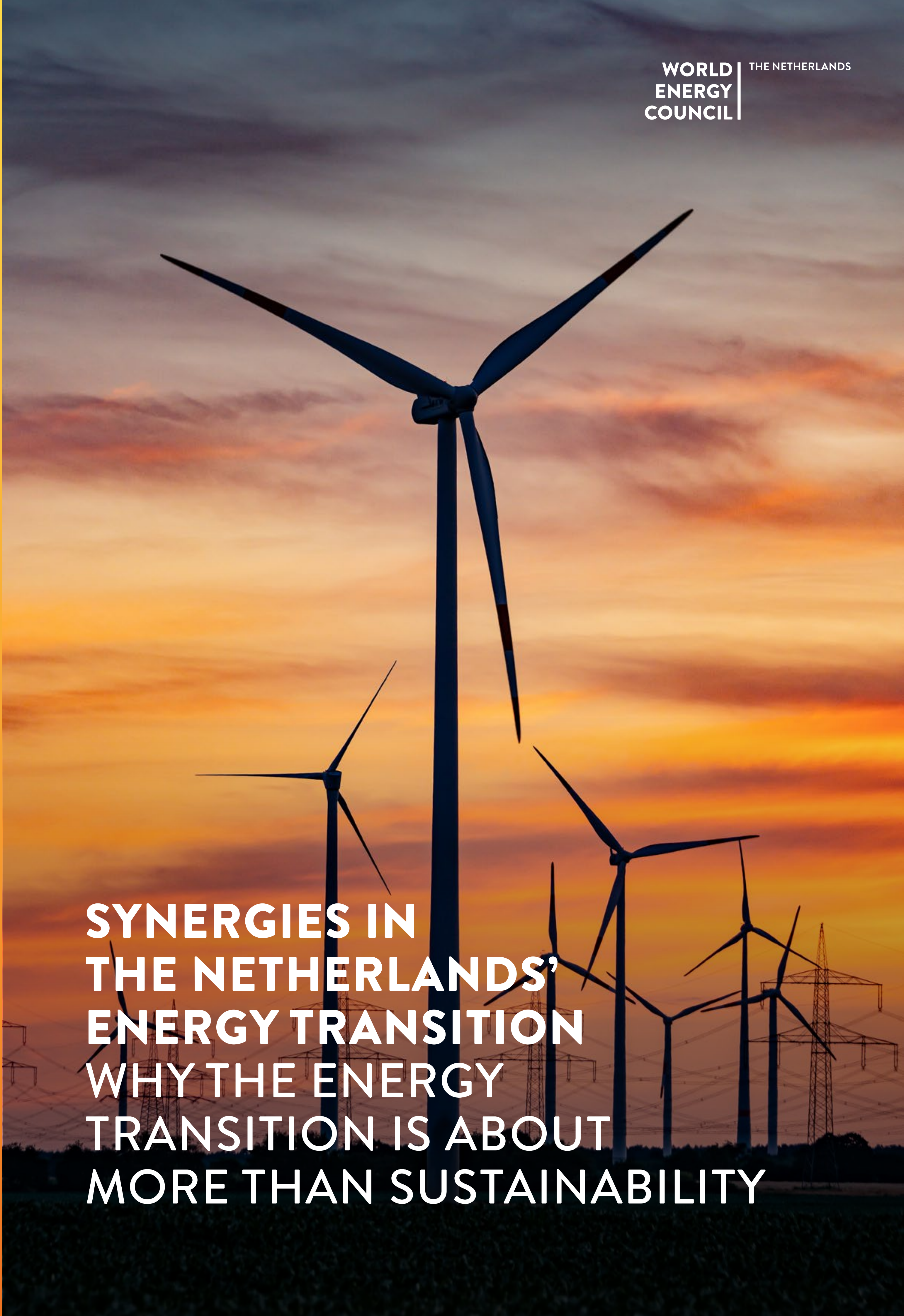

WORLD ENERGY COUNCIL | THE NETHERLANDS

SYNERGIES IN THE NETHERLANDS' ENERGY TRANSITION

WHY THE ENERGY TRANSITION IS ABOUT MORE THAN SUSTAINABILITY

ABOUT

WORLD ENERGY COUNCIL

The World Energy Council is the world's oldest independent and impartial community of energy leaders and practitioners. Through our Humanising Energy vision, we involve more people and communities in accelerating clean and inclusive energy transitions in all world regions. Formed in 1923, the Council is a UN-accredited global energy body that has convened diverse interests from across the full energy ecosystem for a century, and today has over 3,000 member organisations and a presence in more than 100 countries. Our global network draws from governments, private and state corporations, academia and civil society, as well as current and future energy leaders. We collaborate on impact programmes and inform local, regional and global energy agendas in support of our enduring mission: to promote the sustainable use and supply of energy for the benefit of all people. Further details at www.worldenergy.org and on LinkedIn and Twitter.

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EXECUTIVE SUMMARY

The sunshine period: Since 2000s, the EU has started to make its energy system more sustainable. After the Paris agreements in 2015 this became the main focus. Within the European Green Deal, the EU set ambitious targets for 2030 and 2050, and the Netherlands translated these into its own Climate Agreement with a mix of subsidies and CO_2 levies. These policies have contributed to substantial outcomes: greenhouse gas emissions in Europe have roughly decreased by 37% since 1990 while GDP increased by 70%.[1]

Overhauling the global energy system in such a relatively short time inevitably leads to acute dilemmas. To reflect that fact, the World Energy Council introduced the Energy Trilemma in the 2000s[2]: the notion that in general energy must be affordable, reliable and sustainable at the same time, even while these goals often are in conflict with each other. In energy provision, before, during or after a transition, there is no free lunch. For a number of decades, abundant and reliable fossil fuel supplies have kept energy prices relatively low. Within this context, the EU could afford to push the energy transition towards renewables, almost without worrying about the other two corners of the Trilemma: affordability and security of supply.

Clouds on the horizon: A shifting international context and the challenges of energy system change made it increasingly difficult for Europe to balance all three objectives. Since the late 2010s, and especially the early 2020s, Europe has entered a more turbulent phase of the energy transition. Russia is no longer an acceptable fossil supplier, while dependence on China for critical components and materials and on the US for LNG has grown. Furthermore, rising energy prices, slow economic growth, and lagging productivity growth in the EU have put additional stress on the transition. Also within the energy system, the build-out of ever larger-scale infrastructure and matching supply and demand from intermittent energy sources has proven to be challenging.

These trends have redefined the context of the energy transition. The energy system is currently underperforming across all three dimensions: affordability is under pressure, security of supply has been put to the test, and full sustainability is still far from being realized. At the same time, expectations for the energy system of the future have broadened to include other factors such as contributing to industrial competitiveness and strategic autonomy. A relatively high energy intensity in combination with relatively high energy prices, strong sustainability ambitions and the central historical role as an energy roundabout for Europe, and consequently as a home to major industrial clusters all taken together make the Netherlands a proverbial canary in the mine for these trends in the European context.

Off late, this changing context has given rise to several questions within society: are we not pushing whole parts of our industry abroad, with corresponding risks of losing jobs, skills & experience, innovation strength and our future earning capacity; how can we keep energy prices for industry and society affordable; aren't we going too fast, and isn't the energy transition too complex, too expensive, and too difficult to govern?

These lead to one central question: **How does a sustainable energy system fit with the other objectives of the energy system?** In other words, what do these trends mean for how we think about the energy transition – or the energy trilemma.

A new dawn: Three observations point to a perspective in which (sustainable) interventions can simultaneously advance multiple trilemma objectives

This report identifies synergies between the three poles of the trilemma. These synergies illustrate how affordability, security and sustainability might actually enforce each other - and perhaps increasingly so as the transition progresses. Three interdisciplinary observations about the energy transition form the basis for the idea that sustainable interventions create synergies.

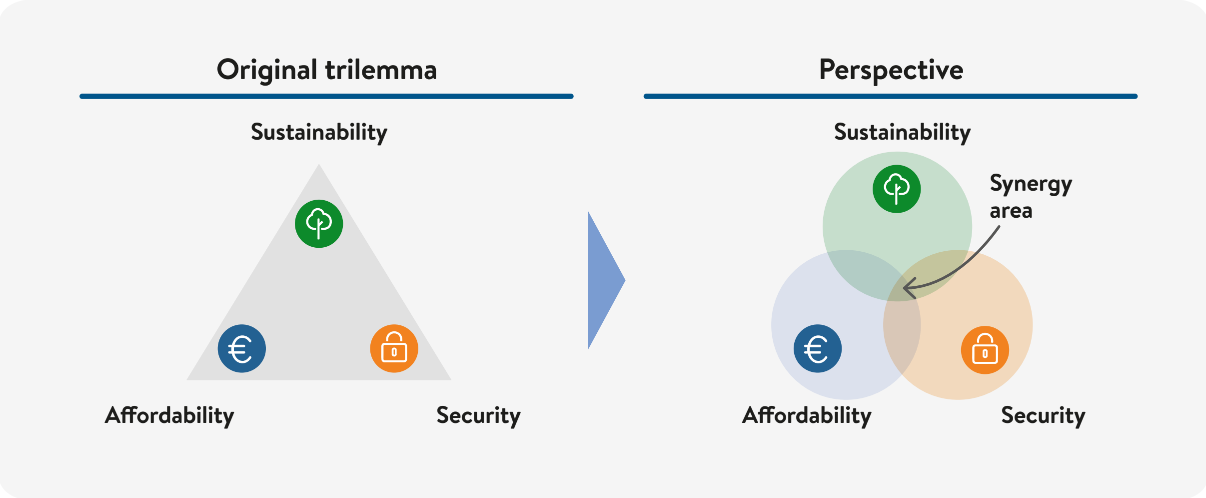
Firstly, one might easily overlook the fact that fossil fuels have lost their own edge in reliability and affordability in Europe, which has softened some of the often considered weak points of green energy. This is illustrated by the recent developments in the Middle East following US-Israeli attacks on Iran which have resulted in severe supply disruptions and a deterioration of the global security of oil and gas supply. The International Energy Agency noted already that this latest energy crisis will be more impactful than the earlier energy crises of 1970s and 2022.[3] That impact could have been much worse, wouldn't Europe not have transited towards a significant portion of power coming from domestic renewables (especially wind and solar), the exposure to supply shocks caused by geopolitical events is already lower than it could have been.

Secondly, when taking a longer time horizon and broader societal view of all the costs and benefits associated with a forceful continuation of the energy transition, it is not unrealistic to assume that doing nothing about climate change as a continent is more expensive in the long run than the energy transition itself.

Thirdly, the role of costs and positive externalities of infrastructure makes the societal business case for the transition more favorable than is often assumed. On top of the spectacular price drops of many aspects of renewable energy, from solar and wind to storage and electrical mobility and equipment, the scale of implementation of those technologies in the system create positive external network effects on their own.

Next to synergies, it is equally important to recognize that one can not define away the trade-offs arising from (sustainable), such as the effects on ecosystems, affordability, or short-term system stability we see today. A balanced perspective must therefore account for both positive and negative effects of interventions. Identifying these trade-offs early also helps develop mitigation measures and enables a more credible and effective transition strategy.

Considering this, we suggest a perspective on the energy system based on the notion of synergies and trade-offs. In this report we develop the original trilemma further: by looking at the overlap between different trilemma poles; by re-examining the drivers of the original trilemma poles; and by acknowledging that there are still trade-offs to be overcome; and by addressing how that can be achieved at lowest societal cost. Our suggested perspective can be visualized by a slight augmentation of the classical trilemna graphic.



This perspective is not entirely new. The European Commission has already presented it within several policy frameworks (e.g. the Clean Industrial Deal[4], Commission Work Program 2026[5]). It has somewhat trickled down into the Dutch context. The Netherlands was recently a co-signatory to the North-Sea treaty for offshore wind (the Hamburg Declaration)[6] which uses this concept. Within the public debate, the Wennink report[7] already noted how action in climate change may coincide with economic opportunities and increased energy security.

We have applied this perspective to the Netherlands in an high-level attempt to identify synergies within the Dutch energy transition. From this initial attempt several synergies have come up that seem to deliver on more than one trilemma pole. From that list of interventions five themes spring out (we spend a chapter on each of the underlying interventions). None of those is radically new, but the point we wish to underline is that each creates probably as many synergies as trade-offs, if a priori a comprehensive viewpoint is adopted.

1. **Complementing intermittency of renewable energy:** By making demand more flexible where possible and adding complementary flexible supply, energy may become more reliable and secure.
2. **Enabling and creating green and low-carbon demand:** Creation of green and low-carbon demand by governments – facilitated with the right infrastructure – makes green and low-carbon business models possible. This applies e.g. to offshore wind, green hydrogen production and adoption of cleantech by industry.
3. **Diversifying supply with green energy sources:** By using alternative green energy sources such as biogas, the energy system can become more robust and have a higher degree of security of supply.
4. **Improving energy efficiency and reducing overall energy usage for households:** Interventions in the built environment (isolation, heat pumps, district heating) and mobility (electric vehicles) could make energy more secure and affordable.
5. **Decarbonizing industry in a competitive way:** Maintaining competitiveness while decarbonizing can help to prevent carbon leakage and boost strategic autonomy.

From this, we deduce four general lessons for the years ahead:

First, this perspective offers a new way to refer to the energy transition. Because the case for transition is no longer the exclusive domain of climate change, this perspective can enable and facilitate better and more constructive societal dialogues. It helps bring together different coalitions behind the energy transition, each with their own narrative.

The second lesson is to focus on synergies when making the energy system not only more sustainable but also more independent and cost efficient. Interventions that serve all three poles of the trilemma provide a much stronger societal business case compared to those that serve sustainability only. We have made an initial attempt at identifying some of the synergies of the transition. Follow-up work can apply this perspective more rigorously and answer the ‘how’ questions which we have not done here.

A third lesson is that interventions with synergies can also impose pressure on the energy system. Recognizing these early, assessing them transparently, and putting mitigation and adaptation measures in place strengthens both the credibility and feasibility of the transition. By systematically managing risks and externalities, policy makers can ensure that synergies are realized without undermining societal acceptance or long-term system resilience.

A fourth lesson is that by making private and public costs and benefits explicit, discussions and ultimately design of policies can be held more fruitfully. Establishing what the private costs and benefits of a project are is complex given the longevity, the scale, and often newness of the project. But if certain associated public costs and benefits are taken in the comprehensive picture, discussions about allocating risks and rewards are become clearer, and motivations for potential tax-payers contributions become more evident. And possibly, the total ‘business cases’ might become more positive.

Note that in this report we are focusing on the positive and synergetic aspects of the energy transition. While we acknowledge that we also face many significant challenges on the way, for example the persistent level of grid congestion, the massive investments required, or “softer” barriers like NIMBY, these are not the focus of our report and will therefore not be dealt with in detail.

Another caveat is that we look at the Netherlands as the region of study. We take its place in Europe as given which means that we do not see Netherlands’ economy or energy system transition in isolation, but we take details of what might happen in countries around us as given. It also means that the global climate change contribution of the Netherlands is ignored.

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1. INTRODUCTION: A CHANGING GLOBAL CONTEXT HAS RAISED QUESTIONS ABOUT THE VIABILITY OF THE ENERGY TRANSITION

SUNSHINE PERIOD: SINCE 2000S, THE EU HAS STARTED TO MAKE ITS ENERGY SYSTEM MORE SUSTAINABLE. AFTER THE PARIS AGREEMENTS IN 2015 THIS BECAME THE MAIN FOCUS

Ever since the Kyoto protocol, in 1997, the EU and by extension the Netherlands, have started to make its energy system more sustainable. After the Paris accords in 2015[8] this became the focus of the energy system – rather than energy affordability or reliability.

The EU as a bloc has formulated ambitious climate legislation within the European Green Deal (2019), setting out to achieve greenhouse gas emissions neutrality by 2050 ('net zero'), and at least 55% greenhouse gas reduction by 2030 (vs. 1990). The Netherlands enacted this with its own policy, including the Climate Agreement (2019) which aimed to reduce emissions by 49% by 2030 and was later updated to 55%. The policies included a set of climate investment subsidy funds ('carrots'), as well as an additional national CO_2 levy on top of the ETS CO_2 price for industry (from 2021, 'sticks') to enforce those targets.

Climate policies aimed to transition to renewable energy have generated tremendous results around the world, especially when considering the continuous development of economic activity. Greenhouse gas emissions in Europe have decreased by 37% since 1990, while GDP has increased by 70%.[9] (Part of that has been due to outsourcing fossil activity to China, but at least more than half the effect has come from policy-induced inherent efficiency). Learning curves have been steep (solar, wind, storage, mobility and household appliances); in brief, transition cost estimates are being tuned down every year for years in a row.

Overhauling the entire Global energy system in such a relatively short time frame, and energy being such a vital resource for global welfare development, inevitably leads to dilemmas. To reflect this, the World Energy Council introduced the term Energy Trilemma, in the early 2000s.[10] The Energy Trilemma stands for the notion that a balance between three fundamental objectives of energy system perspective should be aimed for: energy should be at the same time affordable, reliable, and sustainable. But crucially, in reality these three objectives may often contradict each other. There still isn't such a thing as a 'free lunch', after all.

In the early days of the energy transition in Europe, the abundance of resources, such as gas, coal and oil, delivered by trusted global and increasingly efficient regional markets, ensured that the base price for energy was relatively low, and the availability of primary energy sources fueling the energy systems of Europe was never an issue. In that context, the EU could afford to push the energy transition towards renewables, almost without worrying about the other two corners of the trilemma: affordability and security of supply. The only real geopolitical hindrance has been the financial crisis in '07 and the debt crises that followed subsequently.

CLOUDS ON THE HORIZON: A SHIFTING INTERNATIONAL CONTEXT AND THE CHALLENGES OF RAPID SYSTEMIC CHANGE MADE IT INCREASINGLY DIFFICULT TO BALANCE ALL THREE OBJECTIVES.

Since the late 2010s, and especially the early 2020s, Europe has entered a more turbulent phase of the transition. The geopolitical landscape has changed. Russia can no longer be considered a reliable supplier of fossil fuels, and Europe finds itself increasingly dependent on China for materials and clean energy technologies and on the US for LNG. These developments have heightened concerns about security of supply and global competitiveness of European industry - as Draghi has expressed in his report.[11]

Furthermore, recent developments in the broader Dutch and European economy have put additional stress on the transition. Energy prices, and costs of resources, rose sharply in recent years due to the changed geopolitical landscape and productivity growth[12] has lagged compared to other continents. As a result of lower productivity, geopolitical turmoil, and partly de-industrialization of Europe, large industrial players have delayed investments in electrification, leading to lower than anticipated growth in low-carbon energy demand. Although there are many proponents to keep going, political debates in the EU and the Netherlands have increasingly questioned whether climate ambition might inhibit other societal goals.

Finally, also within the energy system there are systemic changes taking place which have made the transition more turbulent. The goal of homegrown energy to lower energy prices and increase self-sufficiency brings about new challenges. In both the build-out of infrastructure and in matching supply and demand from intermittent energy sources. All of this – in combination with the concept of marginal price setting for electricity – leads to increased price volatility and very high CAPEX needs. This results in uncertainties surrounding coordination of policy instruments, spatial planning, and investment decisions.

These combined trends have redefined the context of the energy transition for the coming decades. Two effects stand out:

First, the energy system today performs less effectively in all three dimensions: affordability has come under pressure, security of supply has been challenged, due to the strong reliance on fossil fuels, and the s-shaped curves necessary for full sustainability remain out of reach. With respect to the latter, it should be noted that for solar and batteries dramatic S-shaped cost reductions have manifested. However, those technologies are by themselves not enough to deliver full decarbonization; complementary technologies (e.g. electrolysis, storage and transport infrastructure, etc.) are not there (yet). In short, these developments have brought ‘affordability’ and ‘reliability’ back into the equation with a vengeance.

Secondly, what makes energy secure, affordable, or sustainable has changed. For instance, secure energy is no longer just about having a diverse supply portfolio. Rather, it also reduce to key dependencies and overall robustness of the energy supply chain.

The Netherlands functions as the proverbial canary in the mine for these trends. It is particularly exposed to these tensions due to its high energy intensity, its high energy tariffs, strong sustainability ambitions and the central role as an energy roundabout for various energy carriers, and home to many industrial clusters. Thanks to these features, the tensions in the Dutch energy system are unlikely to improve in the near future. Note that the situation would have been worse without a significant share of renewables.

This is important for the Netherlands but also for Europe since its energy systems are closely linked. The Dutch energy system is tightly integrated into the wider European network through multiple high-capacity cross-border interconnections for both electricity and gas. Moreover, the Netherlands both imports and exports significant volumes of electricity and gas, acting as a key trading and transit hub in the Northwest European energy market.

This redefined context for the energy transition is reflected in the current political debates in the EU and in Netherlands. Aren't we pushing whole parts of our industry abroad, with corresponding risks of losing jobs, skills & experience, innovation strength and our future earning capacity? How can we keep energy prices for citizens and business affordable?

A NEW DAWN: THREE OBSERVATIONS ABOUT THE TRANSITION POINT TO A NEW PERSPECTIVE IN WHICH (SUSTAINABLE) INTERVENTIONS CAN SIMULTANEOUSLY ADVANCE MULTIPLE TRILEMMA OBJECTIVES

Considering the previously mentioned developments, making the energy system more sustainable might have slipped somewhat on the political priority list. However, in migrating from fossils to renewable, we may need to imagine that green energy is cheaper and, in several respects, more advantageous than is often assumed.

Firstly, fossil fuels have lost their edge in reliability and affordability in Europe, which has softened some earlier considered weak points of green energy. This is illustrated by the recent developments in the Middle East following US-Israeli attacks on Iran which have resulted in severe supply disruptions and have deteriorated global security of oil and gas supply. The International Energy Agency noted already that this newest energy crisis will exceed the earlier energy crises of 1970s and 2022.[13] Due to a significant share of power coming from domestic renewables (especially wind and solar), the exposure to supply shocks caused by geopolitical events is already lower than it could have been.

Secondly, when taking a longer time horizon and broader societal view of costs and benefits into consideration, doing nothing about climate change is more expensive in the long run. Thirdly, the role of prices and positive externalities of infrastructure makes the societal business case for the transition more favorable than we assume now. As many technologies are already more efficient now – both from an energy balance as from a cost perspective – compared to fossil based solutions, i.e. solar and wind power production and electric vehicles.

In this light, this report offers a new perspective on the energy trilemma that helps to see the transition as simultaneously advancing multiple goals. It identifies synergies between the three poles of the trilemma beyond the classical trade-offs. These synergies illustrate how affordability, security and sustainability increasingly reinforce each other at the expense of mutual exclusion. At the same time, it is equally important to recognize that (sustainable) interventions can also come with trade-offs. For instance, the effects on ecosystems, affordability, or short-term system stability. A balanced perspective must therefore account for both positive and negative effects of interventions. Identifying these trade-offs early also helps develop targeted mitigation measures and enables a more credible and effective transition strategy.

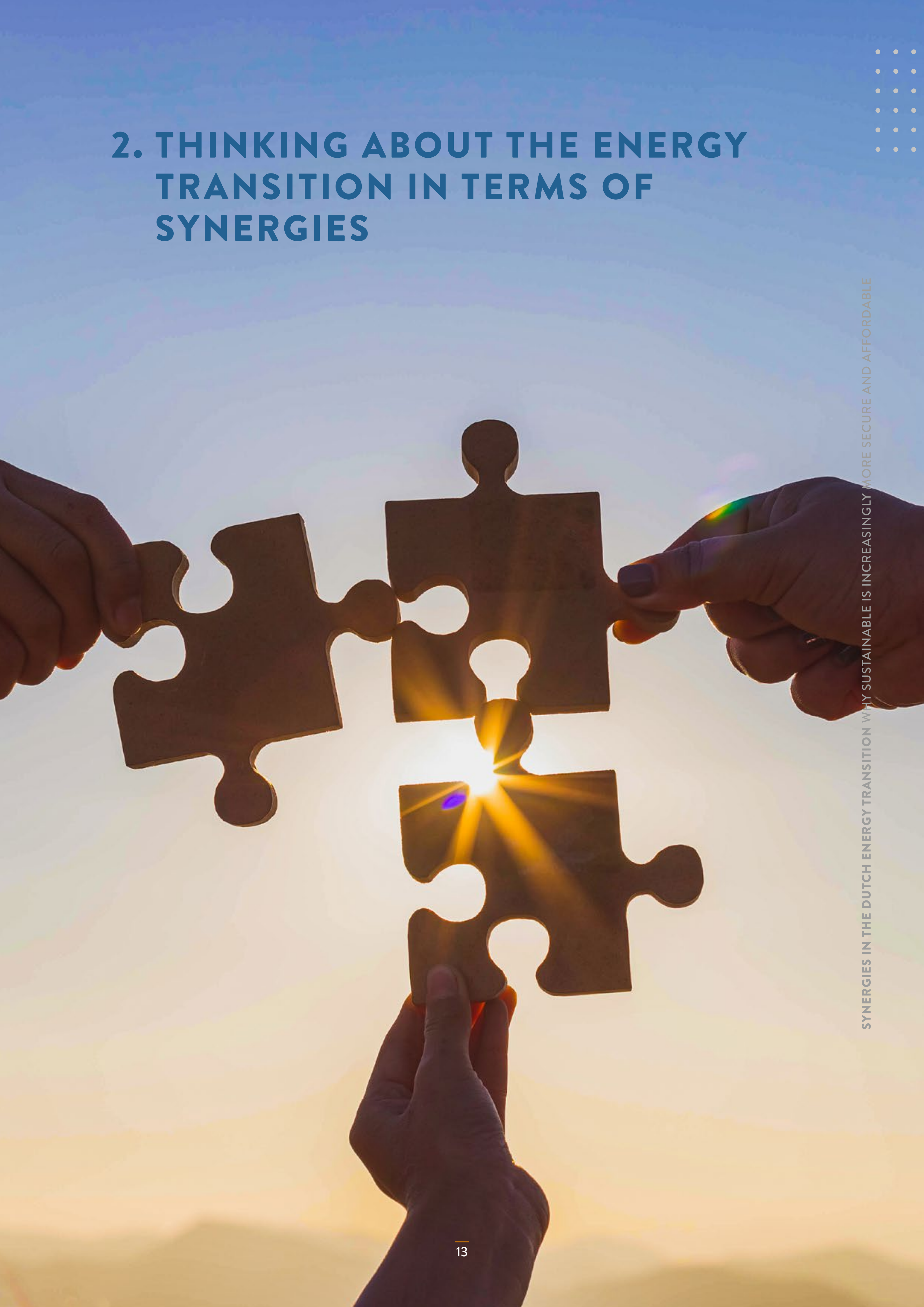
In the next chapter we elaborate on the rationale behind the perspective presented here. The key claim is that (sustainable) interventions in the energy system can simultaneously realize multiple trilemma goals. We call this a 'synergy', the inverse of a 'trade-off'.

The third chapter subsequently applies this perspective to the Netherlands. It comes up with suggestions to realize synergies. The report closes with a few conclusions in the fourth chapter. Four case studies (included in the appendix) from and extensive dialogue with WEC members form the basis of the (application of this) new perspective. These case studies cover a broad variety of aspects of the energy system: production until consumption, a wide spectrum of energy carriers, and different end-users of energy[14].

The four case studies are:
- **Offshore wind**, the primary source of largescale renewable;
- **Energy intensive industry**, which anchors demand, central to NL's competitiveness;
- **E-mobility**, which reshapes energy demand patterns and offers new system flexibility;
- **Green hydrogen**, as a feedstock, as seasonal storage and as a fuel for hard to electrify sectors.

Note that in this report we are focusing on the positive and synergetic aspects of the energy transition. While we acknowledge that we also face many significant challenges on the way, for example the persistent level of grid congestion, the massive investments required, or "softer" barriers like the NIMBY-effect, these are not the focus of our report and will therefore not be dealt with in detail.

2. THINKING ABOUT THE ENERGY TRANSITION IN TERMS OF SYNERGIES



The introduction has already shortly touched upon this notion of synergies – seen against the backdrop of an energy system with clouds gathering above it. But what are the observations that underly this notion about synergies? And how does this idea change our thinking on the energy system – in other words, the energy trilemma.

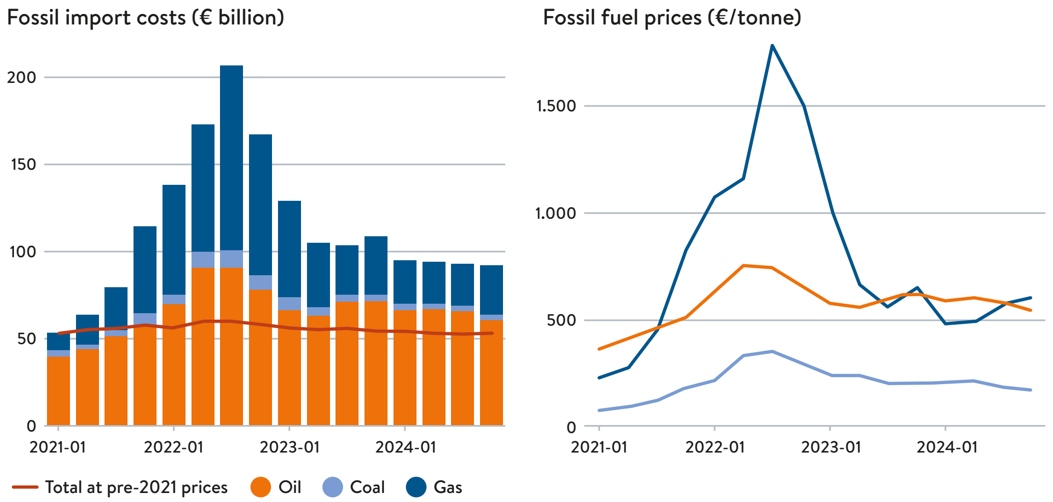
THREE OBSERVATIONS ABOUT THE ENERGY TRANSITION FORM THE BASIS FOR THE IDEA THAT SUSTAINABLE INTERVENTIONS CREATE SYNERGIES

We observe three different interdisciplinary arguments that support the notion that sustainable interventions can realize more than one goal within the energy system and/or society as a whole.

First, fossil fuels have lost some of their traditional strong suits in Europe which has softened some earlier considered weak points of green energy. The EU has lost Russia as supplier of secure and affordable fossil fuels. This has decreased structural access and has exposed the costs associated with fossil fuel dependencies. Fossil fuel imports (shown below) clearly illustrate this. Between 2021 and 2024 the EU spent almost € 1 trillion extra on fossil energy import.[15] This pattern now seems to repeat itself because of the Middle-East crisis. Affordability and security are thus no longer the monopoly of fossil energy.

The EU's fossil import costs spiked during the energy crisis

Fossil fuel imports cost the EU €1.8 trillion between 2021 and 2024



Source: Ember

Calculated costs at pre-2021 prices use five year averages of oil (Brent), gas (Dutch TTF), and coal (Newcastle) costs (2026-2020).

Second, the idea that sustainable interventions can realize goals outside the private sector becomes visible when taking a longer horizon and a broader view of costs and benefits. From the perspective of a private actor, the business case for taking climate action is, despite important exceptions, often negative. However, from a societal point of view, doing nothing creates several public costs and misses benefits. The deepdive presented in box 1 shows that doing nothing also imposes severe costs.

Third, from an economic lense, the business case for the transition may be greater than the sum of the business cases of its individual parts. Laying down the infra for the transition can be seen as a no-regret (look for example at the high-speed railway in France, highway infrastructure in Germany, internet infrastructure, Nieuwe waterweg a century ago, etc.). Also, the dynamics of pricing instruments are often underestimated. High prices attract competitors and help generate scale and learning effects. This reduces prices and brings in additional demand to result in S-shaped curves. The deepdive in Box 2 expands and shows how this is the case for battery energy storage systems (BESS).

BOX 1: WHY THE BENEFITS OF ACTION MIGHT BE GREATER THAN THE COSTS OF INACTION

The potential benefits of the energy transition become clear when taking a longer time horizon and broader view. Continuing our reliance on fossil costs has several costs associated (e.g. health, environmental, energy dependence costs etc.). The benefits of an action-scenario where we decrease CO_2 emissions is that we prevent these costs. By tallying up these benefits, we can give a very broad indication of at what point the total-value-case for reaching net zero in 2050 might become neutral or even positive.

Reducing our CO_2 emissions avoids a wide range of fossil fuel–related societal costs
Below is a non-exhaustive illustration of the net benefits – or prevented costs - of reducing CO_2 emissions from 2026 until 2050 in line with legal CO_2 emission reduction targets in 2030, -40, and -50. It is calculated using the difference in societal costs of scenario A where emissions are constant at 2024 levels and scenario B where emissions are gradually reduced overtime.

Non-exhaustive illustration of the benefits of reaching net zero in 2050 in NL
(2026-2050, in billion €, price index 2024, net present value using 2,6% discount rate, Figures are rounded to tens of billions, so totals are approximate).

Level	Type		Range: Lower	Range: Upper	Description
Local	Energy independence		€ 80	€ 250	Costs of a multi-event LNG supply shock for 3-9 months where industry (partially) stops operating
Local	Air pollution	PM	€ 150		Costs of increased deaths and illnesses due to exposure to particulate matter (PM) from fossil fuel combustion
Local	Air pollution	NO_x, NH_3, N_2O	€ 110		Costs of non-market damages because of NO_x, NH_3 and N_2O emissions from mainly fossil fuel combustion
Global	Air pollution	CO_2	€ 210	€ 250	Costs of international market and non-market damages because of Dutch CO_2 emissions
	Total		**€ 550**	**€ 760**	

Note that most of the benefits are realized locally, except for CO_2 since costs of climate change are shared around the world. Moreover, there is an unquantified but likely small overlap in particulate matter (PM) exposure and NO_x, NH_3, NH_3 associated costs since the latter also contribute to PM formation. Costs are therefore lower than shown here. Finally, since the nature of these costs is societal, action benefits will not always show up in economic metrics. See the appendix for further substantiation of costs used here.

Reducing our CO_2 emissions to net-zero is likely to cost more than € 400 billion
The cumulative energy system transition costs are highly uncertain due to unknowns about a.o. future policy, prices, and the design of the energy system. Netbeheer NL (2023) has the latest and most comprehensive study on system costs in 2050. Additional system costs would amount to between ~ € 20 and € 35 billion extra annually in 2050 compared to baseline policy in the PBL's Klimaat en Energieverkenning 2022. By scaling these costs between 2026 and 2050 linearly with legal CO_2 reduction targets, cumulative (discounted) system costs could tally between ~ € 210 and € 370 billion – depending on the selected energy system scenario.

The energy system scenarios and assumptions for these costs are, however, dated. We can update the infrastructure capex costs component of the Netbeheer NL study using a 2024 FIEN study by PwC-Strategy&. Cumulative costs would then amount to between € 400 and € 560 billion. However, other components of the system cost calculation (i.e. energy production, import of energy carriers, etc.) are likely to have increased as well. Therefore, this figure is an underestimation. We can say that it is very likely that total transition costs exceed € 400 and must stay around € 550 and € 760 billion for the total value-case to remain positive.

BOX 2: THE ROLE OF INFRASTRUCTURE AND PRICE SHOULD NOT BE UNDERESTIMATED

The synergies within the energy system are not the only driver for the transition benefits. There are also two key economic aspects at play: 1) infrastructure and 2) prices.

There are numerous externalities associated to infrastructure that make infrastructure a 'no-regret' investment. But since they are typically difficult to predict, they are often undervalued or ignored, out of carefulness principles These positive externalities may range from new or higher productivity gains in unrelated sectors, to innovation spillovers, or the development of clusters with their own network effects. Examples are numerous. All examples from the high-speed railway in France, the Autobahn network in Germany, the World-Wide Web, Nieuwe Waterweg a century ago, and so on, have all delivered very positive outcomes, many of which have not been imagined beforehand. One prime Dutch energy example stands out: Dutch gas infrastructure roll-out after the discovery of gas fields in 1959. Each of these infrastructure projects at the time of development could reasonably well be priced up front, but the benefits were abstract or could not even be anticipated fully at the time of conception, nor could all ultimate beneficiaries be pinpointed. As a consequence, classical cost-benefit analyses have tended to be conservative, and often negative.

The Nieuwe Waterweg is another notable example. Apart from 'just harbour fees', this infrastructure has delivered at least two positive externalities. It enabled the creation of Dutch energy-intensive industry clusters (such as for the Chemical industry in Moerdijk and Rotterdam) which has improved national productivity, and a crucial engine for economic and societal development. It also created optionalities, as the gradual adaptation of the focus of the harbour over the decades as the World of traded wares evolved has shown. Having a Nieuwe Waterweg has been helpful, to the point that households and business could and can substitute energy carriers over time which benefited welfare, well-being, and public health, to name just one example.

The fact that many of these externalities have benefits several agents in society brings in the argument for at least partly public (financial) contribution. How, in the case of energy transition infrastructure investment this public finance should be structured is another and mostly political question: debt budgetary of monetary, which household stratum (generation?).

Battery Energy Storage Systems (BESS) are a key example of a synergy generated by the pairing with infrastructure. Prices for battery storage have dropped from $1742 per kWh in 2014 to $192 per kWh in 2024. This has been the result of rapid factory scale-up, fierce competition, and oversupply. Cheap batteries now make it economical to pair solar with storage and provide dispatchable power, but only in combination with appropriate infrastructure. The result has been a yearly growth rate (or CAGR) of 80% for battery storage capacity additions, which without infrastructure could to have manifested.

Another economic aspect not to be too easily ignored is the role of prices. There is a tendency to keep prices more or less fixed when making calculations into the future. That is often done for simplicity reasons, because who knows what the power prices or the prices of electric mobility and what have you will be in 2, 5 or 15 years time?

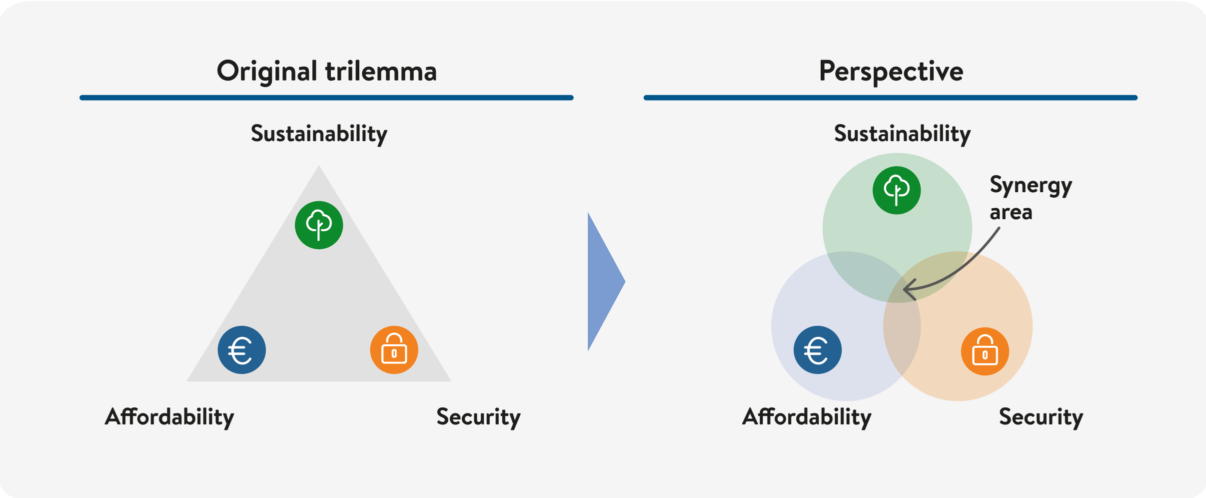
But what we do know is that these prices may not only change drastically over time, but their variability may alter fundamentally as well. Both the expectations of future prices and their volatility will change (mu and sigma-squared). At the same time we know that both changes will affect buyers and investors decisions, as the price shock of natural gas following the Russian invasion of Ukraine has shown.

For economists this means two things. (1) When doing calculations, take a closer look at potential implications for scarcities and price changes, and corresponding behavioral responses. Take those into account when designing policies. And (2) watch out for policies that affect the merits of free markets to allow scarcity signals to reflect in prices - unless there is a very significant argument to do so. Our way of pricing infrastructure investments in user tariffs blocks scarcity signals on energy markets, for instance, which negatively affects the inevitability and the transition to renewables usage and production.

CONSIDERING ALL OF THIS, WE SUGGEST A PERSPECTIVE ON THE ENERGY SYSTEM BASED ON THE NOTION OF SYNERGIES

From this notion of synergies, we further develop the trilemma. The original trilemma contrasts green energy and fossil fuels based on the latter's reliability and security. This report gives a more nuanced perspective on our energy system.

It can be visualized as follows:



We arrive at this perspective from the original trilemma using the following logic:
1. We look at the overlap between the different trilemma poles
2. We examine how the underlying drivers of trilemma poles have changed
3. We acknowledge that there are still residual trade-offs to be overcome

Ad 1: Enhancing sustainability can improve affordability or reliability of energy and create so called synergies, or "win-wins." For example, integrating green hydrogen production with variable renewable generation may help partially absorb peak electricity supply, enhancing system stability and reducing costs, thus improving both affordability and reliability.

Ad 2: Although the end goals of the energy system (secure, affordable, and sustainable energy) have not changed, its underlying drivers have. For instance, having affordable energy is to an increasing extent also driven by the relative price of energy compared to other regions – or competitiveness - and ability to sustain (green) business models. Box 3 (below) elaborates on this point.

Note that in this report, affordability is approached as being a relative concept: it depends on the alternative options available at a given moment, not on an absolute notion of "cheap" energy. It is also time-dependent: what is affordable today may not be affordable tomorrow as fuel markets, geopolitics, policy, and technology costs change. Moreover, the meaning of affordability is expanded to include future competitiveness and contribution to new business models. When we discuss affordability, for the long term, we will consider costs in the broad sense, including relevant externalities and hidden costs (such as import dependence, geopolitical exposure, climate damage and adaptation costs) as well as potential lifecycle benefits from learning effects and scale.

Ad 3: Accelerating the energy transition will succeed only if the negative side effects of decarbonization, so-called trade-offs, are addressed and managed, and do not overshadow the benefits. The negative factors may include local environmental impacts, high upfront capital requirements, exposure to new supply risks (e.g. critical raw materials from China).This perspective is not completely new. Already in 2025, the European Commission presented the Clean Industrial Deal[16] (CID) to turn decarbonization into a driver of growth for European industry. It bundles various packages that touch upon all trilemma poles mentioned here: a.o. Critical Raw Materials Act, Net-Zero Industry Act, Green Deal Industrial Plan etc.

This perspective has somewhat trickled down within the Dutch context. The Dutch have recently (in January 2026) co-signed the Hamburg Declaration[17]. This is an investment pact between North-Sea adjacent countries to turn the North Seas into a major clean energy hub to boost energy security and industrial competitiveness through lower energy prices. It includes initiatives to set up an offshore wind tender pipeline orchestrated at EU level, an offshore financing framework and better coordinated grid planning. Within the public debate, the Wennink report[18] already noted how action in climate change coincides with economic opportunities and energy security.

All in all, this perspective calls for a new way forward in the energy transition. One that focusses on the positive external effects (synergies) and manages the negative external effects (trade-offs). The next chapter will go into more depth on what kind of synergies and trade-offs we can expect in the Netherlands.

It is important to clarify that the goal of this report is not to answer all the questions that arise when using this perspective (e.g. what if any part of fossil-based industries should be kept within the Netherlands). Rather, it intends to offer a useful analytical framework to look at our energy system, and see how we can make it function better in line with society's needs.

Although this report does not give a concrete roadmap on how to implement the energy transition, a few pointers for its success are useful regardless. New incentives will have to be created to shape the behavior of individuals and organizations. Moreover, cooperation between parties will likely have to take on new public/private forms. Finally, the way in which the transition is communicated to society is a key factor in its success.

BOX 3: RE-EXAMINING THE DRIVERS OF THE TRILEMMA POLES

In light of this changing context, the underlying drivers of energy security, sustainability, and security have evolved from the original trilemma.
The WEC came up with the energy trilemma around the 2000s to measure and manage progress in energy systems. It has conducted yearly country assessments to publish an index of a country's relative energy performance – called the WEC trilemma index. The trilemma dimension names and definitions have changed throughout the years. The WEC's international '24 report gives the most recent interpretation of three poles. However, these diverge slightly from the concepts we hear most within the Dutch context. Therefore, we use the most used concepts that contain the essence:

- Sustainability - Reducing carbon emissions and possibly generating a broader environmental impact
- Security - Ensuring a reliable and uninterrupted partly home-grown energy supply
- Affordability - Providing affordable and accessible energy to all

We expand the trilemma definitions to capture the key factors that are driving the poles in today's context. This is not an exhaustive list but one that captures – in our view – the most important drivers:

Poles	Objectives	Definitions
Sustainable	Carbon reduction	Moves towards a low carbon dense energy system
	Ecosystems (new)	Accounts for impacts on ecosystems, land use and local environments
Secure	Security of supply (sources)	Deliver continuous and uninterrupted energy by having a diverse energy portfolio
	System robustness (new)	Ensures the system can withstand shocks and recover quickly with limited disruption
	Supply chain dependencies (new)	Mitigates or adapts to any risks within the energy supply chain (e.g. CRM, technology etc.)
Affordability	Affordability	Keeps energy accessible for all layers of society
	Competitiveness (new)	Avoids competitive disadvantages versus other regions (e.g. US, China, etc.)
	Business models (new)	Supports viable, scalable and exportable business models across the energy value chain

Note that competitiveness is placed in the affordability dimension for visibility reasons but is conceptually also part of security since a competitive economy could provide leverage and thereby security.

3. NEXT STEPS: MAXIMIZING DUTCH SYNERGIES

This chapter applies this perspective to the Netherlands in a first attempt to find suggestions for synergies (that align as best as possible with our comparative strengths and weaknesses). These examples are illustrative and based on input from WEC-members. This has already been done to some extent: The Wennink report[19] identified 18 and the Nationaal Burgerberaad Klimaat[20] (a Dutch representative citizens assembly on climate) identified 13 climate-projects that also cover other poles. We have identified the following interventions.

3.1. HIGH-LEVEL SYNERGIES IN NL

From the interventions that have been identified within the report, five larger themes emerge:

1. **Complementing intermittency of renewable energy**: By making demand more flexible where possible and adding complementary flexible supply, energy could become more reliable and secure.
2. **Enabling and creating green and low-carbon demand:** Creation of green and low-carbon demand by governments – facilitated with the right infrastructure – makes large-scale green and low-carbon business models possible. This applies e.g. to offshore wind, green hydrogen production and adoption of cleantech by industry.
3. **Diversifying supply with green energy sources:** By using alternative green energy sources, e.g. green molecules like biogas and green electricity from wind and solar, the energy system can become more robust and have a higher security of supply.
4. **Improving energy efficiency and reducing overall energy usage for households:** Interventions in the built environment (isolation, heat pumps, district heating) and mobility (electric vehicles) could make energy more secure and affordable.
5. **Decarbonizing industry in a competitive way:** Maintaining competitiveness while decarbonizing can help to prevent carbon leakage and boost strategic autonomy.

We have mapped the underlying interventions from these five themes on our updated interpretation of the energy trilemma to identify where the benefits of the trilemma are realized.

See next page for overview of sustainable interventions

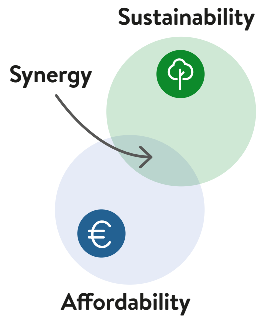
Suggestions for sustainable interventions with synergies

Theme	Interventions	Carbon reduction	Ecosystems	Security of supply	System robustness	Supply chain dependencies	Competitiveness	Affordability	Business models
		Sustain-ability		Security			Afforda-bility		
Complementing intermittency of renewable energy	Integrate production of green molecules (hydrogen) with green electrons	●		●	●			●	●
	Use EV's to make more demand flexible (delayed charging) and offer extra flexible supply (V2G)	●			●			●	●
	Give industries more flexibility to decarbonize (hybrid) and mitigate effects intermittency	●			●		●	●	●
Creating green demand	Create green demand through government interventions	●					●		●
	Accelerate the build-out of infrastructure to make green demand possible	●			●		●		●
Diversifying supply with (international) energy	Stimulate biogas installations for farmers	●	●	●	●	●			●
	Revitalize the market for offshore wind	●		●			●		●
Improving energy efficiency	Stimulate decarbonizing the residential built environment (insulation, heat pumps, heating)	●		●	●			●	●
	Promote large-scale use of electric (shared) cars	●		●	●			●	
Decarbonizing industry in a competitive way	Stimulate use of blue hydrogen as an intermediate step towards green hydrogen for industry	●					●		●
	Explore synergies at the level of industrial clusters (as is done in DIVIT programme)	●					●	●	●
	Create level playing field for industries to be able decarbonize competitively						●		●

● Intervention has a **positive effect** on system objective

These interventions can also be mapped according to the synergy (sustainability-security, sustainability-economic viability, etc.) they could realize. Below is a non-exhaustive list of interventions put forward by WEC members.

3.1.1 SUGGESTIONS FOR SUSTAINABLE INTERVENTIONS WITH ECONOMIC SYNERGIES



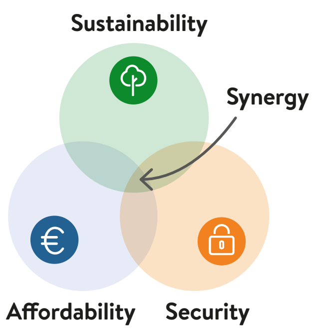
- **Create green and low-carbon demand through government interventions:** Without targeted support, demand for green and lowcarbon products may grow too slowly to justify major investments. The intervention is intended to accelerate green and low-carbon markets so that the energy intensive industry can invest in various available decarbonization routes. Policy options include acting as a launching customer, enforce a demand for green products through mandates or subsidies. This can also be initiated more concretely by first applying such demand creation via tailor-made arrangements in specific regional industrial clusters in the Netherlands, e.g. among Cluster 6 companies. Note that demand creation will only work if there is some form of market protection (such as CBAM).

- **Stimulate use of blue hydrogen as an intermediate step towards green hydrogen for industry:** High electricity prices, grid congestion, difficult-to-abate production processes make full electrification hard for the energy intensive industry. Moreover, the access to competitively priced green hydrogen is not expected to be available on the short term. The intervention is to stimulate the natural gas to blue hydrogen route as an interim solution that fits well with Dutch gas fields and infrastructure. Measures include SDE++ and hydrogen demand subsidies to help implement CCS and bridge the cost gap with natural gas. This could pave the way for upscaling (blue and later green) hydrogen markets and result in technological learning and economies of scale effects.

- **Create a level playing field for industries to be able to decarbonize competitively:** The competitiveness of Dutch industry is threatened by relatively high energy costs (including grid tariffs) compared to neighboring countries. The proposed intervention is to align support schemes across Europe. Concrete policies include a.o. an electricity costs compensation similar to Germany.[21]

- **Explore synergies at the level of industry clusters:** The five industry clusters represent concentrations of energy demand, which may enhance (and derisk) renewable energy production and infrastructure development. The intervention is to explore synergies at the level of industrial clusters. For instance, by clustering around flexible energy conversion facilities (CHP and electrolyzers), and funding shared heat networks, storage and feedstock exchange in industrial clusters. The cluster system analysis (CSA) foreseen in the DIVIT program can help to circumvent (capacity) bottlenecks and identify alternative and achievable decarbonization pathways.[22]

3.1.2 SUGGESTIONS FOR SUSTAINABLE INTERVENTIONS WITH SECURITY, AND ECONOMIC SYNERGIES



- **Integrate production of green molecules with green electrons:** Green hydrogen can in principle absorb surplus wind and solar, reduce net congestion, and support decarbonization of strategic industrial sectors, but production is currently not cost competitive. The intervention is to pair wind with electrolyzers to enable absorption of peak renewable output, to reduce curtailment. Electrolyzers would be placed at Maasvlakte, Eemshaven, Zeeland, etc., directly next to landing stations. This is actually already being planned for 2029 by Vattenfal. [23]

- **Increase the role of EVs as a flexibility resource:** Electric vehicles could support the grid by charging when power is cheap and feeding back when it is scarce, but fiscal and regulatory barriers hinder this. The intervention is to activate EVs structurally for smart charging and vehicletogrid. Measures include removing double taxation on bidirectional flows, setting standards for smart chargers, and introducing tariffs and certificates incentives that reward smart, flexible charging behavior.

- **Give industry more flexibility options to decarbonize:** Weatherdependent renewables increase system volatility, while industry prefers a steady energy supply. The intervention is to mobilize industrial flexibility via fuel-switching (hybrid systems) and dispatchable CHP rather than pure demand response. Examples include incentivizing hybrid electrification with gas backup, maintaining SDE++ support for hybrid solutions, and introducing capacity mechanisms that value dispatchable industrial generation.

- **Accelerate the build-out of infrastructure to make green and low-carbon demand possible:** Delayed grid expansion risks slowing industrial decarbonization and cluster development. The intervention is to allow strategic, anticipatory investments in electricity, hydrogen and CO_2 infrastructure. Policy measures include enabling grid operators to invest in sufficient grid capacity ahead of demand and allowed to absorb the associated risks.

- **Further stimulate biomethane installations for farmers:** Biogas can support energy security, cut emissions and provide new income for farmers while easing the nitrogen impasse. The intervention is to scale sustainable biogas in line with environmental limits.

- **Stimulate making the residential built environment more sustainable:** Home heating drives gas demand and leaves many lowincome households exposed to high energy bills. The intervention is to roll out (hybrid) heat pumps and basic efficiency measures while turning residential districts into small energy hubs. Policies include accelerated renovation program for social housing, targeted financing schemes for households.[24]

- **Promote large-scale use of electric (shared) cars:** Fossil-fuel based vehicles contribute to worldwide emissions whereas car usage weighs on household budgets. The intervention is to shift towards cleaner shared electric mobility where possible. EVs require higher upfront investment so interventions may be aimed at CAPEX subsidies, favorable loans and/or lease constructions.

- **Revitalize market for offshore wind production:** The recent Dutch offshore wind tenders for Nederwiek I-A failed to attract bids. A recalibrated tender design would allow for indexed CAPEX adjustments for steel and turbine components, prioritize grid access certainty and include minimum offtake guarantees from industrial clusters. Furthermore, a temporary CfD scheme for offshore wind (as is also in development in several other European countries) could help derisking investments and stabilize revenues.

3.2 HIGH-LEVEL TRADE-OFFS IN NL

The flipside of some of these interventions is that they come with trade-offs. Some of these trade-offs can very well be resolved in the medium and short term. We refer to those here as 'short-term trade-offs'. Trade-offs of sustainable interventions that cannot be fully resolved have to be (partially) mitigated or adapted. We call those 'long-term trade-offs'. For the long-term trade-offs, we over several possible adaptation/mitigation interventions.

SHORT-TERM TRADE-OFFS

- **Grid congestion:** Further decarbonizing our electricity system – i.e. by producing more offshore wind and solar energy and on the demand side by rapidly electrifying consumption – will exacerbate existing net congestion. This slows the transition since energy intensive industries need green electrons to (partially) decarbonize.

- **Cost pressures:** High energy costs compared to neighboring countries (i.e. Germany, Belgium), makes is difficult for Dutch industry to stay competitive. Energy Intensive Industry faces the most acute exposure to energy cost gaps with the US and China, but the pressure is systemic: renewable buildout, hydrogen production, and electrification all require significant upfront CAPEX, while public tolerance for rising prices remains limited.

- **Increased risks in security of supply:** Some of the interventions mentioned here promote low-carbon molecules (blue hydrogen, natural gas) as an intermediary step towards green hydrogen. Although this will be beneficial in the long run, in the short to medium term, it can keep us dependent on fossil fuels.

LONG-TERM TRADE-OFFS

Reduction of supply chain security:

- **Implement EU-mandated measures to reduce dependency on critical raw materials (CRM):** CComplying with European frameworks such as the Net-zero Industry Act, Critial Raw Materials Act, and the upcoming Circular Economy act will, over time, reduce dependencies and strengthen supply-chain resilience. However, it must be accepted that these risks can only be managed over a longer horizon and full, timely implementation by Member States is essential. At the same time, some degree of CRM dependency will remain unavoidable in the foreseeable future, as reducing it requires substantial investment, industrial scaling, technological progress, time, and not least physical access to raw materials.

- **Support technologies with lower critical raw material intensity:** Investing in next generation electrolyzers and battery chemistries reduces reliance on scarce materials such as iridium, platinum, or cobalt. These technologies can significantly improve the sustainability and resilience of future energy systems. Early public support accelerates innovation cycles and helps domestic industry adopt more secure production pathways. Lower CRM intensity also helps avoid price spikes driven by global scarcity or political disruptions. Over time, these advances increase competitiveness and reduce systemic dependency on vulnerable supply chains.

- **Accelerate circularity and recycling capacity:** By increasing recycling rates, dependence on CRM can be reduced, though only to a limited extent in the short term. The problem is that existing capacities and technologies take time to reach meaningful scale. This process can be accelerated through targeted investments in technologies that boost circularity, improved circular product design and the expansion of recycling infrastructure. Still, even with ambitious circularity efforts, full independence from CRMs is neither achievable nor cost-effective in the near term. Therefore, a certain level of dependency must therefore be accepted and managed through diversification, circularity, and strategic reserves rather than assumed to be fully removable.

Effects on ecosystems:

- **Standardize ecological and circularity criteria in offshore wind tenders:** European offshore wind tenders currently differ significantly between countries, with each North Sea state applying its own ecological, circularity and CSR-related requirements. This results in wide variations in ambition and creates an uneven playing field for developers. The Netherlands is one of the frontrunners: ecological, circularity and CSR criteria already play a substantial role in Dutch offshore wind tenders. Harmonizing such criteria at the European level would increase consistency, comparability, and predictability for developers and suppliers. Standardization would also accelerate the EU's circularity ambitions by incentivizing innovation in circularity.

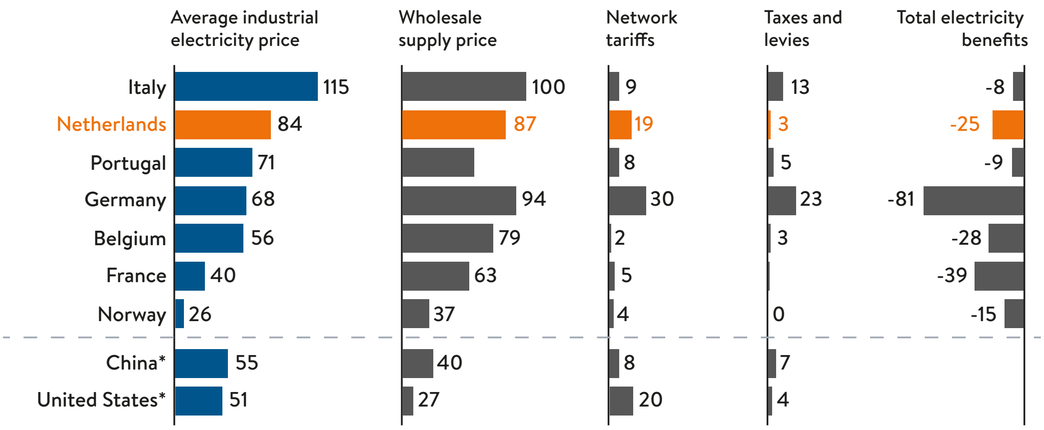
BOX 4: DUTCH STRENGTHS AND WEAKNESSES IN THE ENERGY TRANSITION

The Netherlands has several key strengths and weaknesses in the energy transition. A first key strength is our traditionally strong logistical position at the North Sea (prerequisite for offshore wind) in the delta of Northwest Europe which has historically positioned the Netherlands as a transit country. This transit function is illustrated by the key ports and large import and export volumes of energy. Second, thanks to the discovery of the Groninger gas field, the Netherlands has a relatively large energy intensive / foundational industry (i.e. larger than in Spain, Poland or France), a finely meshed gas infrastructure, and empty gas fields which could be used for CCS.

The Dutch energy system has two vulnerabilities in its energy system which – taken together – make it difficult to decarbonize our energy system. First, net congestion slows down electrification. This is further exacerbated by relatively high electricity prices compared to European peers (as shown below). Second, the Netherlands is highly dependent on fossil energy for other countries – net imports making up 89% of its total energy supply. This exposes the Netherlands to geopolitical risks which is effectively a value driver and accelerator for the energy transition rather than a weakness. The combined effect makes it challenging for Dutch energy intensive industries to rapidly decarbonize.

The Netherlands has high industrial electricity prices compared to the rest of the world

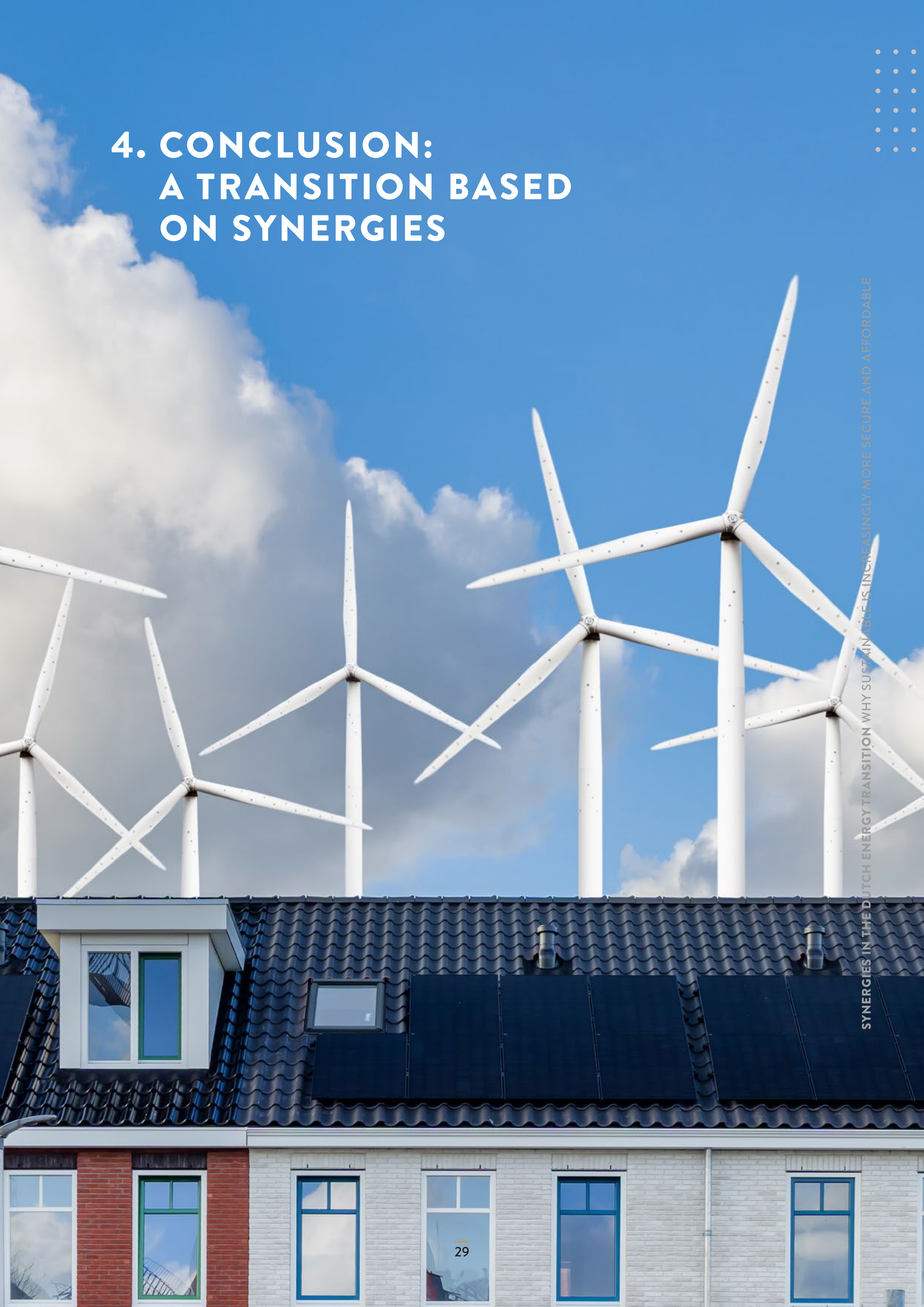
In euro's (€) per megawatt-hour (MWh)



*Average electricity price in the cheapest state/province, excluding benefits.

Source: Wennink Report (2025)

4. CONCLUSION: A TRANSITION BASED ON SYNERGIES



In the introduction, we described how a changing context has cast clouds on the need for and speed of the energy transition. IIn the sunshine period, the EU had started to make its energy system more sustainable – which became the focus after the Paris agreements. However, a changing geopolitical landscape, concerns about the European and Dutch economy, and the systemic change taking place in the energy system made it increasingly difficult to balance sustainability with the other demands of the energy system.

In this report, we suggest a new perspective that puts the transition into a new light. We show that the traditional energy trilemma, where sustainability is a trade-off with (the fossil monopoly of) affordability and security is becoming less applicable to Europe. Instead, an overlap is emerging in which these three poles start reinforcing each other. This reinforcement is getting stronger as security (and therefore cost) of fossil energy decreases with geopolitical uncertainty, whilst the value of strategic autonomy becomes part of the societal business case.

From this new perspective, we deduce four general lessons in confronting the years ahead:

Firstly, this perspective offers a new way to discuss the energy transition. Because the case for transition is no longer exclusively driven by climate change ambitions, this perspective can enable and facilitate better and more constructive societal dialogues. It helps bring together different coalitions behind the energy transition, each with their own narrative.

The second lesson is to focus on synergies when making the energy system more sustainable. Interventions that serve all three poles of the trilemma provide a much stronger societal business case compared to those that serve sustainability only. We have made an initial attempt at identifying some of the synergies of the transition. Follow-up work can apply this perspective more rigorously and answer the 'how' questions which we have not done here.

A third lesson is that interventions with synergies can also impose pressure on the energy system. Recognizing these early, assessing them transparently, and putting mitigation and adaptation measures in place strengthens both the credibility and feasibility of the transition. By systematically managing risks and externalities, policy makers can ensure that synergies are realized without undermining societal acceptance or long-term system resilience.

A fourth lesson is that by making private and public costs and benefits explicit, discussions and ultimately design of policies can be held more fruitfully. Establishing what the private costs and benefits of a project are is complex given the longevity, the scale, and often newness of the project. But if certain associated public costs and benefits are taken in the comprehensive picture, discussions about allocating risks and rewards are become clearer, and motivations for potential tax-payers contributions become more evident. And possibly, the total 'business cases' might become more positive.

5. APPENDICES

APPENDIX A: CASE STUDIES

A.1 CASE STUDY 1 — OFFSHORE WIND

CONTEXT AND CURRENT STATE

Offshore wind is the backbone of Western Europe's electrification push and intended as the anchor for largescale electrification of industry. Electricity from offshore wind displaces fossil-fueled energy generation, reduces exposure to imported fuels, and underpins power-to-X routes such as renewable hydrogen. Upscaling is therefore a climate, competitiveness, and autonomy imperative.

In the Dutch context, the North Sea has the potential to function as both a resource and strategic asset, enabling a shift toward autonomy by coupling abundant electricity generation with coastal industrial clusters and green hydrogen production.

In terms of realization, across the EU, implementation lags behind. Roughly 37 GW of offshore wind are installed today against a 120 GW 2030 ambition. In the Netherlands, policy remains tender driven with a 21 GW goal for 2032 and a 30–40 GW target window for 2040.

While there is strong political backing to support the roll-out of offshore wind across the EU, lagging growth in electricity demand, in combination with rising costs, has slowed down offshore development. Electrification appetite in heavy industry is low, due to relatively high electricity prices compared to gas and energy prices in neighboring countries. In addition, regulatory uncertainty impacts the interest in electrification investments. Limited grid capacity with long waiting lists for grid connections further slows down electrification. After the failed offshore wind tender in 2025, the Dutch government will subsidize two tenders in 2026 with a temporary subsidy scheme followed by a CfD-scheme in 2027. Social acceptance is generally high, especially compared to onshore renewables.

WIN-WINS

Interestingly, the narrative around development of renewables has shifted. Earlier, climate change made it imperative to stimulate renewables development, whereas now strategic autonomy and competitiveness have fueled renewable development.

In the short term, pairing wind build out with nearby electrolyzers potentially creates a flexible sink for surplus power and may relieve bottlenecks at now constrained coastal electricity grid nodes, while initial hydrogen offtake from industrial clusters reduces curtailment risk and stabilizes cash flows.

Over the longer term, the same configuration may mature into a deeply integrated system where offshore wind anchors large scale hydrogen production, industrial electrification provides stable demand, and meshed offshore grids and interconnectors enhance balancing across the North Sea, strengthening security of supply and system affordability simultaneously.

TRADE-OFFS

In the short term, grid congestion at landing points, OEM cost inflation and fragile supply chains hamper the bankability and project viability for new projects. One of the key challenges is that costs are pushed up by high interest rates, inflation, supply chain bottlenecks, long permitting times, higher prices of steel etc. This is one of the reason why many recent tenders have failed (not just in The Netherlands but also in Denmark and Germany). Current tenders do not match the current market conditions. Even projects with CfDs (like Oersted's Hornsea 4) are halted because of the long lead times for such projects meaning that project costs can increase tremendously from the time an auction has been won to the time that all contracts have been signed.

Another crucial factor that is slowing down offshore deployment is the absence of industrial demand for green electricity. This demand is growing at a much slower pace than anticipated by law makers due to the perfect storm we're currently in: high energy prices and cheap imports from e.g. China on a range of products, from chemicals to cars. De-industrialization and pressure on profits leads to this lag of demand growth.

In the long term, dependencies on critical raw materials and non-EU components may persist unless circularity and EU manufacturing capabilities scale, and curtailment risks can reemerge if demand growth or grid reinforcements lag sustained buildout.

RECOMMENDATIONS

A successful offshore wind strategy requires moving beyond capacity targets toward better orchestration of generation, infrastructure, and demand. This is critical because offshore wind offers several win-wins — potentially lower system costs, increased security of energy supply, and a foundation for green hydrogen production — but only if key constraints are addressed.

First, recalibrating tenders to current market conditions helps mitigate short-term trade-offs such as cost inflation, supply-chain fragility, and grid bottlenecks. By linking tender criteria to locational feasibility, industrial offtake readiness, and realistic cost assumptions, the Netherlands can stabilise investment conditions and prevent the mismatch between ambitions and developer capacity.

Second, co-locating electrolyzers near landing points and industrial clusters – or at sea, close to the production of electricity – enables one of the clearest system synergies: offshore wind's intermittency becomes an asset rather than a barrier. Electrolyzers can absorb high-wind, low-price hours, reducing curtailment and relieving pressure on coastal nodes. This strengthens affordability (by lowering system integration costs) and enhances reliability (by providing flexible demand).

Finally, deeper integration with meshed offshore and cross-border grids strengthens long-term autonomy. Shared balancing capacity reduces volatility, increases utilization of wind assets, and helps manage the trade-offs associated with weather-dependent generation.
The Tables below provide more elaborate insights into potential system synergies as well as into the trade-offs to be carefully navigated.

POTENTIAL ENERGY TRILEMMA CONTRIBUTIONS (SHORT TERM VS LONG TERM)

Trilemma Goal	Positive Contributions	Negative Contributions / Pressures
Sustainability	**Short term:** Rapid buildout delivers immediate emissions reductions; supports early industrial electrification; enables first hydrogen pilots through dedicated offshore connections. **Long term:** Becomes the backbone of a net-zero power system; enables deep industrial decarbonization.	**Short term:** Construction impacts and ecological pressures intensify as spatial constraints tighten; increased material demand for turbines and subsea cables. **Long term:** Higher cumulative potential ecological pressure offshore (there are also proven ecological benefits); longlife CRM dependencies persist unless circularity is fully established.
Affordability / Competitiveness	**Short term:** LCOE not falling as expected due to market circumstances; PPAs can stabilize industrial power costs; integrated planning with clusters reduces curtailment risks. **Long term:** Lower LCOE and systemwide costs through upscaling and better project management (e.g. due to the 15GW annual tender promise); hydrogencoupling reduces peak prices and improves system balancing; supports competitive Dutch industrial hubs. Cost competitiveness vs fossil fuels likely to continue to improve due to geopolitics.	**Short term:** High CAPEX, supply chain inflation, and OEM fragility raise costs; curtailment risk if grid/demand lags. **Long term:** Overbuild without sufficient demand or grid capacity raises total system costs; CRM prices and supply-chain concentration may sustain structural cost pressures.
Security of Supply / Autonomy	**Short term:** Reduces fossil fuel imports; expands domestic renewable base; supports cross border grid integration. **Long term:** Anchors structural energy autonomy; supports hydrogen for storage and resilience; enables diversified cross North Sea energy flows.	**Short term:** Grid bottlenecks limit usable output; dependence on non-EU turbine components persists. **Long term:** Continued exposure to CRM markets; weather dependent generation requires strong balancing assets.

POSSIBLE CROSS-CASE SYNERGIES

<table>
<tr><th colspan="2">Key questions</th><th>Affordability/ economics</th><th>Sustainability / transition</th><th>Security/ autonomy</th></tr>
<tr><td rowspan="3">How can offshore wind help other components?</td><td>Green hydrogen</td><td colspan="3">Offshore wind potentially provides affordable and locally produced green electricity. This may increase our energy independence as it reduces the need for imported gas or hydrogen products. The increased amounts will also increase the appetite for investing in hydrogen production in the Netherlands. Furthermore, linking wind assets with electrolyzers near industrial clusters can enhance system integration and enable decarbonization and electrification of industry.</td></tr>
<tr><td>EV infrastructure</td><td colspan="3">Furthermore, deployment of offshore wind potentially reduces exposure to imported fossil fuels for mobility.</td></tr>
<tr><td>Energy intensive industries</td><td colspan="3">Offshore wind can provide Dutch energy intensive industries access to secure locally produced green electricity and (in the long term) renewable hydrogen. This is an important prerequisite for the electrification of industry. This will help reduce emissions and at the same time increase security of energy supply. Note that imports (en exports) will remain important for the foreseeable future. As the European industry is unlikely to be competitive in a fossil-based system due to high prices and limited regional assets, it also offers opportunities for increased competitiveness.</td></tr>
<tr><td rowspan="3">How can other components help offshore wind</td><td>Green hydrogen</td><td colspan="3">The flexibility that green hydrogen offers may buffer intermittent wind energy production.</td></tr>
<tr><td>EV infrastructure</td><td colspan="3"></td></tr>
<tr><td>Energy intensive industries</td><td colspan="3">Rapid electrification of energy intensive industries is likely to increase the demand for offshore wind production. Increased demand will improve long-term security of investment, which will boost the roll-out of offshore wind.</td></tr>
</table>

A.2 CASE STUDY 2 — ENERGY INTENSIVE INDUSTRY (EII)

CONTEXT AND CURRENT STATE

Over the past fifty years, the Netherlands has developed into a country with a strong and highly integrated industrial base, closely connected with our neighboring countries. This position is owed to our strategic location on the North Sea coast, the excellent connections via the Rhine delta, and relatively low energy costs (based on natural gas) for decades. Strong supply chain integration and the hub role (large volumes passing through the Netherlands) have also contributed to our competitive position compared to other regions.

Maintaining an industrial base is of great importance for the Netherlands; not only does it contribute to strategic autonomy and security of supply for essential products such as steel, fuels (including aviation fuel for NATO), and chemical products, but it also reinforces our economic ties with Germany. Dutch industry players provide synergy through strong interrelation within industrial clusters, both nationally and internationally (i.e. ARRRA cluster). In addition, the industry provides high-quality jobs, both directly and in related technology and service sectors.

To comply with EU and national climate targets, the Dutch industry needs to reduce its emissions. What is the most affordable decarbonization option is highly sector specific. Heavy industries (steel, chemicals, refining) are seeking low-carbon energy to meet sustainability pledges and future regulations. E.g. steelmakers in Europe plan to use green hydrogen (from wind power) instead of coal.

Which decarbonization route is most fitting for each of these sectors is still to be determined. But it seems clear that a broad pallet of renewable and low carbon energy sources and associated infrastructures is necessary. Focus on electrification of low-temperature heat demand with hybrid systems where necessary. Complemented by CCS to decarbonize the largest emitters in a cost-effective way. And further supplemented by centrally produced low-carbon hydrogen to decarbonize high-temperature heat demand within and outside the five industrial clusters.

Policy frameworks exist across EU and national levels, stimulating numerous routes, and a hydrogen backbone is planned; nevertheless, high energy prices, grid constraints, and policy discontinuities complicate execution, and electrolysis ambitions for 2035 are not yet backed by instruments that can reliably deliver gigawatt scale coastal assets with synchronized offtake of green electrons or molecules.

WIN-WINS

In the short term, CCS may enable immediate carbon abatements in processes where alternatives are not yet mature, keeping facilities viable while new technologies scale. At the same time, early hydrogen substitution and hybrid electrification can reduce fossil use and improve resilience to price volatility.

Over the long term, stable industrial demand for green electricity or molecules underpins efficient utilization of offshore wind and hydrogen assets, drives down unit costs through scale, and supports a competitive domestic base producing low carbon materials for European markets.

TRADE-OFFS

In the short term, exposure to electricity, and overall energy, price differentials versus global peers threatens competitiveness. Moreover, public acceptance concerns around CCS and blue hydrogen must be managed carefully.

In the long term, technological lock in becomes a salient risk if CCS would stand in the way of structural process change. Also, a reliance on imported molecules or feedstocks could persist if domestic pathways scale too slowly.

RECOMMENDATIONS

Industrial decarbonization is central to the Netherlands' economic resilience and energy system performance. However, high energy prices, grid congestion, and uncertainty around future infrastructure create significant trade-offs that must be managed deliberately.

First, protecting competitiveness while decarbonizing, through targeted compensation, predictable carbon pricing, and alignment with EU peers, can limit relocation risks and keep demand for renewable electrons and molecules in the Netherlands. In parallel, explicit demand-creation mechanisms are needed to accelerate lead markets for low-carbon materials (e.g., product standards, green public procurement, quotas/mandates, and carbon contracts for difference) and to close the cost gap with conventional products. Stable industrial demand is essential to realize system synergies in offshore wind and hydrogen, where scale drives down unit costs.

Second, a cluster-based planning approach allows electrification, hydrogen use, and CCS deployment to proceed in a coordinated way. This sequencing reduces "chicken-and-egg" dynamics, ensuring that grid reinforcement, hydrogen backbone rollout, and CO_2 transport/storage infrastructure materialize where and when industry needs them.

Third, using a pragmatic technology portfolio mitigates short-term trade-offs. CCS offers immediate emissions reductions where alternatives are immature; hybrid electrification reduces gas dependency without overwhelming the grid; and blue hydrogen provides a transitional molecule until green hydrogen matures at scale. This balanced approach maintains production capacity while steering the system toward its long-term synergies.

Where individual subsectors remain structurally uncompetitive, even with mitigation, selective downsizing and portfolio reorientation toward low carbon value chains can help protect the overall system's resilience.

The Tables below provide more elaborate insights into potential system synergies as well as into the trade-offs to be carefully navigated.

POTENTIAL ENERGY TRILEMMA CONTRIBUTIONS (SHORT TERM VS LONG TERM)

Trilemma Goal	Positive Contributions	Negative Contributions / Pressures
Sustainability	**Short term:** CCS enables immediate, large emissions cuts; hybrid electrification reduces gas demand; early blue hydrogen substitution for key processes. **Long term:** Deep electrification and greenhydrogen uptake achieve structural decarbonization; circularity and lowcarbon feedstocks reshape industrial value chains.	**Short term:** Blue hydrogen involves methane leakage and CO_2 storage acceptance challenges. Hydrogen and CCS are still costly solutions. **Long term:** Some process emissions remain difficult to tackle; CCS dependence may risk technological lockin if alternatives scale slowly.
Affordability / Competitiveness	**Short term:** Clusters anchor early hydrogen and CO_2 infrastructure, reducing unit costs; temporary compensation instruments stabilize competitiveness. **Long term:** Modernized lowcarbon industry improves resilience; stable demand supports efficient RES and H_2 utilization and lowers system costs.	**Short term:** High electricity prices vs global peers threaten competitiveness; investment cycles strained by policy uncertainty. **Long term:** If energycost gaps persist, structural relocation becomes a risk; high CAPEX for full decarbonization may accumulate into a systemic cost burden.
Security of Supply / Autonomy	**Short term:** Maintaining domestic industrial capacity preserves strategic EU value chains; early hydrogen backbone enhances system optionality. **Long term:** Decarbonized clusters support European autonomy in chemicals, steel, fuels, and materials.	**Short term:** Electrification adds stress to congested grids; reliance on imported hydrogen or feedstocks may rise during transition. **Long term:** Continued dependency on imports for key molecules or feedstocks remains if domestic pathways scale too slowly.

POSSIBLE CROSS-CASE SYNERGIES

Key questions		Affordability/ economics	Sustainability / transition	Security/ autonomy
How can EII help other components?	Green hydrogen	Energy-intensive industries play a crucial role in enabling the business cases for electrolysis and offshore wind development. Their large and continuous demand for clean energy and green hydrogen provides the stable offtake needed to support investment in large-scale electrolyzer projects and offshore wind farms.		
	EV infrastructure	No direct synergies		
	Offshore Wind	Energy intensive industry requires several processes to decarbonize and electrify. This creates a considerable volume of renewable electricity demand, supporting the investment case for offshore wind. A key enabling component is demand flexibility in industry where feasible, complemented by other flexibility mechanisms such as through electrolysis, batteries, and (dispatch) power.		
How can other components help EII	Green hydrogen	Green hydrogen is, next to blue hydrogen, a critical solution for existing and future decarbonized hydrogen demand in the energy intensive industry and other sectors (mobility, power generation). By placing electrolyzers in the right locations, they can contribute to system flexibility and prevent grid congestion and curtailment of renewables.		
	EV infrastructure	If EV infrastructure can enable flexible charging (i.e. closely matching variable supply of renewables), it can contribute to system flexibility and help prevent grid congestion. This benefits all electricity consumers, including (indirectly) the energy intensive industry.		
	Offshore Wind	The North Sea offers extraordinary opportunities for the Netherlands and Northwest Europe as a major hub for renewable electricity and green hydrogen production. With its vast offshore wind potential, the region can play a crucial role in delivering the clean energy needed to decarbonize key sectors, particularly industrial energy demand. Harnessing the North Sea's resources is essential for achieving a resilient, climate-neutral energy system and strengthening Europe's long-term energy security.		

A.3 CASE STUDY 3 — E MOBILITY[25]

CONTEXT AND CURRENT STATE

Electricity is widely seen as the most favorable energy carrier for transport. Electric drivetrains convert 70–90% of energy into motion, whereas combustion engines convert only 20–30%. This massive efficiency difference reduces overall energy demand for mobility systems and lowers system costs over time, if switching to e-mobility. The pace of changes and the amount of innovation taking place is extremely high. While the start has taken place in passenger transport, new applications like vans, trucks and construction equipment is following. Additionally inland shipping has taken an increasing role in decarbonization of transport, with commercial deployment of sully electric vessels already in place in the Netherlands in 2025 while a lot of innovation is taking place.

Globally and at EU level, transport accounts for roughly 30% of total energy demand. The Netherlands is an exception because the Port of Rotterdam is a major international bunkering hub (supplying fuel to ships and aircraft). A substantial part of the transport fuel sold in the Netherlands is therefore used on international routes outside Dutch territory. When this ‘exported’ bunker fuel is excluded from the national breakdown, transport accounts for only about 21% of Dutch energy demand. The difference is largely explained by this bunkering role.

Current levels of EV are still very modest compared to the total mobility fleet. However, Norway has already shown that with the right policies in place, a very fast uptake is feasible with at the end of 2025 EV share is close to 100% of total new car sales. Globally it is also clear that EV’s dominance has increased, particularly in emerging economies, with a global share of 25% of new sales in 2025.

Electrification has many additional advantages compared to burning (fossil) fuels. Failure to move towards electrified mobility could therefore have a series of negative consequences for the EU and its member states. First, continuing burning fossil fuels will make it much more difficult to reach the climate targets for 2030, 2040 and to turn net zero in 2050. Costs of moving towards net zero will also increase, compared to taking action now. Second, improvements in air quality will take more time to achieve. Hence, this might lead to higher health care costs and loss of labor potential due to illnesses. Thirdly, importing fossil fuels costs hundreds of billions annually. Large-scale electrification could therefore significantly reduce the cash outflow that can be used for better purposes within Europe.

With respect to policy ambitions, the EU aims to drastically reduce emissions from car transport, leading to net zero in 2050. In 2030 at least 30 million EVs should be on the road with sufficient charging stations. EU ETS 2, which covers transport, is expected support the uptake of EVs. RED III has introduced a binding target of at least 29% renewable energy in transport in 2030. The introduction of a certificate system will support the business case of EV charging. All in all, there are many policies in place to support electrification of transport in the EU.

The Dutch government has set targets to accelerate the shift to zero-emission vehicles, including the ambition that all new passenger cars sold should be emission-free by 2030. Although this target has been declared non-binding, current uptake suggests the Netherlands is broadly on track for its. From 1 January 2026, the Netherlands will implement the new EU-aligned certificate system for renewable and low-carbon transport fuels.

WIN-WINS

A larger share of e-mobility can potentially reduce energy import needs by substituting domestically generated electricity for fossil fuels. When combined with smart/bidirectional charging, EVs can shift electricity demand to off peak periods, absorb wind/solar surpluses, and lower energy system costs by avoiding some grid reinforcement. Extending electrification beyond passenger cars, e.g. to vans, trucks, construction equipment, and inland shipping, may extend these benefits into logistics and port ecosystems where the Netherlands has international leverage.

Over the longer term, widespread smart and bidirectional charging might transform millions of vehicles into a stability resource that could reduce peak demand, reduce the need for grid reinforcements, and deepen the integration with offshore wind and logistics ecosystems, including ports and inland shipping.

TRADE-OFFS

Rapid EV uptake can increase grid stress where local electricity capacity is constrained. Moreover, the increased demand for batteries introduces CRM dependencies and there is the challenge of mobilizing resources for infrastructure CAPEX.

Over time, electrifying heavy-duty transport (trucks, logistics fleets and related charging hubs) will likely require substantial upgrades to the electricity grid and charging infrastructure.

RECOMMENDATIONS

E-mobility has the potential to become one of the most powerful enablers of system synergies in the Dutch energy transition. By shifting transport energy demand to domestically produced electricity and by activating EVs as a distributed flexibility resource, e-mobility can contribute simultaneously to affordability, sustainability, and strategic autonomy. Yet these win-wins will only materialize if infrastructure expansion, flexibility activation, and heavy-duty electrification are carefully sequenced and aligned with developments in the broader energy system.

First, charging infrastructure must be deployed in a way that strengthens the wider energy system rather than adding to its pressures. Prioritizing high-power charging in areas with strong renewable supply and sufficient grid headroom - especially coastal regions and logistics hubs- helps absorb surplus offshore wind and solar generation. This could reduce curtailment, ease local congestion, and enhance overall system efficiency. Integrated planning between municipalities, DSOs/TSOs, and charge point operators is essential to avoid reinforcing bottlenecks and to anchor charging infrastructure where it creates positive spillovers.

Second, EVs must be activated structurally as a flexibility resource. Smart and bidirectional charging can transform millions of vehicles into a distributed buffer capable of absorbing energy during periods of surplus and supplying the grid during stress moments. Rewarding this behavior through tariff structures and the new certificate system turns EV flexibility into a durable asset that lowers system costs, reduces the need for grid reinforcements, and ensures more efficient utilization of renewable electricity.

Third, electrification of heavy-duty transport should follow a targeted and system-aware strategy. Freight corridors, logistics hubs, and inland shipping terminals offer the greatest opportunities for emissions reductions and system benefits. Strategic corridor-based planning helps concentrate investments where electrification delivers the strongest synergies. Where grid constraints persist, hydrogen-based solutions might complement electrification and help maintain decarbonization momentum without overloading vulnerable nodes.

Finally, long-term competitiveness and autonomy require proactive management of battery supply-chain risks. Strengthening domestic recycling capacity, speeding up second-life applications, and cooperating in EU-level CRM initiatives lowers exposure to volatile global battery markets. This mitigates one of the main trade-offs of e-mobility and reinforces Europe's strategic autonomy as transport electrification accelerates.

Taken together, these steps allow e-mobility to become not only a decarbonization lever, but a systemic stabilizer that enhances affordability, resilience, and strategic autonomy across the energy system.

The Tables below provide more elaborate insights into potential system synergies as well as into the trade-offs to be carefully navigated.

POTENTIAL ENERGY TRILEMMA CONTRIBUTIONS (SHORTTERM VS LONGTERM)

Trilemma Goal	Positive Contributions	Negative Contributions / Pressures
Sustainability	**Short term:** Immediate tailpipe emission reductions; rapid uptake supported by existing grid headroom in some regions. **Long term:** Systemwide emissions fall strongly as heavyduty, logistics, and inland shipping electrify; recycling and circularity improve lifecycle sustainability.	**Short term:** Battery production involves considerable upstream emissions. **Long term:** Environmental footprint depends on advances in recycling, secondlife systems, and global batterymaterial practices.
Affordability / Competitiveness	**Short term:** Smart charging unlocks early flexibility value; certificates from 2026 improve charging business cases; EVs reduce fuelcost exposure. **Long term:** Large EV fleets provide major flexibility to reduce gridreinforcement costs and integrate offshore wind; declining battery costs improve access.	**Short term:** Local grid congestion drives costly upgrades; rapid charging rollout requires high upfront CAPEX. **Long term:** Heavyduty electrification may demand major infrastructure; CRM price volatility affects longterm affordability unless mitigated by circularity.
Security of Supply / Autonomy	**Shortterm:** Reduced oil dependence increases resilience; **Long term:** Greater autonomy as transport energy shifts to domestically produced electricity; EV fleets act as distributed balancing resources. EVs may improve system stability through V1G/V2G services.	**Short term:** Strong dependency on imported batteries and materials; infrastructure delays may create local supplysecurity vulnerabilities. **Long term:** Continued exposure to global batterymaterial markets unless EU manufacturing and recycling scale significantly.

POSSIBLE CROSS-CASE SYNERGIES

Key questions		Affordability/ economics	Sustainability / transition	Security/ autonomy
How can e-mobility help other components?	Green hydrogen	No direct link with E-Mobility.		
	Offshore Wind	E-mobility is expected to lead to the replacement of a large amount of fossil energy use in transport by electricity. This can lead to a stronger demand for electricity that preferably should be green, and therefore produced from wind or solar energy (in NL). Therefore it may support the offshore wind business case. In addition, it massively improves security and autonomy because the energy is produced and consumed domestically. In terms of sustainability it also offers a benefit as long as the electricity used to fuel cars (and to build them) is green. In any case, the e-mobility has the potential to be much more energy efficient than ICE-cars. Additionally, EV's role in the power system is expected to grow in volume and scope. EV and its charging sessions are flexible, hence might offer new flex options to the power system.		
	Energy intensive industries	No direct link with E-Mobility.		
How can other components help e-mobility	Green hydrogen	No direct link with E-Mobility.		
	Offshore Wind	Further roll-out and deployment of offshore wind, will make EV more attractive when more periods of low or negative prices occur. Energy costs will drop and earning potential by supplying flexibility will increase. Note that if this occurs too often, it will also slow down the roll-out of renewable energy if it isn't profitable.		
	Energy intensive industries	No direct link with E-Mobility.		

A.4 CASE STUDY 4 — GREEN HYDROGEN

CONTEXT AND CURRENT STATE

Hydrogen is central to decarbonizing hard-to-abate sectors such as refining, chemicals, steel, and heavy transport. In that sense, hydrogen may become a key pillar for industrial decarbonization. A successful implementation of hydrogen use means reliable, large-scale production of green hydrogen through integration with renewable power (offshore wind), and the replacement of grey hydrogen in industrial processes. Failure to expand green hydrogen production would mean continued reliance on fossil-based hydrogen or fossil fuels, to a large extent, potentially missing EU and Dutch climate targets, and losing industrial competitiveness as other regions accelerate their hydrogen and/or electrified economies.

EU hydrogen targets are ambitious, with the Fit for 55 package and Renewable Energy Directive (RED III) setting binding targets for renewable hydrogen in industry and transport. The EU Hydrogen Strategy aims for 10 million tonnes of domestic renewable hydrogen production by 2030. For the Netherlands, a target of 4 GW of electrolyzer capacity has been set for 2030. IPCEI and SDE++ subsidy scheme supports renewable hydrogen projects. RED III mandates are supposed to stimulate demand.

In terms of realization, several large-scale projects are under construction across Europe, but overall deployment lags behind targets. Market share of renewable hydrogen remains low and the development and upscaling of the required technology has been less than expected. In The Netherlands, flagship projects like Holland Hydrogen 1 (200 MW; up to 60 t/day) are steadily progressing. Nevertheless, broader scale up depends on grid connections, permitting, stable and supportive policies, and not least costs. The business case needs to make sense to make projects bankable. A persistent bottleneck is demand certainty in industry (refining, chemicals, steel) to underpin investment decisions and pipeline/storage build out.

WIN-WINS

In the short term, blue hydrogen can replace grey in refining and chemicals. This may pave subsequently pave the way for green hydrogen, given the right incentives are in place.

Over the long term, hydrogen may become a backbone of system integration: it can enable the incorporation of large additional offshore wind capacities, up to the levels contemplated in Dutch and regional scenarios, while serving as feedstock in hard to abate processes.

TRADE-OFFS

In the short term, green electrons required for electrolysis may be in scarce supply. If that happens, part of the power may come from fossil-based electricity generation, which reduces the climate benefit of “green” hydrogen. In addition, some electrolyzer technologies (notably PEM) rely on platinum-group metals and other critical raw materials, creating new supply-chain dependencies.

In the long term, utilization risk emerges if backbone availability and offtake do not scale-up in step, while import dependence can shift strategic exposure from fossil fuels to green molecule suppliers and equipment manufacturers.

RECOMMENDATIONS

Hydrogen can become one of the strongest enablers of system synergies in the Dutch energy transition. It could support hard-to-abate processes, enable large additional offshore wind capacity, and offer long-duration storage that enhances resilience. To realize these win-wins, while avoiding high-cost lock-in and strategic dependencies, several coordinated steps are needed.

First, the build-out of electrolyzers, the hydrogen backbone, and industrial demand for green hydrogen must be planned and delivered in step. If production capacity comes online before the backbone and long-term offtake are in place, electrolyzers may run at low load factors, thereby increasing electricity demand during peak hours and raising the cost per kilogram of hydrogen. These offtake contracts will only scale if policy also creates green hydrogen demand (for example through quotas/mandates, carbon contracts for difference, and clear product standards that reward low-carbon production and help bridge the cost gap with grey hydrogen). If the timing and location are right, however, electrolyzers can mainly operate when renewable power is abundant and prices are low. This reduces curtailment, helps relieve congestion at coastal grid nodes, and provides a stable demand anchor for offshore wind.

Second, the Netherlands must enable the development of several large coastal electrolyzers. These early assets are critical to achieving economies of scale and proving integrated system configurations. Their presence would help stabilize early hydrogen markets, lower the long-term cost of green molecules, and provide confidence to both industrial buyers, infrastructure operators, and financiers. This is a clear example of a synergy: coordinated early investments reduce total system costs and accelerate the maturation of a market that supports both sustainability and competitiveness.

Third, the hydrogen strategy should explicitly strengthen the innovation pipeline for second- and third-generation electrolysis technologies. Today's PEM and alkaline systems are limited by material intensity (scarce catalysts and membranes), high CAPEX, and performance drops under variable operation. Investing in advanced concepts - such as high-temperature electrolysis, next-generation PEM with reduced critical raw material content, and novel solid-state designs - can significantly improve efficiency, reduce electricity consumption, ease CRM dependencies, and lower the material bill. Scaling these technologies through R&D programs, pilot deployments, and commercial demonstration creates long-term win-wins: lower cost trajectories, improved system efficiency, and reduced geopolitical exposure.

Fourth, strategic dependencies must be managed deliberately. Even with advanced technologies, the Netherlands will need diversified import routes for hydrogen carriers and a domestic recycling and manufacturing base that limits exposure to concentrated supply chains for catalysts, membranes, and balance-of-plant components. This is essential to prevent the shift from fossil-fuel dependency to dependency on green-molecule suppliers or non-EU equipment manufacturers.

Taken together, these recommendations would help hydrogen fulfil its systemic role: enabling deep industrial decarbonization, integrating offshore wind at scale, providing flexible demand where the electricity grid is constrained, and strengthening strategic autonomy. With the right sequencing of deployment, infrastructure, and innovation, hydrogen becomes not just a decarbonization tool but a foundational element of a more affordable, resilient, and strategically secure Dutch energy system.

The Tables below provide more elaborate insights into potential system synergies as well as into the trade-offs to be carefully navigated.

ENERGY TRILEMMA CONTRIBUTIONS (SHORT TERM VS LONG TERM)

Trilemma Goal	Positive Contributions	Negative Contributions / Pressures
Sustainability	**Short term:** Early green hydrogen replaces grey hydrogen in refining and chemicals; pilots reduce industrial emissions. **Long term:** Enables full decarbonization of hightemperature processes and longduration energy storage; supports deep integration with offshore wind.	**Short term:** upstream impacts from electrolyzer manufacturing. **Long term:** emissions linked to shipping of ammonia/methanol remain a factor.
Affordability / Competitiveness	**Short term:** Electrolyzers co-located at constrained nodes may reduce curtailment and grid costs; targeted subsidies reduce early market barriers. **Long term:** Maturing hydrogen markets lower LCOH as a result of economies of scale; hydrogen hubs improve system efficiency and reduce curtailment costs; supports competitive green industry.	**Short term:** High initial hydrogen costs challenge business cases; infrastructure timing mismatches increase low utilization risk. **Long term:** Large CAPEX for backbone and storage may burden system if demand lags; import dependence creates exposure to global price volatility.
Security of Supply / Autonomy	**Short term:** Provides an additional energy transition vector beyond electricity; strengthens optionality for industrial clusters. **Longterm:** Domestic hydrogen (plus diversified imports) reduces exposure to fossil markets; enhances strategic autonomy.	**Short term:** CRM dependence for PEM (iridium, platinum-group metals); early reliance on imported hydrogen/derivatives. **Long term:** If domestic RES buildout lags, dependence may shift from fossil fuels to imported molecules.

POSSIBLE CROSS-CASE SYNERGIES

<table>
<tr><th colspan="2">Key questions</th><th>Affordability/ economics</th><th>Sustainability / transition</th><th>Security/ autonomy</th></tr>
<tr><td rowspan="3">How can green hydrogen help other components?</td><td>Offshore wind</td><td colspan="3">• As a flexible off taker, electrolysis technology may (with fit-for-purpose technology) enable the ramp up of offshore wind energy production as hydrogen can be produced during high wind/low price hours, reducing the need for economic curtailment. Note that this will have implications for the business case of the hydrogen producer.
• Converting surplus power to hydrogen in the right locations reduces peak grid loads and the need for very costly cable and grid reinforcements, while enabling cheaper long-distance transport and storage.</td></tr>
<tr><td>EV infrastructure</td><td colspan="3">• Green hydrogen can decarbonize heavy and long-distance transport where batteries are expensive or impractical, lowering total system costs by avoiding oversizing the electricity grid for all transport segments.</td></tr>
<tr><td>Energy intensive industries</td><td colspan="3">• Cluster-based hydrogen pipeline and storage networks may give industries access to large amounts of energy and feedstock input for hard-to-abate use cases, enabling low carbon products (e.g. green steel, green ammonia), and protecting access to markets with strict climate policies.
• Sourcing hydrogen locally or from a broader range of countries than currently fossil origins increases energy independence.</td></tr>
<tr><td rowspan="3">How can other components help green hydrogen</td><td>Offshore wind</td><td colspan="3">• Large steady volumes of relatively cheap, green offshore wind power are the main lever to reduce the cost of green hydrogen and make it competitive with grey/imported hydrogen.
• Using the North Sea “Power Resource” offers energy independence especially if equipment is sourced from EU supply chains.</td></tr>
<tr><td>EV infrastructure</td><td colspan="3"></td></tr>
<tr><td>Energy intensive industries</td><td colspan="3">• As large stable buyers sign long-term offtake contracts, industries can provide the demand certainty needed to finance large electrolyzer projects and bring hydrogen unit costs down via scale.
• Concentrated industrial demand justifies investment in dedicated hydrogen pipelines and storage, often reusing existing port and pipeline assets and lowering system wide infrastructure costs.
• Predictable industrial demand in combination with targeted policy instruments (e.g. carbon contracts for difference) could improve economics of green hydrogen and underpin large upstream investments in renewables and electrolyzers.</td></tr>
</table>

APPENDIX B: METHODOLOGY AND SOURCES ILLUSTRATIVE SOCIETAL BUSINESS CASE

Level	Type		Range	Calculation	Key sources	Key assumptions / notes
Local	**Energy independence**		€ 80 - € 250	Shock probability x Potential economic damage	• CBS (2026), Opbouw binnenlands product, nationale rekeningen • Gasunie (2026), GTS visie op een robuuste Europese aardgasvoorziening • EZK (2024), Bescherm- en Herstelplan Gas	• Shock probability = 25% (or once every four years) lasting between 3 and 9 months • Industry is first sector to reduce energy demand in line with plan by EZK (measure C.5) • On year basis, shock would equal 180 TWH of which 77 TWH is mitigated using supply measures • Depending on duration of 3-9 months, final demand reduction would equal 26 to 77 TWh Potential economic damage scales linearly with reduction in gas supply • Costs of supply-side measures to mitigate effect shock have not been accounted for
Local	**Air pollution**	**PM**	€ 150	Benefits in % of GDP x projected GDP	• TNO (2025), Vernieuwende kijk op fijnstof • Rabobank (2025), Potentiele groei NL'se economie t/m 2050	• A linear relationship is assumed between economic damage from PM and CO_2 emissions • Benefits are linearly scaled with % of CO_2 reduction required to move from 2024 emissions to 2030, 2040, and 2050 legal targets
Local	**Air pollution**	**NO_x, NH_3, N_2O**	€ 110	Benefits in % of GDP x projected GDP	• SEO & CE Delft (2025), Stikstofuitstoot en stikstofbeperkingen; Wat is de schade? • Rabobank (2025), Potentiele groei NL'se economie t/m 2050	• A linear relationship is assumed between damage from NO_x, NH_3, N_2O and CO_2 emissions • Benefits are linearly scaled with % of CO_2 reduction required to move from 2024 emissions to 2030, 2040, and 2050 legal targets
Global	**Air pollution**	**CO_2**	€ 210 - € 250	Reduced CO_2 emissions x Social costs of carbon	• EPA (2023), EPA Report on the Social Cost of Greenhouse Gases • Moore et al (2024), Synthesis of evidence yields high social cost of carbon due to structural model variation and uncertainties	• CO_2 reduction scales linearly from 2024 emissions to 2030, 40, and 50 targets • CO_2 prices used vary between € 135 and € 159 per ton
	General		**N/a**	N/a	• Minfin (2025), Rapport Werkgroep discontovoet 2025 • PBL (2025) Klimaat en energieverkenning 2025	• In line with guidance Minfin, a 2,6% discount rate has been selected • 2024 emissions have been used as reference year

ENDNOTES

1 European Environment Agency (2025), Trends and projections in Europe 2025 (link)
2 World Energy Council (March 20, 2026), Our history (link)
3 IEA / Fatih Birol (2026) (link)
4 European Commission (2025), Clean Industrial Deal (link)
5 European Commission (2025), Commission Work Program 2026 (link)
6 UK Department for Energy Security and Net Zero (2026), The Hamburg Declaration (link)
7 Rapport Wennink (2025), De route naar toekomstige welvaart (link)
8 Where most of the World agreed on a clear target to keep the increase of global temperatures below 2 C above pre-9industrial levels
9 European Environment Agency (2025), Trends and projections in Europe 2025 (link)
10 World Energy Council (March 20, 2026), Our history (link)
11 The Draghi Report (2024), The future of European Competitiveness (link)
12 European Commission (November, 25, 2025), New economic guidance to boost EU competitiveness (link)
13 IEA / Fatih Birol (2026) (link)
14 The four sectors are individually not fully exhaustive for the Dutch transition. However, decarbonizing them will have second-order effects upon the whole of society
15 Ember (2025), Shockproof: how electrification can strengthen EU energy security (link)
16 European Commission (2025), Clean Industrial Deal (link)
17 UK Department for Energy Security and Net Zero (2026), The Hamburg Declaration (link)
18 Rapport Wennink (2025), De route naar toekomstige welvaart (link)
19 Rapport Wennink (2025), De route naar toekomstige welvaart (link)
20 Nationaal Burgerberaad Klimaat (2025), Advies (link)
21 See also CBS (2024) (link) and ESB (2025) (link)
22 See for example the strategy to develop a special economic zone around Rotterdam's harbor-industry complex to fast track the energy transition; TNO (2026) (link)
23 Vattenfal (March, 20, 2026), Welkom bij Zeevonk, ons nieuwe windpark (link)
24 Stimulate solutions in a way that directs to a lowest cost outcome for society. For example, in certain regions (historic high density urban areas) it makes more sense to focus on district heat.
25 Rabobank (2024), V2G: Transforming electric vehicles into rolling energy storage (link)

SOURCES

Text
- CPB (2026), Industry energy support and its interaction with EU ETS (link)
- ESB (2025) (link), Compensatie energiekosten nodig voor concurrentievermogen industrie.
- European Commission (2025), Clean Industrial Deal (link)
- European Commission (2025), Commission Work Program 2026 (link)
- European Commission (November, 25, 2025), New economic guidance to boost EU competitiveness (link)
- European Environment Agency (2025), Trends and projections in Europe 2025 (link)
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- TNO (2026), Tijdelijke Speciale Economische Zone rond Rotterdam kan klimaatvertraging en bbp-verlies voorkomen (link)
- UK Department for Energy Security and Net Zero (2026), The Hamburg Declaration (link)
- Vattenfal (March, 20, 2026), Welkom bij Zeevonk, ons nieuwe windpark (link)
- World Energy Council (March 20, 2026), Our history (link)

Figures
1. Ember (2025), Shockproof: how electrification can strengthen EU energy security (link)
2. Ember (2025), How cheap is battery storage? (link)
3. Rapport Wennink (2025), De route naar toekomstige welvaart (link)

Figures
For sources of calculation on costs of inaction, please see appendix B.

WORLD ENERGY COUNCIL

Algeria
Argentina
Armenia
Austria
Bahrain
Belgium
Bosnia & Herzegovina
Botswana
Brazil
Bulgaria
Burkina Faso
China
Chile
Colombia
Congo (Dem. Rep.)
Croatia
Cyprus
Dominican Republic
Ecuador
Egypt (Arab Rep.)
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New Zealand
Nigeria
Norway
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