2	3.2
Gas network 2050	Fully intact	Fully intact	Largely decommissioned	Strongly reduced
Net-zero 2050	No	No	Yes	Yes
Biggest technology bet[13]	None	CCS at scale (30+ types)	Nuclear on schedule	P2L at 240 PJ + nuclear

Source: various. See footnotes

[6] Original source: TNO R10246, Fig. 3.1 (read directly from graph). 2025 numbers only. Extrapolated with 1.5% annual GDP and energy consumption from 2026 – 2050

[7] Original source: TNO R10246, Fig. 3.1 (read directly from graph).

[8] Source: derived. ADAPT trajectory observed from TNO P10162, Fig. 4.3 (2025: 2,506 PJ; 2050: 2,639 PJ, excl. bunkers). Indexed to KEV 2025 anchor of 2,950 PJ: scale factor 2,639/2,506 × 2,950 = 3,107 PJ

[9] Source: derived. TRANSFORM trajectory observed from TNO P10162, Fig. 4.3 (2025: 2,506 PJ; 2050: 2,289 PJ, excl. bunkers). Indexed to KEV 2025 anchor: 2,289/2,506 × 2,950 = 2,695 PJ

[10] Source: derived. Ratio of imported to total installed capacity per scenario for 2050. NT: 4,522/5,065 PJ = 89%. KEV: 2,192/3,484 PJ = 63%. ADAPT: 3,277/5,065 PJ = 65%. TRANSFORM: 1,938/4,410 PJ = 44%. Source: ETM modelling based on TNO OPERA.

[11] Offshore wind (GW): OPERA/ETM model output. BAU: effectively zero (no transition assumed). KEV ≈18 GW: TNO (2025), R10246. ADAPT 40 GW and TRANSFORM 70 GW: TNO (2022), P10162.

[12] Nuclear (GW): OPERA/ETM model output. BAU and KEV: 0 GW. ADAPT and TRANSFORM: 3.2 GW EPR capacity. Source: TNO (2022), P10162

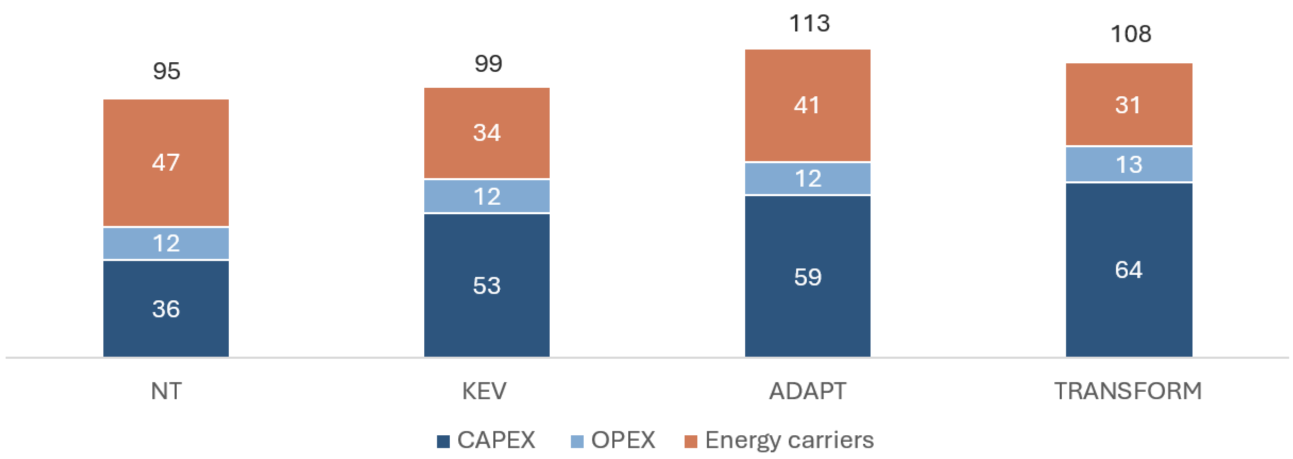
[13] Biggest technology bet: editorial assessment of the highest-risk technology dependency per scenario. BAU: none. KEV: CCS at scale across 30+ application types. ADAPT: nuclear EPR on schedule. TRANSFORM: Power-to-Liquids at 240 PJ + nuclear. Source: TNO (2022), P10162; TNO (2025), R10246.

3. From 'production **cost' to 'expected economic value'**

The transition shifts the costs of our energy system away from imported fuels towards domestic investment.

Production costs are directly extracted from OPERA. Figure 1 provides an annualised cost overview for the period 2025 – 2050. Note that the costs vary over the period. The figures shown are sum totals of the period divided by 25 years to get an annualised number. Energy system production costs are shown in three categories: CAPEX (capital investment consisting of depreciation and commercial discount rates), OPEX (maintenance of infrastructure) and energy carriers (fuel costs such as oil, gas, biofuels, imported green hydrogen, synthetic fuels and uranium).

Figure 1: annualised[14] production costs by scenario (2026 – 2050) (BN)[15]



Source: OPERA output

Note: although based on the same OPERA data, these figures differ in the way they are presented in the *Startrapport Programma EIK* (RVO, 2026). See Annex 11.6 for a reconciliation between figures

[14] The figures shown add up the total financial costs over the period 2026 – 2050 and divide that number by 25 years to give an annualised figure.

[15] Note that NT costs are not the same as 2025 costs. The NT grows GDP and energy consumption by 1.5% annually over the period 2026 – 2050 using the 2025 mix.

Based on financial costs alone, NT compares more favourably with a total of €95BN annually. Half of the total cost consists of fuel, €47BN annually. Production costs are higher for KEV (€99BN annually) and higher still for the two net zero scenarios (€113BN annually for ADAPT and €108BN annually for TRANSFORM). This means that ADAPT and TRANSFORM are 19% and 14% more expensive in cost terms respectively than NT.

Although the cost difference is not insignificant, considering that these are average costs over a 25-year period, the differences are surprisingly small. Perhaps just as important as the overall production cost is the composition of that cost. In the transition scenarios the cost of energy shifts away from fuel consumption towards capital expenditure and the maintenance thereof.

This production cost comparison is the starting point of the analysis in this paper. The next step adds selected effects outside the energy-system ledger to understand how each pathway affects the Dutch economy more broadly.

3.1. Scope clarification: expected economic value, conservatively defined

The analysis adds selected economy-wide costs and benefits that sit outside the OPERA production-cost ledger.

Quantifying broader economic effects is often perceived as problematic for two reasons. First, they often 'feel' less tangible because they do not appear on household or company budget or in the national accounts. A cost or a Euro spent is very direct and very visible. There is an actual transaction. Effects mostly materialise as avoided costs or avoided risks. The Euro never spent is invisible and the beneficiaries are often diffuse. However, is the Euro one spends not worth the same as the Euro one never has to spend?[16]

Second, the effects may accrue in the future. Consequently, when accounting for them there is always some uncertainty to take into consideration. Accounting is based on expected values rather than on actual values. To keep the maths in this paper simple and understandable, expected values are presented as a single value rather than a range. Section 6, sensitivity analysis, provides an overview of those variables which have the

[16] Subject to the application of an appropriate discount factor accounting for time difference

greatest impact on economic welfare. Neither of these points change the necessity of the effect in determining our economic welfare.

The method in this paper uses a deliberately narrow economic scope. It includes effects that can be linked to production, expenditure, healthcare costs, productivity or expected macroeconomic losses. Monetised quality-of-life and mortality values are outside the scope, even where standard appraisal methods exist. This choice keeps the analysis close to costs and economic flows that are familiar in public and private decision making.

This is not an attempt to quantify the full "integrated value" of the energy transition, and the paper avoids indicators that depend primarily on subjective wellbeing or broader quality-of-life framing. The difference is best illustrated by example. Consider that the air pollution resulting from fossil-fuel energy production increases instances of a number of lung and heart diseases. The lost days of work and the financial costs to the health system resulting from treating these diseases directly affect economic welfare. Factors relating to wellbeing, such as the decreased quality adjusted life years that individuals suffer from those diseases can also be monetised. Wellbeing values are typically included in calculations for integrated value. However, as wellbeing does not directly affect GDP, such values are excluded from this analysis. The decision to focus on welfare rather than wellbeing is deliberate. It ensures that the monetisation factors are more easily recognised by accountants in companies, banks and government that need to make financial decisions about the transition. Excluding more subjective indicators also avoids potential politicisation of the findings.

The four effects are also different in economic character. Climate and air pollution are external production costs. Energy security is modelled as an expected macroeconomic loss. The aggregate-demand effect captures the expected economic consequence of shifting expenditure towards domestic investment and activity. They are considered together because each sit outside OPERA's production-cost comparison and can affect the national assessment of future economic output.

The resulting totals should therefore be read as a partial estimate of economy-wide value. Where judgement is required, the central assumptions have generally been chosen to avoid overstating the benefits of the transition. Section 6 tests several of these assumptions and Annex 11 documents the methods and limitations in more detail.

Throughout the analysis, the approach taken aims to be conservative from the point of view of not overstating the economic benefits of the transition. This choice is also deliberate, but it has consequences. Climate scientists may refer to the 'precautionary principle' and argue that higher monetisation factors are needed to account for potential tipping points and tail risks. From this perspective, a conservative estimate of the benefits of the transition may result in under-pricing of climate risk in no transition (NT). Social scientists may argue for a more expansive definition of benefit to include softer wellbeing indicators (e.g. life satisfaction). Readers can form their opinion by reverting to the appendices with details on method, assumptions and calculations.

3.2. Monetising four economy-wide effects

Four effects outside the production-cost comparison are quantified: climate, health, energy security and aggregate demand.

The are a large and diverse number of economic effects associated with the energy transition. The challenge with any impact analysis is that there are so many impacts, and they are so varied, that it is easy to lose focus.

This paper has taken a top-down approach to the selection of economy-wide effects by stepping back and considering how the energy transition fundamentally differs from no transition. Four effects analysed are material to the national debate, can be connected to the scenario outputs and have an existing evidence base from which monetary values can be derived.

Figure 2 summarises the broader economic impacts of no transition versus both transition scenarios across several dimensions.

Figure 2: energy transition fundamentals – broader economic impacts

Dimension / Scenario	No transition	Transition	Broader economic impact
Energy system	Commodity-based	Technology-based	Innovation potential
Production costs	Fossil fuels	Capital investment	Financing opportunity
Energy dependency	Imported fuels	Domestic production	Energy security
Aggregate Demand	Foreign revenue	Domestic investment	Wages & taxes
Air Pollution	Higher health costs	Lower health costs	Healthy workforce
Climate	Hot house world	Orderly transition	Climate resilience

Source: own analysis

Based on this analysis, this paper has chosen to focus on a limited number of four 'no regret' effects. They are economically substantial and are frequently discussed qualitatively in the national policy debate. Moreover, across each of these effects there is a body of research already available from which to draw monetisation factors.

- Value of climate mitigation costs: the economic value of avoiding greenhouse-gas emissions and thereby reducing the harm done to our climate according to the 'polluter pays' principle, measured in tCO_2-equivalent and monetised using a climate shadow price.
- Value of health benefits: the economic value of the benefits of cleaner air, in terms of reduced days of work lost and healthcare costs, measured as the avoided damage through reduced emissions in kilograms of key pollutants (e.g., NO_x, $PM_{2.5}$, SO_2, NH_3, NMVOCs).
- Value of energy security: the economic value of strategic independence achieved through reduced exposure to imported energy and related price/geopolitical risk, determined through expected macroeconomic losses based on historical frequency and severity of energy crises
- Value of increased aggregate demand: The economic value of the boost to aggregate demand in the Dutch economy resulting from substantial increases in domestic capital and operational expenditures in transition scenarios, after accounting for higher production costs and supply-side constraints. The transition increases domestic investment and drives job growth in the Dutch economy. Although wages and taxes are financial costs to the energy system, the economic multiplier effects from increased aggregate demand have positive effects for the wider economy (subject to supply-side labour constraints and opportunity costs).

This is not to say that other factors are not important. On the contrary, the degree to which even a limited number of effects have a significant impact on the economic benefit of transition should be an encouragement to include and monetise a broader set of effects in future analysis. Several omitted effects may strengthen the transition case, while others may add costs.[17] The current totals are therefore a partial comparison of wider economic effects. Section 9, further work, elaborates on several effects that were considered but not included in the scope of this paper. These set out priorities for extending the analysis.

[17] For example, there are some studies which suggest that onshore wind somewhat depresses local land values (e.g. Schutt, 2024).

4. The economy-wide effects of the energy transition

4.1. Economic value of climate

The energy transition will reduce climate mitigation costs to near zero.

Although this paper makes the case that there are energy security, health and macroeconomic reasons to want the energy transition, the transition is often primarily talked about in terms of its necessity to avoid climate catastrophe.

In 2025, the Netherlands emitted 157.3 Mt CO_2 (CBS, 2026b).[18] The central climate value used in this paper is a shadow price of €174 per tCO_2, which is the price used by PBL (PBL, 2025c) and which is based on calculations by the CE Delft (CE Delft, 2023). The value is based on marginal mitigation costs and is used for Dutch cost-benefit appraisal. The annual cost of this externality in 2025 was €27BN. This number excludes damages from air pollution and other negative effects which are captured in this paper in section on 'economic value of health'.

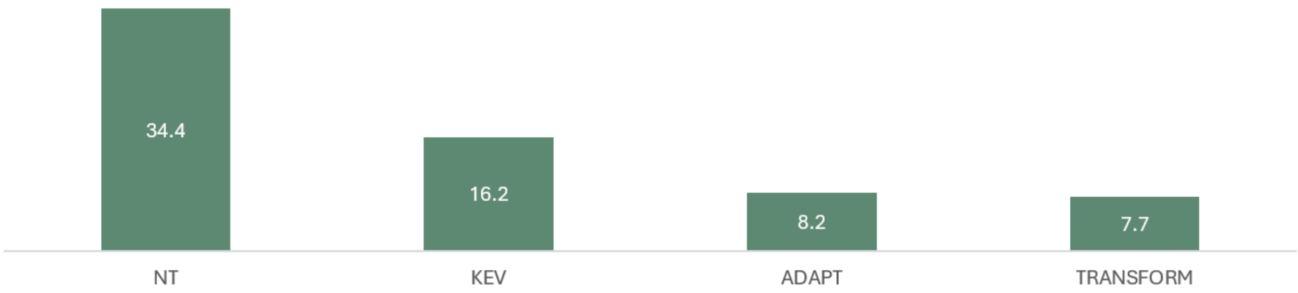
In both ADAPT and TRANSFORM scenarios this cost reduces to €0 by 2050 because of achieving net zero. Note that in both ADAPT and TRANSFORM scenarios there are still negative effects over the entire period 2025 – 2050 as emissions are reduced gradually over time. Current emissions projections (KEV) for 2050 see a reduction of emissions of 57% by 2050 which still carries an annual economic cost of €12BN in 2050 (and an average cost of €16BN over the entire period 2025 – 2050, see figure 3).

It is worth noting that this economic cost is a climate mitigation cost, rather than a climate adaptation cost. It counts the marginal cost to abate[19] climate change but not the cost climate change damages, or adaptation measures to prevent those damages. The logic is that the Netherlands will have to pay for adaptation costs regardless of whether it achieves net-zero itself. Adaptation costs are a function of climate change which in turn is a function

[18] These are the emissions caused by Dutch nationals whether at home or abroad, e.g. including the consumption of services such as shipping and aviation.
[19] in Dutch: *preventiekostenmethode*

of global emissions, not Dutch emissions. This is an important distinction between climate costs and the other economic costs in this paper. Climate effects are global rather than national in nature. In other words, the Netherlands doesn't directly suffer the costs of its own emissions. The whole world does. Similarly, the Netherlands suffers a portion of the climate change costs caused by the rest of the world.

Figure 3: Annualised climate costs by scenario (2026 – 2050) (€BN)



Note: see Annex 11.2 for methodology and calculations

The attribution of the externality resulting from Dutch emissions to the Dutch economy is rather legal and jurisprudential in nature. It follows from the fact that the Netherlands has signed the 2015 Paris Agreement, the 2019 *Klimaatakkoord*, and is subject to the EU climate law since 2021, including its binding net zero target.

Across Europe, judges are increasingly passing judgements to enforce climate action by states. In the Netherlands the courts have held the government responsible its climate commitments in the case of the Klimaatzaak Urgenda (Rechtspraak, 2019) and more recently Klimaatzaak Bonaire (Rechtspraak, 2026). Elsewhere in Europe, courts are also enforcing climate law, notably with the courts in Germany ruling on behalf of 'young peoples' climate interests (Bundesverfassungsgericht, 2021) and the ECHR upholding the case of the Swiss '*Klimaseniorinnen'* (ECHR, 2024). At the macro level, therefore the economic impact of emissions is the result of the increased enforcement of the principle that the polluter pays.

At the micro level, companies in the Netherlands are subject to an expanding scope of the European Emissions Trading System which will increase their operating costs (EU ETS, 2026). Since 2022, the price of EU Carbon Permits has generally been in the range of €60 - €90 per tCO_2. The cost of permits is designed to increase over time. Projections for the price of permits by 2035 are in the range of €180 – 200 (ABN AMRO, 2025)(Bloomberg, 2024).

The ETS cost is not itself an ideal proxy for the economic cost. First, the price of a permit is influenced by supply and demand factors which are influenced beyond economic cost considerations. Second, the effect of permits is redistributive. The transfer of a permit at any price from a seller to a buyer does not affect national economic welfare at the aggregate level. It merely transfers that welfare between stakeholders. Nevertheless, it is a cost that Dutch businesses will be expected to pay, and the projected price of permits is in line with the economic externality as calculated by PBL.

All considered, this paper uses the principle that 'the polluter pays'[20] and hence uses the PBL figure of €174 per tCO_2 as the best available estimate to calculate the impact on economic welfare.
It is unsurprising that climate cost is the greatest of the three negative effects included in this paper. The annual cost of NT would be €34BN over the period 2026 - 2050, greater than the €27BN cost in 2025 owing to the growth in energy production. This adds around a third to the energy production costs of €95BN annually over the same period. Current policies (KEV) reduce this figure by about half, but they are still substantial at €16BN. Both transition scenarios reduce the by half again to €8BN. In the case of the transition scenarios the annual cost is reduced to zero by 2050, and climate costs are mostly incurred early in the transition period 2025 – 2050.

Note that the figures shown in figure 3 are for the period 2026 – 2050 only. Unlike both transition scenarios, NT and KEV will continue to include climate costs beyond 2050. Adding the discounted climate costs[21] for the period 2051 – 2070 would add €158BN to NT and €47BN to KEV (which would add an additional €6.3BN to NT and €1.9BN to KEV annualised figures in Figure 3)

[20] In Dutch *'de vervuiler betaalt'*
[21] Using social discount rates (Rijksoverheid, 2025)

4.2. Economic value of health

The energy transition will reduce the lost days of work and healthcare costs associated with morbidity linked to air pollution.

Air pollution constitutes a major category of externality of our energy system. The combustion of fossil fuels releases particulate matter, nitrogen oxides, sulphur dioxide, and other NEC[22]-regulated pollutants. These pollutants drive morbidity which results in reduced labour productivity, shortened working lives, and healthcare expenditure. Consequently, energy production currently imposes health costs on other productive sectors of the economy borne by individuals, corporate employers and the Dutch public health system.

The impact of morbidity is not strictly economic. Reduced health has major quality of life and broader social implications regardless of any economic damage. As an external calibration anchor, PBL estimates the total wellbeing-based air pollution damage in the Netherlands at €19.5BN per year (PBL, 2025b). The PBL analysis is based on the monetisation of both economic and as well as quality of life factors.

This paper has sought to isolate the economic from broader quality of life impacts. This is achieved through a costs-of-illness (COI) approach: direct treatment costs and productivity losses. It explicitly excludes the statistical value of life (VSL) and the monetisation of lost life-years. This is a deliberate normative choice. VSL-based health valuation is a different and considerably wider concept than the economic productivity framework applied consistently across this paper.

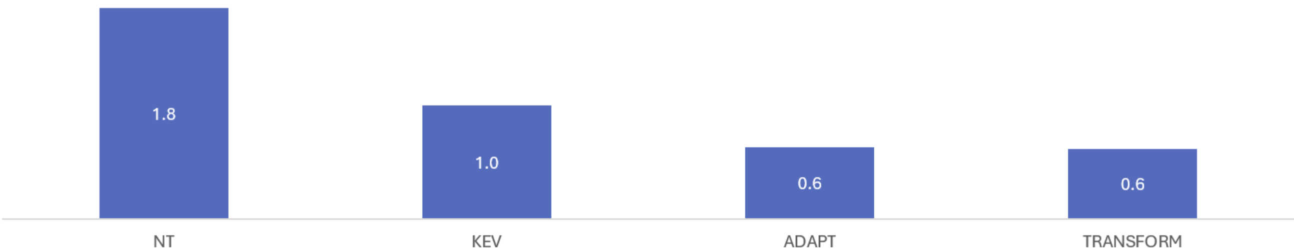
COI costs are calculated for the emission trajectories of five NEC-pollutants (NO_x, $PM_{2.5}$, SO_2, NH_3, and NMVOCs) and valued at Dutch-specific damage cost factors from the CE Delft Handbook on Environmental Prices (CE Delft, 2023). The 2025 calculated COI of €1.5BN, represents around 7.5% of the PBL welfare estimate. This is consistent with the pollutant-specific COI fractions derived from the CE Delft Handbook, which range from approximately 5% to 13%. The gap between the PBL analysis and the COI approached used in this paper demonstrates how conservative the economic case is compared with broader

[22] National Emission reduction Commitments, or national air emission ceilings. These are European obligations and quantitative environmental targets that include a monitoring obligation and a mandatory program. The NEC Directive aims to reduce the surface area in Europe affected by acidification by at least half.

quality of life considerations. The approach should therefore represent a floor of health damage, not the ceiling.

Figure 4 shows the annualised impact across scenarios over the 2025–2050 period. Annualised health-related air quality costs average approximately €1.8BN per year under NT. Cleaner air reduces this cost to approximately €1.0BN under KEV and €0.6BN under both ADAPT and TRANSFORM. These estimates include an assumed real increase in the costs associated with illness over the model period.

Figure 4: Annualised expected health costs by scenario (2026 – 2050) (€BN)



Note: see Annex 11.3 for methodology and calculations

The difference between KEV and the net-zero scenarios is meaningful and merits explanation. Combustion-linked pollutants (NO_x, $PM_{2.5}$, SO_2) are proxied using each scenario's energy-related CO_2 trajectory relative to KEV, so they track the pace of fuel switching. KEV does not reach net zero and retains significant combustion-related emissions through 2050, resulting in an annual health cost of approximately €0.9BN by that year. ADAPT and TRANSFORM, by contrast, reduce combustion emissions to near zero by 2050, bringing health costs down to approximately €0.3BN annually. The remaining costs largely relate to NH_3 and NMVOC emissions, which are held constant across scenarios.

This is three times lower than under KEV at the end of the period. The similarity of the ADAPT and TRANSFORM results across the full 2025–2050 horizon reflects a deliberate methodological choice: NH_3 and NMVOCs are held constant across scenarios because they are not primarily affected by the energy transition (their emissions are primarily caused by agriculture and solvents).

This approach excludes health effects from indoor combustion, thermal comfort, damp and mould, ventilation, noise, active mobility, accidents, occupational exposure and energy poverty. Some of these effects are likely to favour the transition scenarios, while others depend strongly on implementation quality and technology choices. The reported health value should therefore be interpreted as a partial estimate rather than the full health benefit of the energy transition.

Including the value of health strengthens the argument in favour of the transition. Moreover, whereas climate damages are partly global in attribution, with longer term implications beyond 2050, health costs are domestic and are materialising now. Individuals, employers, the Dutch public health sector and its insurers are already paying a share of these costs from their own budgets each year. This means that the energy transition will reduce these costs conservatively estimated at €1.2BN a year annually from 2026 – 2050.

4.3. Economic value of energy security

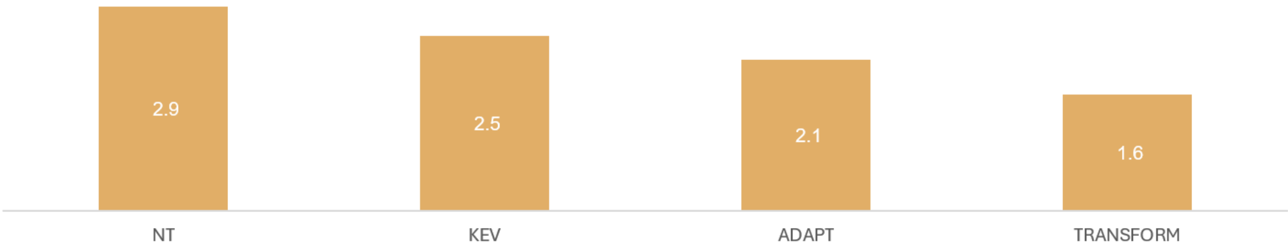
Decreased dependence on foreign fuel sources will reduce the macroeconomic impacts of energy crises that have plagued the country in the (recent) past.

Energy dependence is a structural risk of the Dutch the current system. When the Netherlands relies heavily on imported fossil fuels, it is vulnerable to global price volatility, supply disruptions, and geopolitical risk. For example, the Dutch central bank has estimated that the Russia-Ukraine war resulted in a national income loss of around €17BN in 2022 (DNB, 2023a). Strategic independence is therefore not a "soft" political preference; it is a measurable economic vulnerability with expected losses that can be calculated.

This paper has modelled how the energy transition reduces the vulnerability to international shocks in two ways: 1) by measuring the decrease in overall import dependence, and 2) by determining how the resulting energy carriers vary with global oil prices. In 2025, the Netherlands was 89% dependent on imported energy. The remaining 11% produced domestically, largely through renewable energy and remaining domestic production. Since the closure of the *Groningenveld* in 2024, there is only small-scale drilling remaining in the Netherlands.

This study has looked at the macro-economic damage of fossil-driven energy crises over the last 75 years. Allowing for higher levels of geopolitical uncertainty going forward, an estimate for expected economic losses has been calculated for each scenario. See figure 5.

Figure 5: Annualised expected security losses by scenario (2026 – 2050) (€BN)



Note: see Annex 11.4 for methodology and calculations

By 2050, physical import dependency falls to approximately 65% in ADAPT and 44% in TRANSFORM. The security calculation further adjusts this exposure for the assumed sensitivity of different imported energy carriers to oil-price shocks. On this basis, the modelled exposure factor falls to approximately 38% in ADAPT and 19% in TRANSFORM. Those energy carriers which the Netherlands will have to import, such as biomass and uranium vary much less with international oil prices than our current energy system. Greater strategic independence therefore strengthens reduce the expected economic losses from international energy crisis substantially. In TRANSFORM, the best performing scenario, the vulnerability is almost half that of no transition.

What has not been factored into this analysis yet, but could be in future, is the degree to which energy carriers are sourced from countries with different geopolitical risks. For example, most uranium is imported from Canada which arguably carries less geopolitical risk than fossil fuel imports from the Persian Gulf.

The numbers in figure 5 should again be seen as a floor rather than a ceiling of the expected security benefit of the transition. They estimate the macroeconomic benefit. Several additional strategic benefits are significant, can be monetised but are not yet included in this estimate. First, renewable energy infrastructure is cheaper to defend. Currently, infrastructure is geographically concentrated in a few large facilities (e.g. oil refineries) while renewable energy production is more geographically distributed across smaller-scale assets (e.g. solar panels). The ongoing Russia-Ukraine war is demonstrating how vulnerable (and flammable) fossil infrastructure is to enemy attack from drones and missiles. Dutch military and civilian infrastructure expenditure will have to reflect these new threats. Early estimates put the structural costs of increased civilian resilience are in the range of €769MM – €4.6BN (Staatscourant, 2026). Second, energy import dependence reduces the Netherlands freedom to make decisions regarding international alliances and defence spending in additional ways which are not captured by these macroeconomic estimates.

4.4. Economic effect of increased aggregate demand

The energy transition will increase aggregate demand in the Dutch economy which increases economic output (GDP) through multiplier effects.

The energy transition is fundamentally a shift from commodity-based system to a technology-based system. For the Netherlands this means that costs of imported fossil fuels are reduced and energy production will become more domestic and reliant on capital expenditure instead. Whereas every Euro spent on importing fuel is lost to the Dutch economy, that same Euro invested domestically will increase aggregate demand which in turn will have an impact on gross domestic product (GDP).

The model distinguishes between accrual CAPEX used in the production-cost comparison and actual new investment spending used for the aggregate-demand calculation. Over 2026–2050, modelled new investment spending is approximately €0.56TN under NT, €1.01TN under KEV, €1.31TN under ADAPT and €1.43TN under TRANSFORM. The net-zero pathways therefore bring substantially more investment expenditure into the model period.

The increase in aggregate demand is easily taken from the OPERA model output. It is the increase in domestic expenditure, mostly driven by the increase in capital expenditure, minus the increased production cost. Increases in energy production costs lead to higher prices which must be paid for by other sectors of the economy which carries opportunity cost.

The relationship between aggregate demand and economic output is more complex. It must be estimated based on GDP 'multiplier effects'.[23] The Netherlands does not maintain a generic economic multiplier to calculate the economic effects of an increase in investment (CPB, 2023). Internationally multipliers for renewable investment are empirically demonstrated to be in the range of 1.1 – 1.5 (IMF, 2021). This is substantially higher than

[23] The estimate in this paper is the result a simple multiplication 'Aggregate Demand' times 'Multiplier'. See Annex 11.5. A better estimate could be achieved through use of a General Equilibrium Model

fossil fuel energy investment multipliers which are in the range of 0.5 to 0.6. The primary reason for this is that clean energy is more labour intensive (IMF, 2021). Expanding energy grids, building wind and solar parks, improving insulation of buildings will sustain[24] hundreds of thousands of new jobs in the Dutch economy. Across a range of energy transition technologies, every €1MM invested is estimated to create 6 – 12 jobs (Rutovits et al, 2025) (CE Delft, 2026).

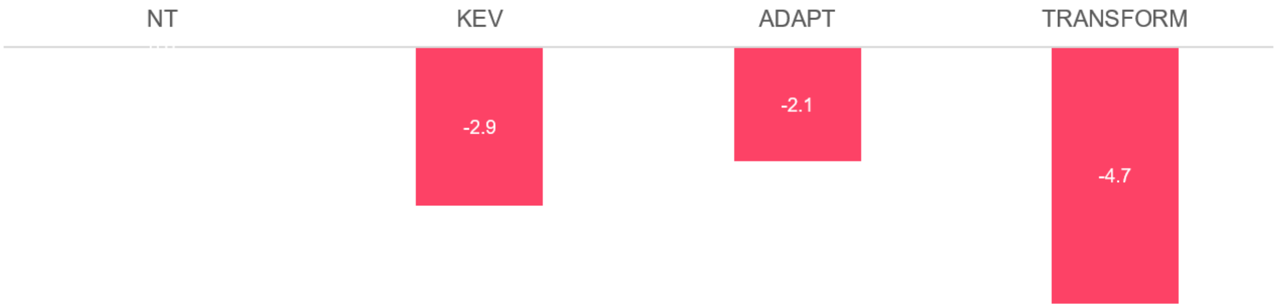
However, the Netherlands is unlikely to achieve the multipliers effects seen internationally. In the short term, grid congestion and skilled labour shortages are supply side constraints which hamper any the increase in economic output. The increase in aggregate demand translates into inflation and opportunity cost rather than increase in economic output. Output will only increase if productivity can be increased. This study has modelled this dynamic by taking haircuts of the potential benefits of 100% in 2030 and 50% in 2035. This means that the full potential economic upside is only modelled from 2040 onwards. With determination, 15 years should be sufficient to solve for supply-side constraints. For example, a shortage of technical skills cannot be solved within a period of a year, but over a decade training programmes and market incentives could solve for them.

Longer term, the Netherlands expects conditions of full employment to persist because of structurally high labour market demand (Denkwerk, 2025). In fact, due to persistent labour shortages in the Dutch economy, stimulating employment is currently not seen as an advantage (SZW, 2026). In economies at full employment, multiplier effects are lower (CPB, 2023). This study has modelled the expected increase in output based on a conservative multiplier of only 0.3. This is the equivalent of the direct impact of wages and taxes only (CBS, 2026a). This multiplier is also consistent with aggregate demand boosts observed in advanced economies at times of economic expansion (Sheremirov and Sprivska, 2022).

Nevertheless, even with a conservative multiplier, the impact on economic output modelled is significant. Figure 6 shows the impact of the aggregate demand boost in the energy sector on the wider Dutch economy across scenarios vis-à-vis 'no transition'.

[24] The effects of investment on capital expenditure are sustained longer term. Throughout the 25-year period from 2026 – 2050 investment levels are high. The depreciation period of ~90% of assets built is under 25 years. This means that additional jobs will be sustained even beyond 2050 as assets get rebuilt or replaced.

Figure 6: Annualised aggregate demand impact potential by scenario (2026 – 2050) (€BN)



Note: figures are negative because a positive externality reduces the cost to the wider economy. See Annex 11.5 for methodology and calculations.

TRANSFORM performs best compared with 'no transition' with annual economic multiplier effects of €4.7BN (the equivalent of ~5% of current energy production costs). The impact is also significant on KEV and ADAPT, albeit less pronounced. The reason ADAPT underperforms against KEV even though it has higher capital expenditure, is because of the relatively higher production costs of ADAPT.

The creation of thousands of highly-value-adding renewable energy jobs in the economy may be useful as a hedge against future economic downturns. Historically, across the economic cycles over the last 50 years the Netherlands has been in full employment only half of the time (CBS, 2024). The impact of Artificial Intelligence (AI) on labour market flexibility and labour productivity is also unclear. Although the expected impact of AI in the short-term is generally expected to be muted (OECD, 2023), its longer-term employment impact in advanced economies is expected to be substantial (IMF, 2023). The effects of a combination of higher productivity growth resulting from AI with higher aggregate demand resulting from capital expenditure in the energy sector are hard to predict but may substantially increase output. If over the next 25 years the Netherlands would have excess unemployment[25] at historical levels and would achieve the higher multiplier of 1.1 observed in international empirical studies, then the impact on economic output in figure 6 would more than double (see table 21).

[25] unemployment higher than 5%

5. The economic case for the energy transition

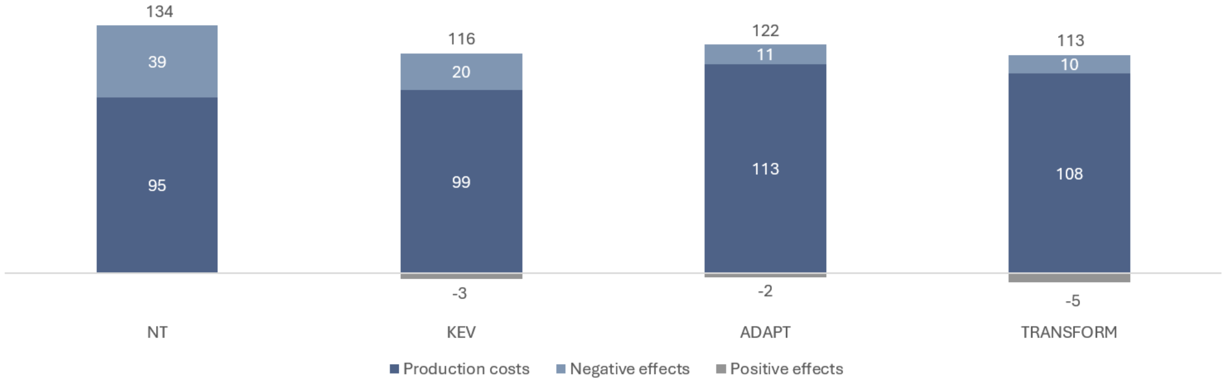
Under the central assumptions, NT has the highest economy-wide cost; KEV and the two net-zero pathways achieve rough parity in terms of economic cost.

The inclusion of economy-wide effects alters the cost-benefit analysis across scenarios (see figures 7a and 7b). On the production costs alone, no transition (NT) offers the Netherlands the most cost-effective energy system (at €95BN over 2026 – 2050). However, once the additional effects are included NT is the worst performer (at €134BN over 2026 – 2050). This is perhaps unsurprising given that it is the scenario that is most heavily penalised by including the cost of carbon emissions, and that it does not benefit from the change over to the more cost-effective renewable technologies that benefit current policies and the transition scenarios.

TRANSFORM performs best once economy-wide effects are included with an economic cost for the energy system of €113BN annually over 2026 – 2050. It performs marginally better than KEV and ADAPT with economic costs of €116BN and €122BN respectively. The increased capital expenditure driving the financial cost of the transition scenarios are effectively paid for by better economic effects, with these numbers largely offsetting each other.

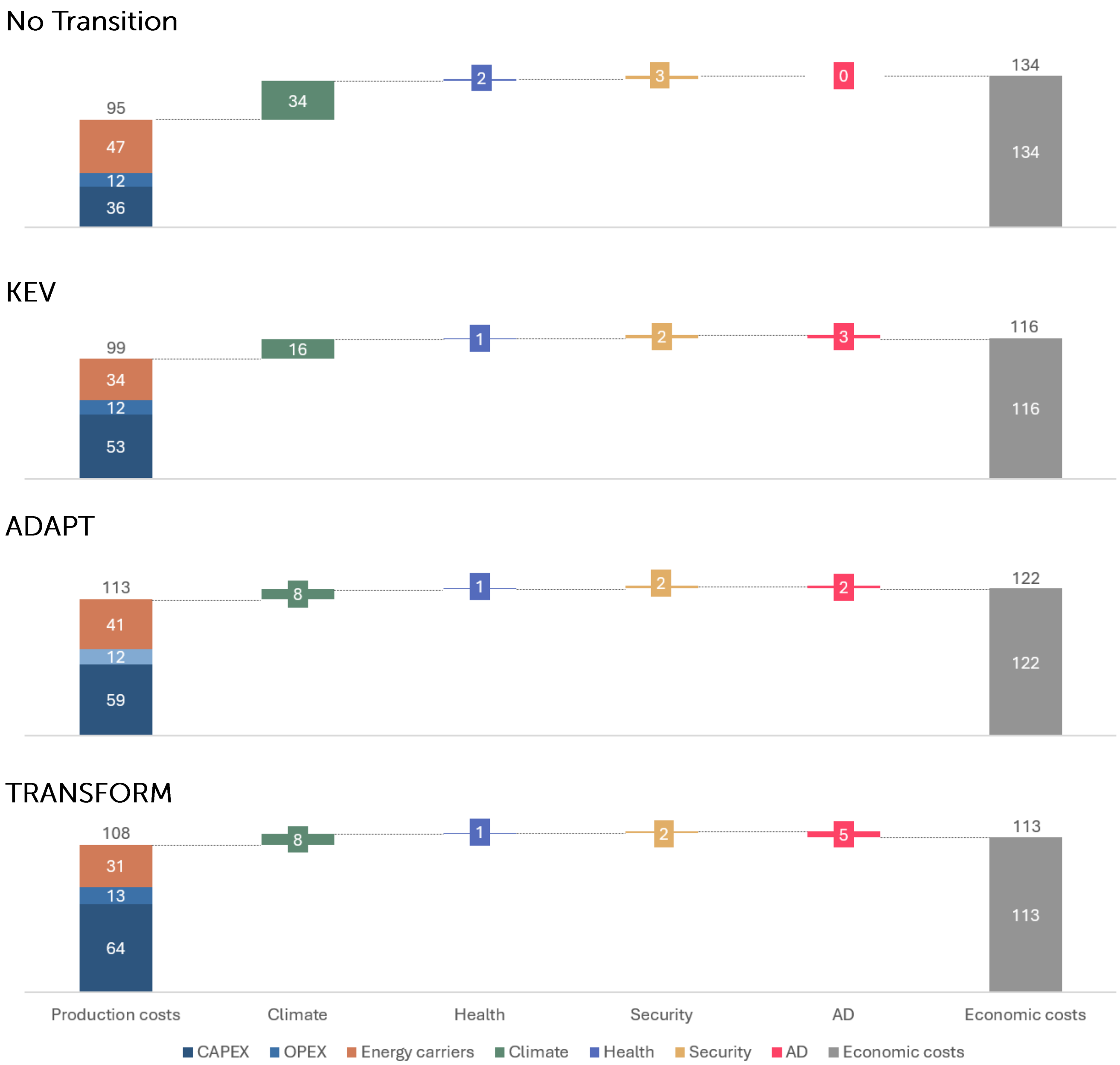
The intentionally headline grabbing title of this paper 'free energy transition' is derived from this insight of near parity. Should this however mean that the Netherlands should be indifferent between our current trajectory and a policy of pursuing net zero? Far from it.

Figure 7a: breakdown of production costs and wider economic effects 2026-2050 by scenario(€BN/year)



Note: production costs are the same totals as shown in Figure 1

Figure 7b: breakdown of production costs and wider economic effects 2026-2050 by scenario(€BN/year)



Note: Production costs are the same totals as shown in Figure 1.

Benefits beyond 2050

The benefits of a full energy transition would materialise definitively once costs and externalities beyond 2050 are included

The scenarios have data up until 2050, but their economic consequences extend well beyond that. ADAPT and TRANSFORM incur the investment costs required to reach net zero within the modelled period. KEV reaches 2050 with residual emissions, continuing fossil-fuel dependence and part of the required transition investment still ahead.

This creates an asymmetry. The costs of completing the transition are included for ADAPT and TRANSFORM, while these same costs are omitted from KEV and NT because they will still have to occur after the scenario's end date in 2050. Several categories of economic impacts remain outside the current model boundary:

- the investment required to replace remaining fossil technologies and infrastructure;
- continued expenditure on fossil fuels and other energy carriers;
- the residual value of renewable energy assets and possible write-downs of fossil-dependent assets; and
- climate, health and security effects after 2050.

A first terminal-value calculation covers climate alone. Discounted to 2025, post-2050 climate costs add approximately €158BN to NT and €47BN to KEV, while the corresponding value for ADAPT and TRANSFORM is close to zero. On an NPV basis, KEV's advantage over ADAPT falls from approximately €78BN within the 2026–2050 period to €32BN once this climate terminal value is included.

This remains a partial terminal-value calculation. The remaining transition investment, continued energy-carrier expenditure, health and security effects and asset values after 2050 have not yet been quantified. Their inclusion would provide a fairer comparison of pathways that reach 2050 in materially different states.

6. Sensitivity Analysis

The economic cost benefit analysis is most sensitive to energy prices, financing conditions, the climate shadow price and the aggregate-demand assumption.

The cost analysis produced by EIK, upon which this integrated cost – benefit paper is based, extensively documents the various uncertainties inherent in the scenarios (RVO, 2026). For example, the economic viability of several technologies included in the transition scenarios is dependent on policy choices. This paper refers to the EIK initial report for a better understanding of their modelling assumptions (RVO, 2026).

Nevertheless, the key insight in this paper that the energy transition can be had for 'free' is based on chosen values for four variables which have a significant impact on the cost-benefit calculations. Choices to input different values into these variables changes the business case for the transition in different directions.

In this context it is worth considering four key variables and asking the following questions:

1. How is the cost – benefit analysis affected by different input values for these variables?
2. In which direction is the variable trending long-term?
3. What level of control does the Netherlands have over these variables?

Tables 2-3 look into four variables with a material effect on the results: energy prices, financing conditions, the climate shadow price and the aggregate-demand assumption. Table 2 provides an overview of the values chosen for these variables, the nature of the sensitivity affecting the benefit analysis, and the long-term direction in which the values are trending. Table 3 provides comment over the level of influence or control the Netherlands has over these variables.

The sensitivity analysis does not support a precise and permanent ranking of KEV, ADAPT and TRANSFORM. The differences between these scenarios are small relative to the uncertainty surrounding several individual assumptions. The stronger conclusion is directional: including wider economic effects substantially narrows, and under several assumptions removes, the apparent cost premium of reaching net zero.

Table 2: sensitivity and trends of key variables affecting the benefit analysis

#	Variable	Value	Source	Sensitivity & trend
1	Oil price (barrel)	€75	PBL, 2025e	• Higher oil prices favour transition as the percentage of fuel costs is lower in transition scenarios • OPERA outputs have likely overstated the relative costs of the transition as oil prices are currently higher than modelled. Q2 2026 prices have averaged \$100 / €86 (FT, 2026) and are 15% higher than modelled • Modelling with Q2 2026 oil prices would add €6.8BN to the annual NT cost • Oil is a commodity and a scarce resource with higher prices expected by 2050 in the IEAs 'current policies' scenario (IEA, 2025a)
2	Financing costs/ discount rate (%)	4% (households and regulated sectors) 8% (firms)	OPERA	• Higher discount rates adversely affect the transition, as capital expenditure is higher in transition scenarios • The transition is capital intensive and relies on borrowing costs which is heavily impacted by interest rates • OPERA models with rates that approximate the borrowing costs of households and firms, but do not include risk premium
3	Climate shadow price[26] (tCO_2)	€174	PBL, 2025c	• Higher carbon prices favour transition scenarios with lower emissions • The central value is €174/tCO_2e, based on PBL and the CE Delft Handbook. • Higher future shadow-price paths increase the relative cost of pathways with residual emissions, particularly KEV and NT.
4	Investment Multiplier (unemployment rate)	31%	Calculations Annex 11.5	• Higher multipliers favour transition, as the transition has higher domestic expenditure • The range of values varies substantially: -30% – 220% (CPB, 2023) • The multiplier is sensitive to numerous factors such as assumptions of full employment and other supply side constraints (see Annex 11.5)

[26] Climate shadow price of abatement-cost-based carbon value

Table 3: Level of influence or control over the variables affecting the benefit analysis

#	Variable	Level of influence or control over variable
1	Oil price (barrel)	• No control. Price is dependent on global supply & demand factors. Sensitivity to supply chain and geopolitical risk
2	Financing costs/ discount rate (%)	• No control. ECB policy rates are outside Dutch national control. • Substantial influence. Predictable government policy, blended finance instruments and guarantees, affect both the risk premium that households and companies attach to investments as well as the effective rates paid by them for borrowing
3	Climate shadow price (tCO_2)	• No control: the impact of climate change is almost entirely driven by global, rather than Dutch emissions and mitigation costs. Some local adaptation investments may shield the Netherlands from the economic impact of acute climate events, but doesn't change Netherlands legal obligations (Paris, *Klimaatakkoord*, EU Climate Law). • Limited influence: If advanced countries, such as the Netherlands, lead in the transition and establish the viability of net-zero then mitigations efforts elsewhere have an increased chance of success
4	Investment Multiplier (unemployment rate)	• Short term limited influence: supply side bottlenecks will negate the benefits of increased in the Netherlands through higher inflation and opportunity cost without much that can be done about it • Longer term significant influence: government policies can effectively manage supply side bottlenecks to contain inflation. Indeed, the national action plan for green and digital jobs intends to do just that (Rijksoverheid, 2023a)

A general insight around the sensitivity of these four key variables is that collectively they are trending in favour of the transition. In other words, if this exact study were to be carried out in five years' time, the expected economic benefits of the transition would likely be greater than today.

The policy relevance lies in the distinction between variables that the Netherlands can influence and those it cannot. The government has considerable influence and control over the discount rate and investment multiplier to favour transition. It can influence project risk, financing conditions, permitting, grid availability, workforce capacity and policy continuity. Policies designed to improve these conditions do more than speed up implementation. It directly reduces the economic cost of the transition. Variables that the government cannot control, namely oil price, geopolitical shocks and carbon, should feed into a discussion about the kind of energy risk profile the Netherlands chooses to have.

7. Risk and resilience

The energy transition is a shift away from recurring and increasing commodity price, geopolitical and climate risks towards more immediate financing, infrastructure and delivery risks to achieve longer-term resilience.

The economic comparison shows that affordability alone gives an incomplete basis for choosing between pathways. The scenarios expose the Netherlands to different risks, at different times and with different degrees of policy influence.

As established in section 6, the transition business case is sensitive to a limited set of four key variables subject to different uncertainties and vulnerable to different types of risk. Table 4 below provides an overview of the key risks of the current system risks versus those of the transition. Assigning probabilities to these risks is a fool's errand. As Niels Bohr is attributed to saying: *"Prediction is very difficult, especially about the future."*

Nevertheless, there is a benefit to understanding the nature and character of the risks we currently face versus those that we will have. An understanding of these risks is important not just to determine how fast to implement the energy transition, but also to determine effective policy to manage and mitigate the risks inherent in the resulting national risk profile. In the overall comparison of the risks of transition versus the risks of no transition there are three characteristics related to timing, influence and reversibility that stand out.

Timing: Slower transition pathways retain recurring and increasing exposure to fossil-fuel prices, geopolitical shocks, climate effects, legal obligations and a delayed transition investment requirement. The risk profile of the energy transition is marked by taking more financing, technology and delivery risks up front to achieve longer term resilience. This means that transition risks inherent in a chosen pathway should be weighed purposefully in comparison to avoided longer term risks.

Influence: from an overall perspective, Dutch and European policy has more direct influence over many of the risks associated with the energy transition, than those of our *status quo*. ETS prices, effective interest rates[27], government policy and project delivery risks are all risks that can be managed at national and European levels. This is not say that there are no costs or difficulties in management of these risks, but rather that there are instruments available should policy makers wish to use them. Policy can affect effective financing costs, infrastructure availability, permitting, revenue certainty and aspects of project delivery. Technology development and global supply chains remain partly outside national control. Oil prices and international supply shocks are largely external.

[27] Headline interest rates are determined independently by the European Central Banks. However, policy makers can have influence over effective interest rates paid by corporates and households for renewable energy investments through guarantees, and blended finance instruments. See Sustainable Finance Lab paper for details and options to neutralise interest rate risk (Sustainable Finance Lab, 2023)

Table 4: comparing key risks of the current system vs the transition

Key risks of no transition	Key risks of the transition
Oil price risk: short- and long-term supply and demand factors which affect the price per barrel of crude oil (and other correlated fossil fuel prices) (IEA, 2025a) **Geopolitical risk**: the broader economic costs that the Netherlands incurs because of energy dependence on both allies and adversaries. See section 4.3 for the economic impact of acute crisis events. **Physical climate risk**: worsening climate change affects not only the acute damages resulting from acute climate events but also impacts on increasing adaptation costs that the government will have to plan for e.g. the billions required to strengthen the Afsluitdijk (Rijksoverheid, 2026). **Legal risk:** the compensation costs resulting from enforcement by the courts for the Dutch government to abide by its international treaty commitments (Paris) as well as domestic and EU legal frameworks (Klimaatakkoord, EU 2022 Climate Law). Increased litigation by NGOs and potentially also foreign states is already evident through e.g. the climate case brought to the Government by Greenpeace regarding Bonaire (Rechtspraak, 2026) **Stranded asset risk**: the write-downs on fossil-fuel dependent assets resulting from changes that affect the economic viability of these assets (e.g. policy changes, carbon taxes, cheaper renewable alternatives)	**ETS price risk**: like exposure to oil price today, the ETS price will depend on supply and demand conditions which are unknown. The price itself changes the cost-benefit of fossil fuel vs clean technologies **Interest rate risk**: The degree to which borrowing costs affect the investment decisions upon which the more capital-intensive transition technologies depend. See Sustainable Finance Lab paper for details and options to neutralise (Sustainable Finance Lab, 2023) **Policy risk:** across several value chains of the energy transition the transition requires (e.g. electricity, hydrogen, heat), collective action problems need to be overcome. A stable policy environment is essential for investment decisions, especially in assets which have a longer depreciation period (10 – 25 years), than the duration of a Parliament **Technology risk**: several technologies, especially in the TRANSFORM scenario, currently do not yet have a viable business case without additional policy. See EIK report for details and considerations (RVO, 2026). Investments in immature technologies also contain risk. **Project delivery risk:** Budgeted capital costs for major infrastructure projects (e.g. nuclear powerplants) are frequently exceeded owing to factors that include overly optimistic planning and unforeseen circumstances.

Technology risk management is somewhat different. Green hydrogen, parts of CCS and Power-to-Liquids currently face greater uncertainty around cost, timing, performance and deployment at scale. Although there are financial instruments and guarantees that can support the scale up of these new technologies, as a small country, the Netherlands has only limited influence over technology maturity. Instead, the management of technology risk requires a pragmatic approach to implementation over the next 25 years. It includes making sound judgements regarding the timing of technology implementation and potentially substituting of specific technologies where necessary.

Reversibility: the fear of placing bets on the 'wrong' technologies is real. Policy makers should of course be mindful and cautious to consider technological maturity before making public commitments to that technology. However, across energy transition actions early investments in grids, skills and low-carbon infrastructure create option value by supporting more than one future technology pathway. Delaying these investments may retain financial resources near-term, but also lock in dependency on fossil energy sources which drags out the transition timeline. Overall, it is easier to change course by slowing down than it is to suddenly have to accelerate. The timing of investment therefore changes both the risks carried today and the options available later.

The transition shifts part of the exposure away from recurring fossil-price and geopolitical risk towards financing, infrastructure, technology and delivery risks. Ultimately the Netherlands needs to weigh not just the risks associated with transition investments but also those of the no transition status quo. The Netherlands needs to choose what risk profile it wants to have based on the risks it will be exposed to, when these risks will arise, and to what extent they can be influenced and managed at the national level.

8. From macro insight to micro action

Policy makers should work to align the individual decisions made by households, companies, financiers, network operators and public bodies with economy-wide value

The model operates at the macro level of the Dutch economy. The energy transition however does not happen at the macroeconomic level. Thousands of individuals across households, companies, financiers, network operators and public bodies need to make investment decisions that stack up. Policy makers need to ensure that these decision makers face the right incentives. The transition is not "free" for everyone. Individuals within value chains depend on the cooperation of others. The system benefits are real and economy-wide, but they are distributed unevenly across actors and over time. Costs are often incurred upfront and concentrated, while benefits are diffuse, delayed, or captured by different parties. Decision makers who will need to determine the appropriate decarbonisation pathway for the Netherlands can take three recommendations from this paper:

1. **Include monetised values of external effects into decision making**. Major policy and investment decisions should not be made based on production costs alone but include at a minimum the climate-, health-, security-, and macroeconomic impacts elsewhere in the economy. Extend, with an appropriate discount factor, the cost benefit analysis beyond 2050. This prevents pathways from appearing cheap simply because their costs fall beyond the model horizon.
2. **Align the incentives of individual decision makers with the economy-wide value of the transition.** The costs and benefits of the transition fall to different actors and at different times. Decision makers should identify where households, companies, financiers and network operators lack a workable investment case, and use pricing, compensation, finance and risk-sharing instruments to close that gap.
3. **Consider the downside risks of no transition and keep options open**. The national level business case is sensitive to a number of key variables and technological developments. The differences between the economic costs of each of the scenarios, KEV, ADAPT and TRANSFORM are small relative to developments in these sensitivities. Decisions need to be understood in terms of expected values as well as in terms of resilience of worst-case outcomes.[28] This is not a question of picking a

[28] so called max-min strategies

scenario and sticking with it, but requires a much more dynamic approach that takes the best elements of the net zero scenarios as and when decisions need to be made.

9. Further research

The current model provides a proof of concept and a clear agenda for the next round of analysis.

It is probably fair to say that the work on this economic impact analysis will never truly be done. This paper is intended to be seen 'proof-of-concept' for the value of a broader study around of economic benefits.[29] Several categories of work would enhance the future utility of the analysis:

- **Further substantiation and sensitivity analysis of the four monetised economy-wide effects** in this paper: climate, health, security, and aggregate demand. Annexes 11.2 – 11.5 document the modelling limitations and suggested improvements to the methodology of each of the four effects considered.
- **Monetisation of additional effects.** The effects modelled are important but not complete. Future work could include indoor air quality, healthy housing, active mobility and noise, energy poverty, stranded assets and local effects of energy infrastructure. Positive and negative effects should be treated symmetrically.
- **Extension beyond 2050.** One of the self-imposed constraints in the benefits methodology is to limit the analysis to the period 2026 – 2050. The pathways reach 2050 with different stocks of infrastructure, residual emissions, fuel dependence and remaining investment requirements. Extending the horizon would allow a fairer comparison of pathways that end the current model period in different states.
- **Integration of insights with those the broader EIK programme**. EIK has divided up work into concrete work packages, which have impacts on each other. For example, the study of macroeconomic impacts and external benefits affect government finances. The aggregate-demand effect in particular should eventually be tested through the macroeconomic and fiscal models used by government.
- **Further sensitivity analysis**. The sensitivity analysis in section 6 is largely qualitative and static. Although the model built for this study allows for the analysis of the impact of individual variables, it is not a dynamic equilibrium model which allows for

[29] Work packages on macroeconomic impacts and external benefits are planned to be studied in 2027 as part of the EIK programme (EIK, 2026).

the analysis of changes to multiple variables simultaneously. Further sensitivity analysis would give policy makers a more complete understanding of the impact of the four key variables (oil price, carbon price, discount rate, economic multiplier / unemployment rate) on the overall results

- Further study of the risk impacts. The implication of the shifting of economic benefits towards the transition has implications for the fossil-fuel dependent economy and increases the risks of stranded assets. The phase of the transition which is marked by non-linearity and disruptive change (Loorbach, et al, 2017) may be closer than market participants expect. Real economy energy and infrastructure assets often depreciate over a period of 25 - 40 years. Investment decisions made today will likely still impact our economy beyond 2050.
- Distributional effects . A national economic benefit can coexist with unattractive business cases for individual actors. Future work should map who pays, who benefits and who carries risk across households, industry, network operators, government and finance, then test the effects of alternative cost-allocation and compensation mechanisms.

This paper has aimed to give the best insight into economy-wide value given the limitations of data and time available at this point. The suggestions for further work would strengthen the core argument in and underpin the conclusions reached in this paper: namely that affordability should not be the key constraint on the transition.

10. Conclusion

The inclusion of monetised values for climate, security, health and macroeconomic impacts materially changes the Netherland's business case in favour of the energy transition.

This paper provides a conservative macro-economic rationale for accelerating the transition.
It started from EIK's cost analysis. Using the ADAPT and TRANSFORM scenario pathways and a conservative valuation approach, this paper expanded the ledger beyond the energy-system balance sheet to the entire Dutch economy. It has layered on an analysis of four monetisable economy-wide effects: the value of climate, the value of health, the value of security, and the value of increased aggregate demand.

A key aim has been to encourage policy makers to look more holistically at the business case of the energy transition and account for the additional economy-wide effects, both positive and negative. By assigning values to climate, security health and macroeconomic impacts policy makers will be able to make better informed decisions. Even under prudent modelling assumptions and scope, the conclusion is clear: the Netherlands does not need to sacrifice economic welfare to achieve net zero by 2050. The energy transition effectively pays for itself over the transition period (2026 – 2050). Including longer-term benefits beyond 2050 tips the balance of the scale even more in favour of the transition.

Another aim of this paper has been to move public discourse on from a limited question of affordability towards a broader discussion about the risk profile the country chooses to take on. The differences between the economic costs of each of the scenarios, KEV, ADAPT and TRANSFORM are small relative to risks that the economic business case is sensitive to.

Navigating these challenges requires both a coherent research agenda and a policy agenda at the same time: mapping distributional effects, testing alternative compensation and cost-allocation mechanisms, and identifying the institutional and value chain bottlenecks that block coordinated action. Dealing with these challenges will be easier to solve when people can see that there is money on the table.

11. Annexes

11.1. General assumptions

This paper has sought to build on the OPERA methodology in the most consistent possible manner. The analysis includes the following general assumptions:

- **System boundary.** National (Netherlands), economy-wide framing, consistent with scenario outputs and Dutch valuation handbooks.
- **Time steps.** Results are calculated in 2025, 2030, 2035, 2040, 2045, 2050. Where needed, values are aggregated into five-year blocks for comparability across streams (e.g., 2025 represents 2021–2025 average annual value or the "period up to year", depending on the underlying dataset definition).
- **Scenario basis.** Scenario logic and decarbonisation pathways are taken from the TNO 2050 scenario update, modelled with OPERA.
- **Valuation basis.** Where possible Dutch standard values are used (e.g., the Handbook of Environmental Prices for €/kg pollutant damage costs).
- **Calibration principle.** Where external Dutch benchmarks are used (e.g., national monetised damage totals), calibration is applied as a uniform level shift and does not alter relative scenario differences.
- **Price base and real terms.** Unless stated otherwise, all monetary results are reported in euros at a consistent price basis year. Where input parameters originate from different price years (e.g., environmental price factors), values are converted to the report's common price basis using a transparent deflator convention. Results are presented in real terms (no inflation) unless explicitly labelled nominal.
- **Time aggregation.** Scenario outputs are evaluated at milestone years (2025, 2030, 2035, 2040, 2045, 2050). Values labelled "per year in the five-year period up to YEAR" are interpreted as average annual values over that period; five-year totals are computed by multiplying annual values by five, unless the underlying source already provides period totals.
- **Discounting.** The main results are reported in 2024 constant prices without discounting to preserve comparability across economy-wide effects and avoid embedding an additional normative assumption. Where relevant, discounting is treated as a sensitivity parameter.
- **System boundary and double counting.** The valuation focuses on national, Netherlands-wide impacts consistent with the scenario outputs. Where an externality overlaps with components already included in the financial system-cost baseline (e.g., fuel imports), the valuation is framed as an exposure/risk or externality effect to avoid double counting.

- **Scenario comparison and calibration.** NT is used as the primary reference for avoided damage/value calculations unless specified otherwise. Where calibration to external benchmarks is applied, it adjusts absolute levels only and does not change relative differences between scenarios.

11.2. Calculations: economic value of climate

Definition and scope

This impact estimates the economic value of avoided greenhouse-gas emissions under each scenario relative to NT. It focuses on energy-related CO_2e trajectories consistent with the scenario set and expresses results as (i) avoided emissions and (ii) monetised avoided climate damage using an explicit €/tCO_2e coefficient.

Assumptions and sources

The economic cost used for calculations in this paper is €174 per tCO_2, which is the price used by PBL (PBL, 2025c), which is in turn based on calculations performed by the *Handboek Milieuprijzen* 2023 (CE Delft, 2023).[30] The underlying methodology used is the cost to prevent climate change and is based on a median price of international literature on the basis of an IPCC 1.5-degree scenario with limited overshoot. The handbook recommends this price used for economic cost-benefit analyses.[31][32]

Methodology and computation

The absolute emissions (CO_2e) of KEV, ADAPT and TRANSFORM are outputs of the OPERA model. The emissions of NT have been constructed based on the 2025 baseline extrapolated with GDP growth for comparability. The economic costs are a simple multiplication of the emissions (tCO_2e) multiplied by €174 per tCO_2e. See tables 5 & 6 below.

[30] Tabel 33 Nieuwe CO_2-prijzen, in €2021 per tCO_2 exclusief btw, page 130.

[31] maatschappelijke kosten-batenanalyse (MKBA)

[32] Note that the CE Delft methodology applies a discount factor of 4.3% annually. This paper has not indexed the PBL €174 2024 figure to €181in 2025. The computation does not materially impact the analysis and avoiding additional computations improves transparency and comparability with other public sources

Table 5: annual emissions by scenario ($MtCO_2e$)

Scenario	2025	2030	2035	2040	2045	2050
NT	157.3	169.3	182.5	196.6	211.8	228.2
KEV	157.3	121.6	105.8	95.3	74.6	67.6
ADAPT	-	98.4	68.6	45.7	22.9	0.0
TRANSFORM	-	87.3	68.6	42.7	22.9	0.1

Source: Opera output

Table 6: annualised climate costs by scenario (€BN)

Scenario	2025	2030	2035	2040	2045	2050
NT	27.4	29.5	31.8	34.2	36.9	39.7
KEV	27.4	21.2	18.4	16.6	13.0	11.8
ADAPT	-	17.1	11.9	8.0	4.0	0.0
TRANSFORM	-	15.2	11.9	7.4	4.0	0.0

Source: own calculations

Uncertainty and sensitivity

The correct cost of emissions is much debated, and the range calculated by various studies is huge. The CE Delft handbook recognises this and provides a high and a low range for CO_2 costs (even though it recommends the mean price for cost-benefit analysis).

Moore et al have carried out a comprehensive meta-analysis of1,823 CO_2 price estimates in 147 international studies carried out since 2000 (Moore et al, 2024). Across these studies they have found that CO_2 prices range from \$32 – \$874 (5% – 95% range – 2020 prices). They have analysed the drivers of variance across these estimates and conclude the three biggest variables explaining differences are: 1) the discount factors used to calculate future economic damage (25% of total variance), 2) the underlying economic model used (25% of total variance), and 3) growth damages, or assumptions regarding the reversibility of economic losses once incurred[33] (13% of the total variance).

The paper constructs a synthetic distribution of carbon prices to allow for comparability which has a mean of \$283 per tCO_2 and a synthetic median of \$185. The substantial difference between the mean and the median is explained by the long right tail in the distribution of paper outcomes.
The PBL number used in this paper is reasonably close to the median price in the Moore et al paper (€174 vs \$185). Using the number that is closer to the median can be considered

[33] In other words, whether climate tipping-points are reached and therefore whether economic losses resulting from climate change are acute or structural

prudent from the perspective of not over-estimating climate costs. However, it should be acknowledged that this leaves some tail risk unaccounted for in the economic cost calculation.

Limitations

Any single €/tCO_2 estimate is an approximation and reflects both methodological and ethical choices. Results should be interpreted as order-of-magnitude comparisons under a consistent pricing convention, not as precise forecasts of future damages. Benefits can never be known with certainty as they materialise as avoided costs and risks and are therefore invisible at any point in time.

Policy grounding

Explicit carbon valuation globally is widely used in appraisal practice and impact accounting. The value of €174 per tCO_2 (PBL, 2025c) is recommended for cost-benefit analysis in the Netherlands. The value is within comparable range of the mean value of international studies and below the €180-€200 expected cost of EU ETS permits by 2035 (ABN AMRO 2025, Bloomberg, 2024).

Steps to improve the methodology

A better understanding of the economic costs is a matter of constant attention and research. The social cost of carbon should be updated as and when better information becomes available. An additional dimension of research could be to analyse the Netherlands' climate adaptation investments. For example, the government is investing €2BN in making the Afsluitdijk climate resilient (Rijksoverheid, 2026). Another approach is legal rather than economic in nature. The degree to which the Netherlands is liable for the climate damage it is causing (rather than suffering) is still a matter where the courts may in future pronounce themselves more forcefully. The legal case regarding Greenpeace Bonaire is only scratching the surface in this regard.

11.3. Calculations: economic value of health

Definition and scope

This impact quantifies the economic damage from air pollution associated with the Dutch energy system. The calculation covers five NEC-regulated pollutants: nitrogen oxides (NO_x), ammonia (NH_3), fine particulate matter ($PM_{2.5}$), sulphur dioxide (SO_2), and non-methane volatile organic compounds (NMVOCs). The geographic scope is national; the time horizon is 2026–2050 in five-year intervals, consistent with the other externality modules. Damage is estimated exclusively on a costs-of-illness (COI) basis: direct treatment costs and productivity losses attributable to illness. Mortality-related damage, the VSL, and the monetisation of lost life-years are explicitly excluded. This is a deliberate normative choice: VSL-based health valuation applies a fundamentally different and considerably broader welfare concept than the economic productivity framework applied consistently throughout this paper. The underlying CE Delft damage factors are expressed in 2021 prices. The model subsequently applies a real growth adjustment to the illness-related economic costs, as described below.

Assumptions and sources

The damage cost factors used in this paper are derived from the CE Delft Handbook on Environmental Prices NL 2023 (CE Delft, 2023). The Handbook provides total environmental prices per kilogram of emission for each NEC pollutant, as well as a breakdown by damage component (Tables 2, 20, 24, 37, 72, and 73). This paper uses only the COI components: direct treatment costs (COI health) and material damage (COI material). The resulting COI fraction (the share of the total environmental price that represents economic productivity loss rather than welfare loss) ranges from 5.1% for NH_3 to 12.7% for SO_2. The underlying CE Delft damage factors are expressed in 2021 prices. The model subsequently applies a real annual increase of 0.975% to the monetised COI damage, based on an assumed growth rate of 1.5% and an elasticity of 0.65. The adjustment is applied at the midpoint of each five-year period. It increases the damage factor to approximately 1.28 times its base value by 2050. This adjustment reflects the expectation that the economic costs associated with illness will rise in real terms over the modelling period. It is separate from general inflation, which is excluded from the analysis. Table 7 below summarises the damage factors applied.

Table 7: COI damage factors by pollutant (CE Delft 2023, 2021 price level)

Pollutant	Total environmental price (€/kg)	COI health (€/kg)	COI material (€/kg)	Total COI (€/kg)	COI fraction
NO_x	29.9	1.3	1.1	2.4	8.0%
NH_3	49.3	2.5	0.0	2.5	5.1%
$PM_{2.5}$	121.0	6.7	2.5	9.2	7.6%
SO_2	57.5	3.0	4.3	7.3	12.7%
NMVOCs	2.73	–	–	0.14	5.0%

Source: CE Delft 2023

As an external calibration anchor, PBL estimates the total welfare-based damage from air pollution in the Netherlands at €19.5BN per year (PBL, 2025b). This figure encompasses mortality valuation and is therefore considerably higher than the COI estimate in this paper: the weighted average COI fraction across all pollutants in the NT base year 2025 is approximately 7.5%, making the COI estimate roughly one-twelfth of the PBL welfare total. This gap reflects the deliberate exclusion of mortality costs and makes explicit that the health contribution to the transition case as presented in this paper is a conservative floor, not a ceiling.

For scenarios where pollutant-specific emission projections are unavailable (ADAPT, TRANSFORM, and NT), combustion-linked pollutants (NO_x, $PM_{2.5}$, SO_2) are scaled using the ratio of energy-related CO_2 emissions per scenario relative to KEV, as derived from the ETM modelling. NH_3 and NMVOCs are not scaled and are held equal to the KEV trajectory across all scenarios, as both are dominated by non-energy sources (agriculture and solvent use respectively). Table 8 gives the scaling factors applied per scenario and period.

Table 8: CO_2 scaling factors relative to KEV (index: KEV = 1.00)

Scenario	2030	2035	2040	2045	2050	Applied to
NT	1.29	1.39	1.73	2.06	3.38	NO_x, $PM_{2.5}$, SO_2
KEV	1.00	1.00	1.00	1.00	1.00	reference
ADAPT	0.81	0.65	0.48	0.31	~0	NO_x, $PM_{2.5}$, SO_2
TRANSFORM	0.72	0.65	0.45	0.31	~0	NO_x, $PM_{2.5}$, SO_2

Note: NH_3 and NMVOCs: not scaled; held equal to KEV across all scenarios.

Methodology and computation

The KEV emission baseline is read directly from PBL's *Actualisering monetaire milieuschade* (PBL, 2025b, emission table ERL 2025). Values for 2025 through 2035 are observed; values for 2040 through 2050 are extrapolated by applying the implied annual growth rate per pollutant over the 2025–2035 period. Table 9 gives the resulting baseline.

Table 9: KEV emission baseline (kilotonnes per year)

Pollutant	2025	2030	2035	2040[1]	2045[1]	2050[1]
NO_x	270	229	195	166	141	120
NH_3	120	102	98.7	95.5	92.4	89.4
$PM_{2.5}$	16.1	14.8	14.0	13.2	12.5	11.9
SO_2	23.3	20.0	18.5	17.1	15.8	14.6
NMVOCs	244	234	229	224	219	215

Source: own calculations

[1] Linear extrapolation based on implied annual growth rate over 2026–2035.

Emissions for the other scenarios are derived by applying the CO_2 scaling factors from Table 8 to the combustion-linked pollutants. The scaled emissions (kt/year) are then multiplied by the COI damage factor (€/kg) from Table 7 to produce annual damage costs per scenario. A calibration factor of 0.92 is applied uniformly across all pollutants and scenarios to align the modelled welfare total for NT in 2025 with the PBL anchor of €19.5BN; this leaves relative differences between scenarios unchanged. The calibrated welfare damage is subsequently multiplied by the pollutant-specific COI fraction to produce the economic damage layer reported in table 10 below.

Table 10: annual health costs by scenario (€BN)

Scenario	2025	2030	2035	2040	2045	2050
NT	1.46	1.40	1.56	1.71	2.10	2.30
KEV	1.20	1.08	1.02	0.97	0.93	0.89
ADAPT	–	0.93	0.76	0.62	0.49	0.30
TRANSFORM	–	0.86	0.76	0.60	0.49	0.30

Source: own calculations

Note: ADAPT and TRANSFORM share the KEV 2025 starting value; divergence from KEV begins in 2030.

Uncertainty and sensitivity

The principal source of uncertainty in this calculation is the COI fraction per pollutant, derived from CE Delft Handbook tables rather than directly observed. These fractions combine epidemiological evidence with economic cost assessments, both of which carry inherent estimation uncertainty. A sensitivity range of ±40% around the central COI factors has been applied, consistent with the uncertainty ranges documented in the Handbook. Table 11 summarises the effect on annualised average health costs.

Table 11: sensitivity analysis on COI damage factors (annualised average 2026–2050, €BN/yr)

Scenario	Low (–40%)	Central	High (+40%)
NT	1.09	1.81	2.54
KEV	0.59	0.98	1.37
ADAPT	0.37	0.62	0.87
TRANSFORM	0.36	0.60	0.84

Source: own calculations

The scenario ranking (NT > KEV > ADAPT ≈ TRANSFORM) is robust across the full sensitivity range. A further source of uncertainty is the CO_2-ratio proxy used to scale combustion pollutants across scenarios: the relationship between fossil fuel use and NO_x, $PM_{2.5}$ and SO_2

emissions is in practice technology-specific and not fully linear. This structural uncertainty is not separately quantified in the table above.

Limitations

The numbers calculated should be seen as a conservative lower bound on the true economic cost of air pollution from the Dutch energy system rather than a precise estimate. Three limitations are particularly relevant. First, NH_3 and NMVOC emissions are held constant across scenarios. To the extent that behavioural change in TRANSFORM also reduces agricultural or solvent-related emissions, the health benefit of the deepest transition scenario is understated. Second, the CO_2 ratio proxy for combustion pollutants is an approximation that does not capture technology-specific emission factors: the actual NO_x and $PM_{2.5}$ profiles of biomass and hydrogen pathways may differ materially from fossil gas. Third, the COI approach excludes welfare damage from premature mortality. A VSL-based monetisation of the same emission trajectories would yield figures approximately twelve times higher. The COI estimate is a floor on health damage, not a ceiling, and should be interpreted accordingly. Fourth, the real growth adjustment is based on a simplified relationship between economic growth and the costs associated with illness. Both the assumed growth rate and elasticity affect the later-period results and should be tested through sensitivity analysis.

Policy grounding

Dutch and European policy has long recognised air quality as both a public health and an economic issue. The Netherlands is legally bound by the EU NEC Directive (2016/2284/EU), which sets binding national emission reduction commitments for the five pollutants covered in this analysis. PBL's annual monitoring of monetised environmental damage (from which the €19.5 bn welfare anchor in this paper is drawn) provides the institutional framework within which these figures sit (PBL, 2025b). At the European level, the Zero Pollution Action Plan targets a 55% reduction in premature deaths from air pollution by 2030 relative to 2005 (European Commission, 2021). The energy transition directly supports these targets by reducing fossil fuel combustion, the primary energy-sector source of NO_x, $PM_{2.5}$, and SO_2.

Steps to improve the methodology

The methodology used here is a first-order approximation that could be further developed in several directions. A preferred approach would link scenario-specific fuel mix outputs directly to technology-level emission factors for each pollutant, rather than using the CO_2

ratio as a uniform proxy. This would allow NO_x, $PM_{2.5}$, and SO_2 to be modelled separately by fuel type and combustion technology, which is particularly relevant for biomass and hydrogen pathways. A second improvement would extend the pollutant scope to include NH_3 and NMVOCs as scenario-sensitive variables, by drawing on agricultural transition modelling that is currently outside the scope of this paper. Third, a parallel welfare-based calculation using the same emission trajectories and CE Delft total environmental prices could be presented alongside the COI estimate for policy audiences where mortality valuation is considered appropriate. This would allow readers to situate the COI figure within the full range of monetised health damage, rather than treating it as the only available estimate.

A fuller assessment of the health implications of the energy transition beyond the effects of outdoor air pollution could be developed through three additional modules.

- Indoor combustion. This module would assess the health effects of phasing out gas-based cooking and heating. It would require scenario-specific estimates of the number of gas appliances in use, changes in indoor exposure to pollutants such as NO_2 and particulate matter, and Dutch cost-of-illness estimates for the associated health outcomes.
- Healthy housing. This module would examine the combined effects of insulation, indoor temperature, ventilation, damp, mould and energy poverty. The health impact of renovation depends not only on lower energy use, but also on whether homes become warmer, drier and adequately ventilated. Poorly designed renovation could also create negative effects, particularly through overheating or insufficient ventilation.
- Mobility and noise. This module would assess health effects from changes in travel behaviour and transport technology. Relevant channels include physical activity from walking and cycling, road safety, exposure to traffic-related air pollution and changes in noise. Electrification may reduce noise at lower speeds, while the larger effect may come from any reduction in total vehicle use.

These modules would require additional data that are not available in the current energy model.

11.4. Calculations: economic value of security

Definition and scope

Since the second world war, energy crises have wreaked economic havoc worldwide. Crises are unpredictable in terms of cause, frequency and severity. This paper has looked back at the crises over a period of 75 years to attribute an annual expected impact based on energy import dependence. This attribution factor has then been applied to each of the scenarios based on the import dependence of that scenario.

Assumptions and sources

The impact of five major supply side energy crises over the last 75 years have been included in this analysis. Various studies have estimated the percentage GDP impact of these crises on the Dutch economy (see table 12). To ensure like-for-like comparisons of these crises, the € GDP impact has been scaled to a figure assuming 100% import dependence. For example, the DNB estimates that the 2022 winter energy crisis following the Russian invasion of Ukraine, cost the Dutch economy 2.0% of GDP growth, or €17BN over two years (DNB, 2023a, 2023b). However, this is at a time that the Netherlands is 89% dependent on energy imports. The €20BN impact is the extrapolated impact had the Netherlands been 100% import dependent.

Current Dutch GDP levels have been taken from CBS national accounts and have been scaled for comparability (CBS, 2025).

Table 12: Dutch GDP impact from global energy shocks

Energy Crisis	**GDP impact (%)**	**GDP scaled[34] impact** (€BN 2024 prices)	**Source**
1973 Oil Crisis: OPEC Embargo	3.0%	€30BN	CBS 2026b
1979 – 1980 Oil Crisis: Iranian Revolution & Iran-Iraq War	3.3%	€33BN	CBS 2026b
1990 Gulf War	0.4%	€4BN	ESB 1990
2022 Russia-Ukraine energy crisis	2.0%	€20BN	DNB 2023a.
2026 Iran-US conflict	0.4%	€10BN	OECD 2026
Total GDP impact		**€97BN**	

[34] Normalised impact is a calculation that included fossil-fuel dependence. A 100% fossil fuel dependent energy system is 100% vulnerable to volatility of global oil and gas prices. The current Dutch energy system is 88% dependent on fossil imports, and the GDP impact is scaled accordingly

Annual attribution (divided by 75 years)	**€1.3BN**	
Scaled for uncertainty (multiplied by 3.3x WUI)	**€4.3BN**	WUI 2026

Source: various (see right hand column). Own calculations to scale GDP impact

A purely historical perspective is however likely to underestimate the expected impact over the period of 2026 – 2050. We live in a world marked by VUCA (volatility, uncertainty, complexity and ambiguity). Any regular news reader hardly needs to be convinced of this. At time of writing, energy shock resulting from the ongoing Iran-US conflict has already depressed growth across Europe (OECD, 2026), with further downward pressure possible.

Current levels of uncertainty can be quantified. This paper has used the World Uncertainty Index (WUI) developed by the Economist Intelligence Unit (EIU) as the best available proxy to scale historic impact to the future. Historically, over the last 75 years the Index for the Netherlands has averaged around 26. The average over 2025 has been 3.3x that figure at 87.

The resulting expected annual GDP impact on a Dutch economy that is 100% on energy imports is therefore calculated to be €4.3BN. Note that this number is modelled as a one-off hit to growth, rather than a persistent growth damage (which would be a higher number).

Methodology and computation

The OPERA model calculates energy production by energy carrier. For each carrier the energy input has been classified as either imported or domestic. For example, solar and wind power are produced domestically, whereas oil and nuclear have been classified as imported. Note that gas has also been classified as imported as the *Groningenveld* gas field remains closed and other domestic gas production is minor. The resulting import dependence is summarised in table 13.

Table 13: import dependence by scenario (%)

Scenario	2025	2030	2035	2040	2045	2050
NT	89%	89%	89%	89%	89%	89%
KEV	-	85%	81%	77%	65%	63%
ADAPT	-	82%	74%	70%	68%	65%
TRANSFORM	-	79%	67%	61%	49%	44%

Source: OPERA output

The next step is to determine the degree to which imported energy carriers vary with oil price. The higher the variance, the greater the vulnerability to oil price shocks and geopolitical events.

Table 14: assumed oil price variability of top-5 imported energy carriers

Energy Carrier	Assumed oil variance	Rationale
Oil	1.00	Reference
Biofuel	0.25	Price of biofuel is primarily cost driven. Oil prices influence biomass indirectly through logistics, competing fuel markets, and policy incentives
Gas	0.40	Historically linked to oil price, in Europe correlation has declined post 2022 following decoupling from Russia. It is now driven more by factors such as storage levels and cargo availability
Imported electricity	0.60	In Europe primarily driven by gas price
Naphtha	0.95	A refinery output
Uranium	0.05	A separate market

Source: own research

To get to an expected loss per scenario, the import dependence has been multiplied by the degree to which the energy carrier varies with oil price and the €4.3BN (from table 12) and is summarised in table 15 below.

Table 15: annual expected security loss by scenario (€BN)

Scenario	2030	2035	2040	2045	2050	'26 -'50 average
NT	2.9	2.9	2.9	2.9	2.9	2.9
KEV	2.8	2.7	2.5	2.2	2.1	2.5
ADAPT	2.7	2.4	2.0	1.9	1.6	2.1
TRANSFORM	2.6	2.1	1.6	1.1	0.8	1.6

Source: own calculations

Uncertainty and sensitivity

The expected economic loss is highly uncertain by nature. The biggest sensitivity in the numbers used in the paper is regarding the factor by which historical uncertainty is scaled to future uncertainty. The method to use the WUI is based on a judgement that it is a meaningful proxy.

This paper has therefore also calculated an alternative method to apply expected losses. Taking the energy shocks of the last five years, rather than the last 75 years, would have resulted in an annual expected loss of €6.0BN[35] rather than €4.3BN (2024 prices for an economy with 100% import dependence). This more recent timeframe is perhaps a closer approximation of the geopolitical reality that we currently live in but is so short that it is not statistically useful. Nevertheless, it provides an alternative data point through which the €4.3BN can be substantiated as a reasonably prudent approximation of expected future economic losses.

The outcome of this expected security loss is consistent with TNO analysis which concludes that the economic shocks following energy crises are 60 – 90% less severe in transition scenarios (TNO, 2025).

Limitations

The biggest limitation of the current approach is that not all import dependence is equal. For example, the current approach does not distinguish between LNG imports from Qatar and uranium imports from Canada. The reader may surmise however that the risk profile of these energy sources, and the price volatility resulting from a global energy shock, vary substantially. The result of this limitation is that the energy security premium in the transition scenarios is undervalued.

There are additional aspects to energy security such as supplier concentration risk and infrastructure sabotage risk which are also not included in this analysis. The net effect of these limitations is less clear. Infrastructure sabotage risk would likely be higher for fossil fuel dependent energy sources. Clean-technology supply chain dependencies on China are also currently a cause for concern.

This is not a probabilistic geopolitical risk model. It is an economic exposure proxy that does not fully capture supplier concentration, infrastructure sabotage risk, clean-tech supply chain dependencies, or endogenous policy response (e.g., subsidies). Those elements can be added as optional sensitivity layers.

Policy grounding

European and Dutch policy increasingly frames acceleration of clean energy deployment as a security strategy: reducing dependence on imported fossil fuels and improving resilience. In its National Plan for Energy (NPE), *"The government chooses with this NPE to reduce the*

[35] The total loss to the Dutch economy over five years was €30.0BN. €20.0BN from the 2022 Russia-Ukraine war and €10.0BN from the US-Iran war.

dependency on countries outside the EU" (Rijksoverheid, 2023). The government states that it does so because of geopolitical developments over the last few years.

Steps to improve the methodology

Future studies could improve the methodology used by addressing the limitations described in the paragraph above. This would include modelling the degree to which various fuel sources (e.g. biomass or uranium) correlate with global oil price movements. An even more extensive paper would investigate the specific security vulnerabilities inherent in each energy source.

Another separate analysis could focus on the impact of improved energy security on defence spending. For example, by analysing how a distributed energy production system impacts on the costs incurred defending critical infrastructure.

11.5. Calculations: Economic value of increased aggregate demand

Definition and scope

This is the impact of the positive externality of the increased aggregate demand that the energy sector transition is estimated to have on the wider Dutch economy. The transition scenarios effectively 'onshore energy production' by shifting the cost of energy away from imported fuels towards capital investment and maintenance thereof. The increases in CAPEX and OPEX in the energy sector also increase aggregate demand in the wider Dutch economy. At the same time, increases in energy production costs will translate into higher energy prices which decreases aggregate demand. The central question is therefore how these two aggregate demand movements net out to affect Dutch GDP.

Excluded from this analysis are any of the benefits of how employment affects people's wellbeing. Although there are studies which quantify life satisfaction (e.g. Connolly and Garling, 2022), these do not fall into the more narrower definition of economic benefit of this study.

Assumptions and sources

The increase in aggregate demand can easily be deduced from the OPERA model output. It is the increase in domestic expenditure, mostly driven by the increase in capital expenditure, minus the increased production cost. Increases in energy production costs lead to higher prices which must be paid for by other sectors of the economy which carries opportunity cost.

The economic multiplier is key variable to determine the link between the increase in aggregate demand resulting from increases in capital expenditure and economic output. There are no standard multipliers in the Netherlands to model the impact of additional investment GDP growth (CPB, 2023). Globally the investment multiplier has been empirically validated to be in the range of 1.1 to 1.5 (IMF, 2021). This is substantially higher than fossil fuel energy investment multipliers which are in the range of 0.5 to 0.6. The primary reason for this is that clean energy is more labour intensive (IMF, 2021). Expanding energy grids, building wind and solar parks, improving insulation of buildings will sustain[36] hundreds of thousands of new jobs in the Dutch economy. Across a range of energy transition technologies, every €1MM invested is estimated to create 6 – 12 jobs (Rutovits et al, 2025) (CE Delft, 2026).

In the Netherlands there are two supply-side constraints which depress any positive impact on GDP, at least in the short-term. First is grid congestion[37]. The physical limits of the electricity grid have already resulted in excess demand presently. Potentially productive renewable energy investments are currently held back because of this congestion. BCG, based on Ecorys data, has estimated that the Netherlands misses out on between €10 – 35 BN of economic benefits because of grid congestion (Ecorys, 2024) (BCG, 2024) (Ecorys, 2025). In the short term any additional demand will similarly be held back.

Second, skilled labour shortages in the renewable energy sector are an issue internationally which are particularly acute in the Netherlands. Internationally, the IEA documents that clean energy sectors are labour intensive and that skills constraints and hiring bottlenecks increasingly shape delivery capacity; an important feasibility constraint when interpreting scenario deployment rates (IEA, 2023). In the Netherlands, the labour market has been unusually tight over the last few years and economy is operating at conditions of full employment (CBS, 2026c).[38] Shortages in skilled labour are a well-documented problem across multiple studies (CBS, 2020) (TNO, 2022) (PBL, 2023) (SZW, 2026) (TNO, 2026).

---

[36] See footnote 24
[37] In Dutch: *'netcongestie'*
[38] Unemployment in mid-2026 stands at 3.8% (CBS, 2026c) and unemployment is expected to rise only slightly to 4.2% by end-2027 (OECD, 2026).

There are several factors, such as demography and sectors competing for scarce labour (housebuilding, health and social care, defence) which are structural in nature (Denkwerk, 2025). This means that high demand for labour is expected over the longer-term. Increases in employment in the energy sector will therefore result in labour moving from other sectors which would depress output there. This high labour demand will erode the effect of increased aggregate demand through inflation and opportunity cost.

A dynamic General Equilibrium Model (GEM) would be able to determine how an increase in aggregate demand affects quantities and prices of outputs produced across multiple segments of the Dutch economy over time. Such a model would be the best way of determining the economic impact considering Netherlands specific factors and constraints. Such a model has not been available for the purposes of this study. Consequently, the economic impact has had to be estimated based on a static multiplier derived by proxy. This multiplier is then compared with other multipliers observed in empirical studies that seek to determine the range of outcomes of aggregate demand boosts in advanced economies at time of expansion (rather than recession).

Central Bureau of Statistics (CBS) data for the construction sector has been used as a proxy to estimate the impact of CAPEX and OPEX on the Dutch economy (CBS, 2026a). Of the sectors, listed in the national accounts, the construction sector[39] approximates the impact of the additional CAPEX and OPEX most closely.[40] The energy transition requires building a great many things ranging from electricity networks, to home isolation, to nuclear power stations (in the case of ADAPT). This is an obvious simplification, but it aligns reasonably well with estimates that of the jobs created by the energy transition will be roughly one-third manufacturing and roughly two-thirds transportation and installation (CE Delft, 2026). The CBS breaks down construction sector output into: 51% intermediate consumption (input from other sectors of the economy), 14% imports, 15% operating surplus, 11% wages, 4% taxes and 5% other. The treatment of component is treated as follows:

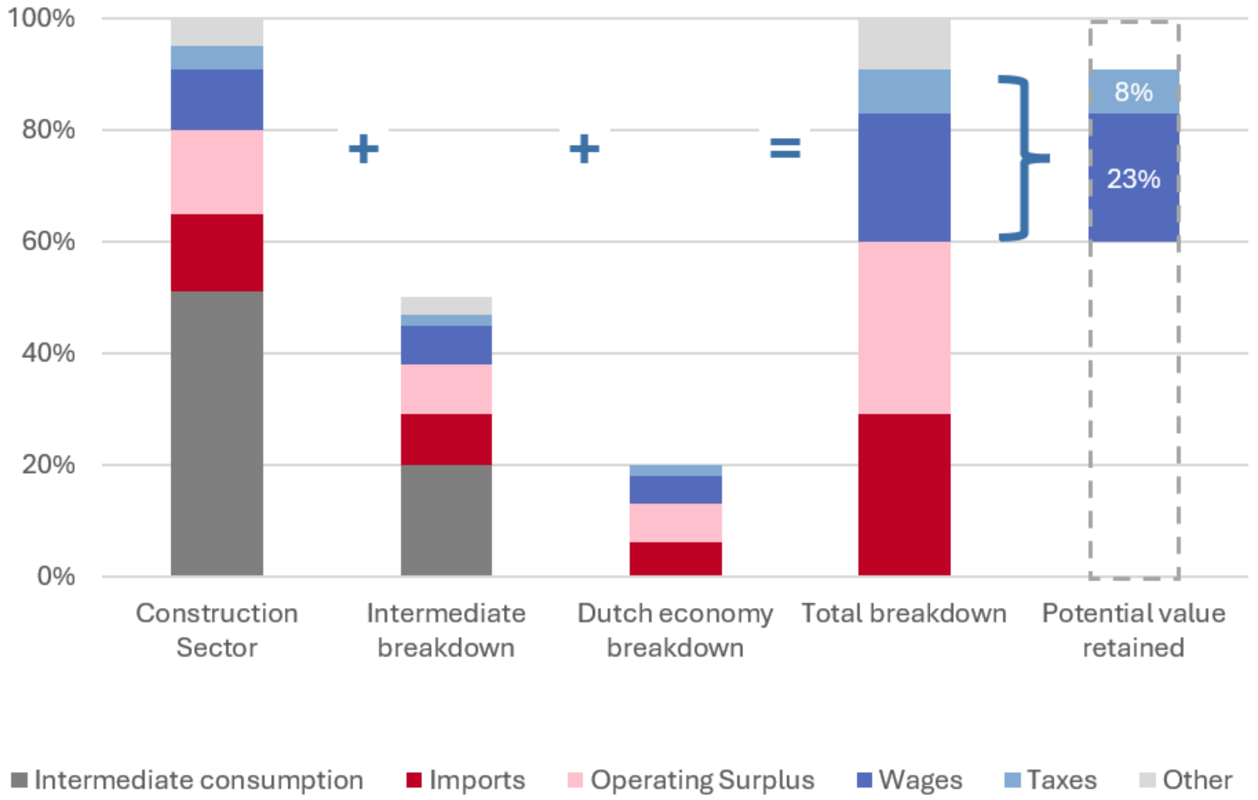
- Intermediate consumption: has been broken down by sector to derive the wage, tax, import and surplus components of those sectors. For the residual of the intermediate consumption of those sectors the average of the entire Dutch economy has been applied (see figure 8 below)

[39] Note that the Dutch national accounts split out the construction sector into three sub-sectors: 1) Construction buildings, development , 2) Civil engineering, 3) Specialised construction activities. The total of the three sub sectors is included in the study.
[40] Note that the statistical group 'energy and gas supply' does not approximate the impact of CAPEX precisely because it has historically contained a significant operating surplus resulting from revenues on gas.

- Imports: are not counted as increasing aggregate demand
- Operating surplus: is not counted as increasing aggregate demand. The Netherlands is an open economy and any dividends paid are accrued by shareholders anywhere across the world.
- Wages: are counted as being retained in the Dutch economy (increasing private consumption, C)
- Taxes: are counted as being retained in the Dutch economy (increasing government expenditure, G)

Figure 8 shows how this treatment produces a retained-value coefficient of 0.31, based on the wage and tax shares of the construction sector and its intermediate inputs. This coefficient is used as a proxy in the central calculation.

Figure 8: construction sector breakdown into wages and taxes (CBS, 2026a)



Source: CBS 2026a, own calculations

This number is in the range of academic studies listed by the Centraal Planbureau which is large: -0.3 – 2.2 (CPB, 2023). And it approximates the impact of a boost to defence spending in times of economic expansion, which has a multiplier of 0.3 (Sheremirov and Sprivska, 2022).

The treatment of the 31% benefit varies over time. Adjustments have been made roughly account for the effects of supply-side constraints in the Dutch economy. These constraints are assumed to be short-term fixed and longer-term variable. For example, a shortage of technical skills cannot be solved within a period of a year, but over a decade training programmes and labour market incentives could solve for them. No aggregate-demand benefit is recognised in 2030. In 2035, 50% of the potential effect is recognised. The full base-case coefficient is applied from 2040 onwards. Skills, infrastructure and other supply constraints can be substantively dealt with over a 10–15 year period.

Methodology and computation

The increase in aggregate demand can be derived from OPERA by taking the increased expenditure in the Dutch economy (CAPEX and OPEX) minus the increased energy production costs. Increased energy production costs will translate into higher energy prices which are an opportunity cost for the rest of the economy.

Table 16: annual energy system costs (€BN)

Scenario	2030	2035	2040	2045	2050	'26 -'50 average
NT	81.5	87.8	94.6	101.9	109.8	95.1
KEV	90.4	96.8	107.8	102.6	99.2	99.4
ADAPT	99.7	100.8	116.2	118.5	130.1	113.1
TRANSFORM	91.5	92.2	109.0	116.5	131.5	108.1

Source: OPERA output

Table 17: of which annual CAPEX + OPEX* (€BN)

Scenario	2030	2035	2040**	2045**	2050**	'26 -'50 average
NT	29.6	31.9	34.4	37.1	39.9	34.6
KEV	56.3	49.6	58.8	52.8	45.9	52.7
ADAPT	69.9	57.3	82.0	44.0	71.3	64.9
TRANSFORM	64.4	60.8	80.1	65.6	80.3	70.2

Source: OPERA output

* Note that across most of the paper CAPEX figures are stated in terms of depreciation plus discount rate. For calculating the employment benefit the sum of the investment within the period has been used instead. This is because an accruals-based accounting method does not give the investment within the studied period.
** Note that the ADAPT and TRANSFORM scenarios see higher CAPEX + OPEX in 2040 and 2050 relative to 2045. This is due to an idiosyncrasy of the OPERA model, which sees the expiration of the depreciation period of a substantial number of CAPEX items that require reinvestment in 2050. Real world investment levels are likely to be much smoother than modelled.

Table 18: annual increase in aggregate demand compared with NT (€BN)

Scenario	2030	2035	2040	2045	2050	'26 -'50 average
NT	0.0	0.0	0.0	0.0	0.0	0.0
KEV	17.8	8.6	11.3	15.0	16.5	13.8
ADAPT	22.2	12.3	26.1	-9.6	11.1	12.4
TRANSFORM	24.8	24.4	31.3	13.9	18.7	22.6

Source: own calculations

The increase in aggregate demand (Table 18) resulting from the boost in domestic energy expenditure (Table 17) has been netted out against decreases in demand owing to higher energy prices resulting from increases in energy production costs (Table 16). Take for example the average 2026 – 2050 figures for the KEV scenario. The annualised CAPEX and OPEX is €18BN higher than in no transition (€53BN minus €35BN). However, the total energy production costs are €4BN higher (€99BN minus €95BN). This €4BN has opportunity cost and is subtracted from the €18BN to get an annualised aggregate demand increase of €14BN vis-à-vis no transition.

The annual expected increase in economic output has been derived by taking the increase in aggregate demand and making two computations:

1. A multiplication of aggregate demand by the economic multiplier 0.31 to determine the longer-term potential of the increase in output
2. Taking haircuts to the potential longer-term benefit of 100% in 2030 and 50% in 2035 to reflect short-term supply-side constraints existing in the Dutch economy

The result of this computation is shown in table 19 below and forms the base case for the estimated impact shown in the main body of this paper:

Table 19: annual expected increase in economic output – structurally high labour demand (€BN)

Scenario	2030	2035	2040	2045	2050	'26 -'50 average
NT	0.00	0.00	0.00	0.00	0.00	0.00
KEV	0.00	-1.34	-3.49	-4.64	-5.12	-2.92
ADAPT	0.00	-1.91	-8.08	2.96	-3.44	-2.09
TRANSFORM	0.00	-3.79	-9.70	-4.32	-5.79	-4.72

Note: numbers are noted as negative, because the OPERA model output is noted in costs. Positive effects are therefore subtracted from these costs.

Uncertainty and sensitivity

The impact of the aggregate demand boost resulting from the increased capital expenditure in the energy transition are sensitive to a range of factors. Principal among them is the degree to which labour shortage is structural to the Dutch economy (as is the assumption in the base case expected benefits, as shown in table 19), or whether unemployment patterns follow historical cycles instead. No one can predict with any certainty whether labour market equilibrium will be achieved considering both these structural labour demand factors as well as labour productivity increases. Sensitivity to this dynamic is therefore worth analysing.

Notwithstanding current constraints on the labour market, the Netherlands has experienced peaks in unemployment in the recent past, e.g. 9% in 1984 and 7% in 2014 (CBS, 2024). Since 1975, the Netherlands has only been in full employment roughly half of the time, with unemployment exceeding 5% in 26 out of 51 years (51% of the time) (See table 20) (CBS, 2025c).

Table 20: historical unemployment in the Netherlands

Unemployment (%)	Number of years (#)	Number of years (%)	Years
< 4%	17	33%	1978, 1979, 1980, 2001, 2002, 2007, 2008, 2018, 2019, 2020, 2021, 2022, 2023, 2024, 2025
4% – < 5%	8	16%	1975, 1976, 1977, 1999, 2000, 2006, 2017
5% – < 6%	5	10%	1998, 2003, 2004, 2005, 2016
≥ 6%	21	41%	1981–1997, 2009–2015
Total	**51**	**100%**	**1975–2025**

Source: CBS, 2025c

If the Netherlands would achieve the range of multipliers of 1.1 – 1.5 observed internationally in empirical studies (IMF, 2021) at times of excess unemployment, then the

expected impact on economic output will be substantially higher. Table 21 shows what the expected increase in output in full employment using a multiplier of 0.3 (occurring 50% of the time) and an increase in output with excess unemployment using multiplier of 1.1 (also occurring 50% of the time) would be. Noting that, as with the impact estimated table 19, the same haircuts are applied to account for short-term supply-side constraints.
The average increase in economic output of this plausible 'would be' scenario is more than double that of the more conservatively estimated base case scenario of expected benefits shown in table 19. Rather than show the expected value of the transition, these numbers show the extent of the additional upside in a scenario with economic downturns occurring at a historical frequency.

Table 21: annual increase in economic output – historical unemployment (€BN)

Scenario	2030	2035	2040	2045	2050	'26 -'50 average
NT	0.00	0.00	0.00	0.00	0.00	0.00
KEV	0.00	-3.05	-7.94	-10.55	-11.65	-6.64
ADAPT	0.00	-4.34	-18.37	6.74	-7.81	-4.76
TRANSFORM	0.00	-8.62	-22.05	-9.82	-13.16	-10.73

Source: own calculations

Limitations

The aggregate-demand estimate should be interpreted as an indicative macroeconomic proxy rather than a precise structural multiplier for the Dutch economy. A dynamic general equilibrium analysis would be needed to test how additional investment affects output, prices, imports and labour allocation simultaneously.

The numbers calculated should be seen as rough indications of the potential macroeconomic impacts rather than a precise estimation of the exact benefit. The potential is estimated based on one proxy for the renewable energy sector, rather than a detailed analysis by technology. The haircuts made to the benefit resulting from supply-side constraints have been asserted rather than based on actual economic modelling.

Jobs are not automatically welfare gains: they can reflect necessary effort rather than productivity improvements. Monetising job-years can also risk double counting if wages are treated as "benefits" without accounting for opportunity costs. For this reason, the more conservative base case estimate (table 19) is used in the overall analysis rather than the higher estimate (table 21).

Policy grounding

The government has recognised the transition as a labour-market and skills challenge. The government has a national action plan for green and digital jobs and regularly updates Parliament on progress with regards to several stated initiatives (Rijksoverheid, 2023a). The four pillars of Dutch government policy are: 1) Increase the inflow into education in Science, Technology, Engineering, and Mathematics (STEM) (in Dutch called: *bètatechnisch onderwijs*).2) Increase inflow and improve retention of technical jobs. 3) Improve labour productivity. 4) Improve cooperation.

Steps to improve the methodology

The size of the potential benefit, as well as the limitations of the approach used in this study mean that the macroeconomic impact of the energy transition merits much further investigation. A preferred approach would be to run the transition scenario parameters through a dynamic General Equilibrium Model. The development of such a model has been beyond the scope of this paper but would be able to more accurately predict how quantity and price changes in the renewable energy sector reverberate throughout the Dutch economy over time. Within such a model, the following elements could be studied:

- The link between investment volumes to renewable energy sub-sector (e.g. solar, wind) -specific labour coefficients for construction, manufacturing, installation and O&M
- The impact of the scenarios under both labour shortage and high unemployment scenarios
- Sensitivity to import propensity and differences between different industrial policy assumptions (e.g. the impact of EU vs imported manufacture of several technologies such as solar panels).
- Skills requirements to deal with supply-side constraints and the impacts of training lead times, wage pressures

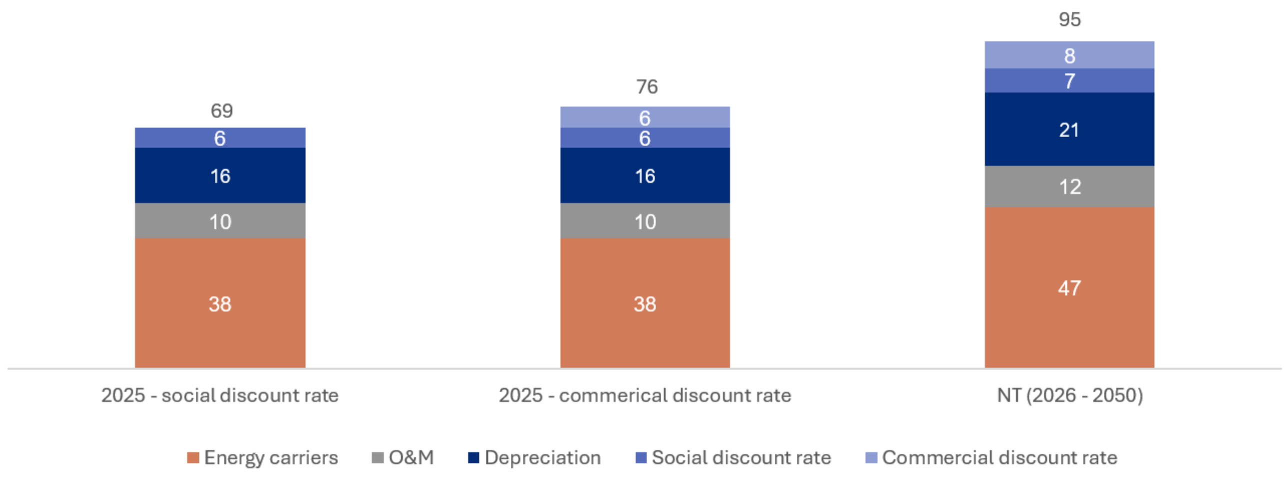
Each of these elements individually will have a major impact on the potential benefit. Collectively these impacts may have secondary effects which lead to additional insights.

11.6. Reconciliation with EIK figures

The production cost of 'no transition' (NT) as stated in Figure 1 in section 3 is €95BN a year. This number differs from the 2025 energy cost of €69BN as stated in the EIK *startrapport* (RVO, 2026). The difference between these two figures is the result of two factors (summarised in Figure 9 below):

1. The OPERA model separates depreciation, the social return and the commercial cost of capital. The EIK startrapport presents capital costs using the social appraisal convention. This paper uses the commercial discount rate from the OPERA output (8% for market-exposed ETS1 sectors and 4% for other sectors). In 2025 this increases the reported energy-system cost from approximately €69BN under the EIK presentation to approximately €76BN under the commercial financing assumptions used here.
2. This paper shows financial figures in annualised figures for the entire period 2026 – 2050. All the scenarios provide for Dutch energy consumption for an economy that grows at 1.5% annually. In the case of no transition, this results in an increase in energy production of 1.5% also which averages out over the entire period to costing €95BN, other things being equal.

Figure 9: Reconciling 'No Transition' annualised cost figures with EIK 2025 energy costs (€BN/year)



Source: OPERA output and own calculations

Glossary

ADAPT – One of the 2 net-zero scenarios used in this paper. ADAPT reaches climate neutrality by 2050 while retaining much of the Netherlands' current industrial structure and living patterns (see section 2.4).

Aggregate demand (AD) – Total demand for goods and services in the economy. In this paper, the increase is calculated by the increase in capital expenditure (CAPEX) and operational expenditure (OPEX) minus the increase in the cost of production costs versus the no transition (NT) scenario (see section 4.4).

CAPEX – Capital expenditure. Investment in long-lived assets and infrastructure such as electricity grids, wind farms, heat networks, industrial installations and generation capacity (see section 3).

CCS – Carbon Capture and Storage. The capture of CO_2 emissions from industrial or energy processes and their permanent storage, usually underground.

Climate shadow price – A monetary value assigned to greenhouse-gas emissions for economic appraisal. This paper uses €174 per tCO_2e, based on Dutch public appraisal guidance and CE Delft (see section 4.1).

COI – Cost of Illness. A health-economics approach that values direct treatment costs and productivity losses associated with illness. In this paper, COI excludes mortality valuation and broader quality-of-life effects (see section 4.2).

Discount rate – The financing cost of capital used to fund investment. OPERA uses different commercial WACC assumptions for different sectors in the production-cost calculations (see section 2.2).

EIK – *Energietransitie Integraal Kostenbeeld*. A Dutch knowledge programme that develops an integrated view of the costs of the energy transition and provides the OPERA outputs used as the analytical starting point for this paper (see section 2.1).

EPR – European Pressurised Reactor. A generation III+ nuclear reactor design used as the assumed nuclear technology in the ADAPT and TRANSFORM scenarios.

ETM – Energy Transition Model. A modelling environment used to translate and analyse energy-system pathways, including inputs derived from TNO/OPERA scenarios (see section 2.1).

ETS / EU ETS – European Union Emissions Trading System. The EU carbon market under which covered emitters must surrender allowances for their greenhouse-gas emissions (see sections 2.3 and 4.1).

GDP – Gross Domestic Product. The monetary value of goods and services produced within an economy over a given period.

GHG – Greenhouse gas. In this paper, greenhouse-gas emissions are generally expressed in tonnes of CO_2-equivalent.

GW – Gigawatt. A unit of power equal to one billion watts, used in this paper for generation capacity.

KEV – *Klimaat- en Energieverkenning*. The Netherlands' current-policy energy and climate outlook. In this paper KEV is used as the current-policy trajectory and does not reach net zero by 2050 (see section 2.4).

LCOE – Levelised Cost of Electricity. The average lifetime cost of producing electricity from a generation technology, expressed per unit of electricity generated.

$MtCO_2e$ – Million tonnes of carbon dioxide equivalent. A common unit for aggregating greenhouse-gas emissions.

NEC pollutants – Air pollutants covered by the EU National Emission reduction Commitments framework. This paper considers NO_x, $PM_{2.5}$, SO_2, NH_3 and NMVOCs (see section 4.2).

NMVOCs – Non-methane volatile organic compounds. A group of air pollutants associated with, among other sources, solvents and industrial processes (see section 4.2).

NO_x – Nitrogen oxides. Air pollutants produced mainly through combustion processes (see section 4.2).

NPV – Net Present Value. The value today of costs or benefits occurring over time, after applying a discount rate (see section 5).

NT – No Transition. A hypothetical counterfactual constructed for this paper that holds the 2025 energy mix broadly constant while energy demand grows with GDP (see section 2.4).

OPEX – Operating expenditure. Recurring expenditure associated with operating and maintaining assets and infrastructure (see section 3).

OPERA – TNO's optimisation model of the Dutch energy system. OPERA identifies cost-minimising energy-system configurations subject to assumptions about demand, technology, infrastructure and emissions constraints (see section 2.1).

P2L – Power-to-Liquids. The production of synthetic liquid fuels using electricity, hydrogen and captured carbon. TRANSFORM assumes deployment of P2L at a scale that is not currently commercially established (see section 2.4).

PJ – Petajoule. A unit of energy equal to 10^{15} joules.

$PM_{2.5}$ – Fine particulate matter with a diameter of 2.5 micrometres or less. Exposure is associated with significant health effects (see section 4.2).

SO_2 – Sulphur dioxide. An air pollutant primarily associated with the combustion of sulphur-containing fuels (see section 4.2).

TRANSFORM – One of the 2 net-zero scenarios used in this paper. TRANSFORM reaches climate neutrality by 2050 with greater energy-demand reduction and stronger reliance on technologies still developing today (see section 2.4).

VSL – Value of a Statistical Life. A welfare-economics measure used to monetise mortality risk. VSL is deliberately excluded from the central health calculation in this paper (see section 4.2).

WUI – World Uncertainty Index. An index used in this paper as a proxy for the level of economic and geopolitical uncertainty when estimating future energy-security exposure (see section 4.3).

References

ABN AMRO (2025). ESG Economist - Scenarios shaping EU ETS prices. https://www.abnamro.com/research/en/our-research/esg-economist-scenarios-shaping-eu-ets-prices

Banking on Climate Chaos (2026). Fossil Fuel Finance Report 2026. https://www.bankingonclimatechaos.org/wp-content/uploads/2026/06/BOCC_2026_vFINAL. pdf

BBVA (2025). Spain | Reaping the Benefits of Renewable Energy in the Spanish Economy. https://www.bbvaresearch.com/en/publicaciones/spain-reaping-the-benefits-of-renewable-energy-in-the-spanish-economy/

BCG (2024). Haal de kink uit de kabel. https://web-assets.bcg.com/f3/0f/b2c90d5a4157b7ac7fa3de0b95c7/haal-de-kink-uit-de-kabel.pdf

Bloomberg (2024). EU ETS Market Outlook 1H 2024: Prices Valley Before Rally. https://about.bnef.com/insights/commodities/eu-ets-market-outlook-1h-2024-prices-valley-before-rally/

Bundesverfassungsgericht (2021). Press Release: Constitutional complaints against the Federal Climate Change Act partially successful. https://www.bundesverfassungsgericht.de/SharedDocs/Pressemitteilungen/EN/2021/bvg21-031.html

CE Delft (2023). Handboek Milieuprijzen 2023. Methodische onderbouwing van kengetallen gebruikt voor waardering van emissies en milieu-impacts. https://ce.nl/wp-content/uploads/2023/03/CE_Delft_220175_Handboek_Milieuprijzen_2023_DEF_v1.1.pdf

CE Delft (2026). Labour demand in the energy transition. https://ce.nl/wp-content/uploads/2026/02/CE_Delft_250253_Labour_demand_energy_transition_Def.pdf

CBS (2020). Investeringen in energie en de daarmee gepaard gaande werkgelegenheid. https://www.cbs.nl/nl-nl/longread/diversen/2020/economische-ontwikkeling-van-de-energievoorziening/4-investeringen-in-energie-en-de-daarmee-gepaard-gaande-werkgelegenheid

CBS (2021). Hernieuwbare Energie in Nederland 2020. https://www.cbs.nl/nl-nl/longread/aanvullende-statistische-diensten/2021/hernieuwbare-energie-in-nederland-2020/2-algemene-overzichten

CBS (2022). Nitrogen emissions into the atmosphere. https://www.cbs.nl/en-gb/dossier/nitrogen/nitrogen-emissions-into-the-atmosphere

CBS (2024). Werkloze beroepsbevolking 1945-2022. https://www.cbs.nl/nl-nl/achtergrond/2024/40/werkloze-beroepsbevolking-1945-2022

CBS (2025a). 1973 Oliecrises en stagflatie. https://www.cbs.nl/nl-nl/longread/diversen/2025/tijdlijn-internationale-handel/4-1973-oliecrises-en-stagflatie

CBS (2025b). Opbouw binnenlands product (bbp); nationale rekeningen. https://www.cbs.nl/nl-nl/cijfers/detail/85865NED

CBS (2025c). Unemployment rate at its most stable since 1988. https://www.cbs.nl/en-gb/news/2025/07/unemployment-rate-at-its-most-stable-since-1988

CBS (2026a). Opbouw binnenlands product (bbp); nationale rekeningen. https://www.cbs.nl/nl-nl/cijfers/detail/85865NED

CBS (2026b). Raming CO2-emissie naar lucht; Nederlandse economie, Nationale rekeningen. https://www.cbs.nl/nl-nl/cijfers/detail/84057NED

CBS (2026c). Unemployment declined in June. https://www.cbs.nl/en-gb/news/2026/29/unemployment-declined-in-june

CPB (2023). Nieuwe inzichten over multipliers overheidsbestedingen. https://www.cpb.nl/nieuwe-inzichten-over-multipliers-overheidsbestedingen

Connolly and Garling (2022). Mediators of Differences Between Employed and Unemployed in Life Satisfaction and Emotional Well-being. https://link.springer.com/article/10.1007/s10902-021-00466-2

Denkwerk (2025). Kiezen én Delen. https://denkwerk.online/media/1146/denkwerk-kiezen-%C3%A9n-delen.pdf

DNB (2023a). Nederland leed in 2022 inkomensverlies door duurdere energie. https://www.dnb.nl/algemeen-nieuws/nieuws-2023/nederland-leed-in-2022-inkomensverlies-door-duurdere-energie/

DNB (2023b). Economische Ontwikkelingen en Vooruitzichten. https://www.dnb.nl/media/fa2biq5o/eov-juni-2023.pdf

Ecorys (2024). De netto maatschappelijke kostprijs van netcongestie: eindrapport. https://www.rijksoverheid.nl/documenten/2024/06/25/studie-maatschappelijke-kosten-netcongestie

Ecorys (2025). De netto maatschappelijke kostprijs van netcongestie: vervolgonderzoek. https://open.overheid.nl/documenten/cec87d92-5128-4aa4-9abc-06f6ff877dec/file

EIK (2026). Kennisprogramma Energietransitie Integraal Kostenbeeld. https://energy.nl/energietransitie-integraal-kostenbeeld/

ECHR (2024). CASE OF VEREIN KLIMASENIORINNEN SCHWEIZ AND OTHERS v. SWITZERLAND *(Application no. 53600/20)* JUDGMENT. https://hudoc.echr.coe.int/eng#{%22appno%22:[%2253600/20%22],%22itemid%22:[%22001-233206%22]}

ESB (1990). Olieprijsstijging en dollardaling: risico's voor de Nederlandse economie. https://esb.nu/wp-content/uploads/2022/11/editie_pdfs_1990_0238_tcm445-261785.pdf

EU ETS (2026). EU Emissions Trading System (EU ETS). https://climate.ec.europa.eu/eu-action/carbon-markets/eu-emissions-trading-system-eu-ets_en

European Commission (2021). Pathway to a Healthy Planet for All — EU Action Plan: 'Towards a Zero Pollution Ambition for Air, Water and Soil'. COM(2021) 400 final, 12 May 2021. https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52021DC0400

European Environment Agency (2024). European Air Quality Index. https://www.eea.europa.eu/en/ analysis/maps-and-charts/index

European Parliament (2025). Sustainability reporting and due diligence: MEPs back simplification changes. https://www.europarl.europa.eu/news/en/press-room/20251106IPR31296/sustainability-reporting-and-due-diligence-meps-back-simplification-changes

FT (2026). Commodity tearsheet – Brent Crude Oil. https://markets.ft.com/data/commodities/ tearsheet/summary?c=Brent+Crude+Oil

Greenpeace (2026). Klimaatzaak Bonaire: het vonnis uitgelegd. https://www.greenpeace.org /nl/algemeen/73528/klimaatzaak-bonaire-het-vonnis-uitgelegd/

IEA (2023). World Energy Employment 2023. https://www.iea.org/reports/world-energy-employment-2023/

IEA (2025a). World Energy Outlook 2025: Current Policies Scenario. https://www.iea.org/reports/ world-energy-outlook-2025/current-policies-scenario

IEA (2025b). Energy snapshot 17.03.2025. https://www.iea.org/newsletters/energy-snapshot/17-03-2025/the-battery-industrys-next-phase

IMF (2021). Building Back Better: How Big Are Green Spending Multipliers? https://www.imf.org /-/media/files/publications/wp/2021/english/wpiea2021087-print-pdf.pdf

IMF (2023). Labor Market Exposure to AI: Cross-country Differences and Distributional Implications. https://www.imf.org/-/media/files/publications/wp/2023/english/ wpiea2023216-print-pdf.pdf

Loorbach, et al (2017). Sustainability Transitions Research: Transforming Science and Practice for Societal Change.
https://www.annualreviews.org/content/journals/10.1146/annurev-environ-102014-021340

Moore, et al (2024). Synthesis of evidence yields high social cost of carbon due to structural model variation and uncertainties.
https://www.pnas.org/doi/10.1073/pnas.2410733121

NEA (2026). OECD Nuclear Energy Agency: Levelised Cost of Electricity Calculator. https://www.oecd-nea.org/lcoe/

OECD (2016). The economic consequences of outdoor air pollution. 20160620-policy-highlights-economic-consequences-of-outdoor-air-pollution-web.pdf

OECD (2023). OECD Employment Outlook 2023 ARTIFICIAL INTELLIGENCE AND THE LABOUR MARKET.
https://www.oecd.org/content/dam/oecd/en/publications/reports/2023/07/oecd-employment-outlook-2023_904bcef3/08785bba-en.pdf

OECD (2026). OECD Economic Outlook, Interim Report March 2026. https://www.oecd.org/en/ publications/oecd-economic-outlook-interim-report-march-2026_d4623013-en/full-report.html

PBL (2022). Inzicht in arbeidsmarktknelpunten voor de uitvoering van het klimaatbeleid. https://www.pbl.nl/uploads/default/downloads/pbl-2022-inzicht-in-arbeidsmarktknelpunten-voor-de-uitvoering-van-het-klimaatbeleid-4931.pdf

PBL (2023). Tekort aan technici voor de energietransitie vergt prioritering in investeringen. https://www.pbl.nl/uploads/default/downloads/pbl-2023-tekort-aan-technici-voor-de-energietransitie-vraagt-om-prioritering-investeringen-5147.pdf

PBL (2024). Klimaat- en Energieverkenning 2024. https://www.pbl.nl/system/files/document/ 2025-01/pbl-2024-klimaat-en-energieverkenning-2024-5490.pdf

PBL (2025a). Actualisering Monetaire Milieuschade. Een verkenning naar de welvaartsverliezen door milieuvervuiling in Nederland in 2022. https://www.pbl.nl/system/files/document/2025-06/PBL-2025-Actualisering-monetaire-milieuschade-5537.pdf

PBL (2025b). Emissieramingen luchtverontreinigende stoffen 2025. https://www.pbl.nl/publicaties/emissieramingen-luchtverontreinigende-stoffen-2025

PBL (2025c). Klimaatverandering in de prijzen in 2024. Analyse van de beprijzing van broeikasgasemissies in Nederland. https://www.pbl.nl/publicaties/klimaatverandering-in-de-prijzen-in-2024

PBL (2025d). Beleidsoverzicht en Factsheets Beleidsinstrumenten. https://www.pbl.nl/system/files/document/2025-03/pbl-2025-beleidsoverzicht-en-factsheets-beleidsinstrumenten-achtergronddocument-kev2024-en-erl2025-5832.pdf

PBL (2025e). Klimaat- en Energieverkenning 2025. https://www.pbl.nl/system/files/document/ 2025-09/pbl-2025-klimaat-en-energieverkenning-2025-5692.pdf

Rechtspraak (2019). Klimaatzaak Urgenda. https://uitspraken.rechtspraak.nl/details?id=ECLI:NL:HR:2019:2006&keyword=ECLI:NL:HR:2019:2006

Rechtspraak (2026). Klimaatzaak Bonaire https://uitspraken.rechtspraak.nl/details?id=ECLI:NL:RBDHA:2026:5739

Rijksoverheid (2019). Klimaatakkoord. https://www.rijksoverheid.nl/documenten/2019/06/28/klimaatakkoord

Rijksoverheid (2023a). Overzicht acties groene en digitale banen. https://www.rijksoverheid.nl/documenten/2023/02/03/overzicht-acties-actieplan-groene-en-digitale-banen

Rijksoverheid (2023b). Nationaal plan energiesysteem. https://open.overheid.nl/documenten/ 2f5cbb52-0631-4aad-b3dd-5088fab859c5/file

Rijksoverheid (2024). Bijlage miljoenennota 2024. https://www.rijksoverheid.nl/documenten/ 2023/09/19/bijlagen-miljoenennota-2024

Rijksoverheid (2025). Rapport Werkgroep discontovoet 2025. https://www.rijksoverheid.nl/documenten/2025/09/19/rapport-werkgroep-discontovoet-2025

Rijksoverheid (2026). MIRT Overzicht 2026. https://open.overheid.nl/documenten/3f628b3d-1389-4d2d-b37a-5853a52a9f08/file

RIVM (2023). Methodology for the calculation of emissions from product usage by consumers, construction and services. https://www.rivm.nl/bibliotheek/rapporten/2023-0046.pdf

Rutovits et al (2025). Updated employment factors and occupational shares for the energy transition. https://www.sciencedirect.com/science/article/pii/S1364032125000127

RVO (2026). Kosten van de energietransitie. Synthese van kennis en kennislacunes. Startrapport Programma EIK. https://energy.nl/publications/kosten-van-de-energietransitie/

Schutt (2024). Wind Turbines and Property Values: A Meta-Regression Analysis. https://link.springer.com/article/10.1007/s10640-023-00809-y

Sheremirov and Sprivska (2022). Fiscal multipliers in advanced and developing countries: Evidence from military spending. https://www.sciencedirect.com/science/article/abs /pii/S0047272722000330?via%3Dihub

Sustainable Finance Lab (2023). Options for the ECB to neutralise the negative effects of its monetary policy for the European energy transition. https://sustainablefinancelab.nl/wp-content/uploads/sites/334/2023/06/230614-van-Tilburg-SFL-ECB-options.pdf

Staatscourant van het Koninkrijk der Nederlanden (2026). Regeling van de Minister van Klimaat en Groene Groei van 21 april 2026, nr. WJZ/104144617, tot wijziging van de Energieregeling en enkele andere regelingen in verband met de uitwerking van de bescherming van vitale processen van systeembeheerders, het projectbesluit van de minister en enkele technische en overige wijzigingen. https://zoek.officielebekendmakingen.nl/stcrt-2026-15354.html

SZW (2026). Ministerie van Sociale Zaken en Welzijn. Verkenning werkgelegenheidseffecten van overheidsbeleid. https://open.overheid.nl/documenten/1ff32777-3ab0-4e61-b7da-18e69a0b4804/file

TNO (2020). OPERA: A New High-Resolution Energy System Model for Sector Integration Research. https://publications.tno.nl/publication/34636654/nvBkU1/stralen-2020-opera.pdf

TNO (2022). De Energietransitie moet sneller. https://publications.tno.nl/publication/34639337/a94XXR/TNO-2022-energietransitie-sneller.pdf

TNO (2023). Developing a methodology to track financial flows in the energy system. Financing the Energy Transition in the Netherlands. https://publications.tno.nl/publication/34640735/ yumrsz/TNO-2023-P10551.pdf

TNO (2025). Weerbaarheid van het energiesysteem tegen een energiecrisis. https://publications.tno.nl/publication/34645263/wusGlJsi/TNO-2025-R11805.pdf

TNO (2026). Werkwijzer brede welvaart energie- en klimaatbeleid. https://publications.tno.nl/publication/34646419/IJKIDn6G/TNO-2026-16174.pdf

UNEP (2024). Emissions Gap Report 2024. https://www.unep.org/resources/emissions-gap-report-2024

World Health Organisation (2021). WHO global air quality guidelines: particulate matter (PM2.5 and PM10), ozone, nitrogen dioxide, sulphur dioxide and carbon monoxide. https://www.who.int/publications/i/item/9789240034228

WUI (2026). World Uncertainty Index. https://worlduncertaintyindex.com/

WUINLD (2026). Federal Reserve Bank of St. Louis (FRED). World Uncertainty Index for Netherlands. https://fred.stlouisfed.org/series/WUINLD