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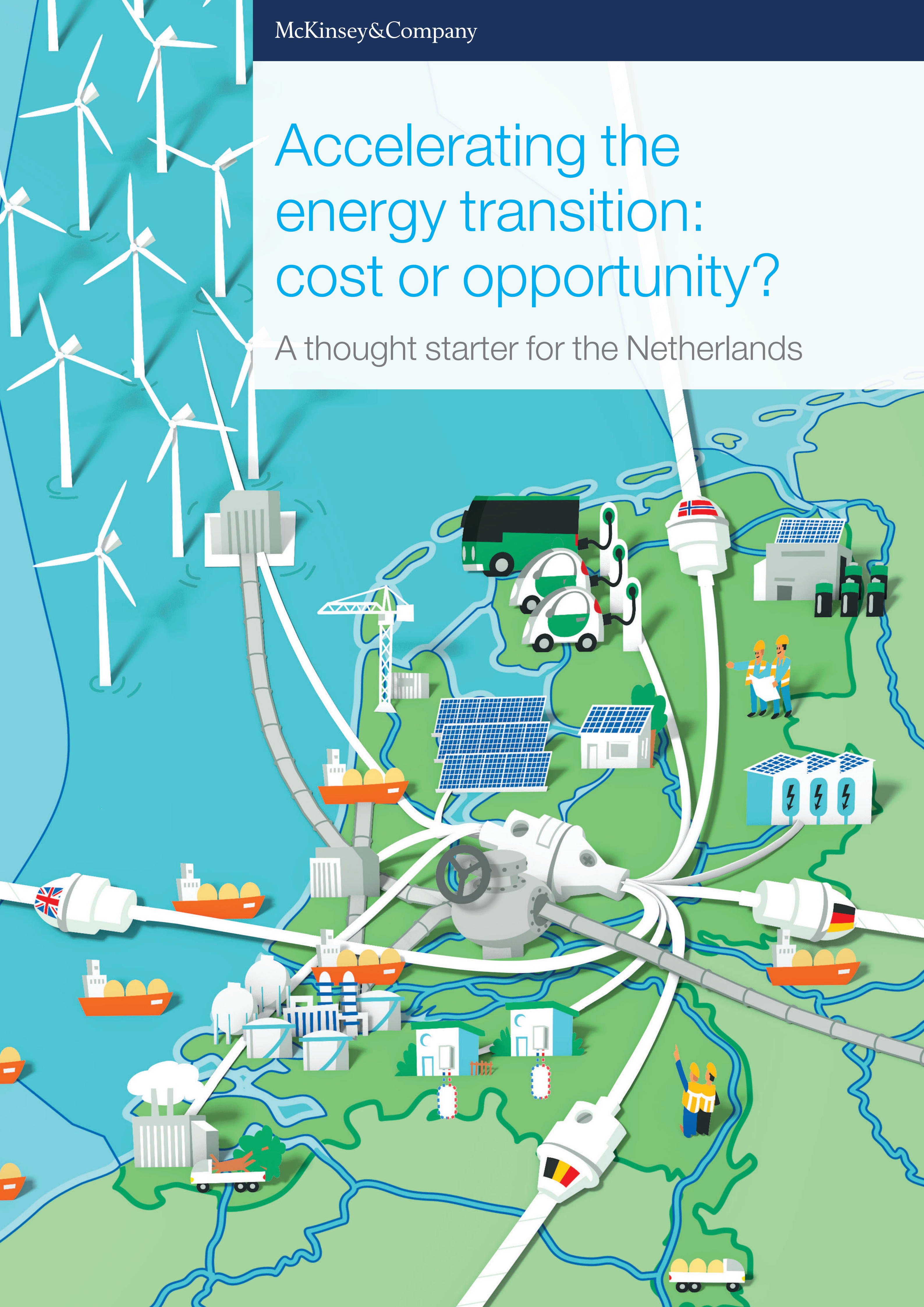
A thought starter for the Netherlands



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Preface

Over the past years, the Netherlands has taken the first steps on potentially one of the most profound transformations in its history: the transition of the Dutch energy system. Signs of this transition have appeared across the landscape. In 2015, a district court in The Hague ruled that the government must set policies ensuring that greenhouse gas (GHG) emissions fall by at least 25 percent by 2020. Five coal-fired power plants have been designated for closure. Owners of electric vehicles can now recharge them at some 23,000 (semi)public stations across the country. And in June 2016, the government awarded a contract to build an offshore wind farm that will be the least expensive of its kind in the world.

As a member of the EU, the Netherlands is expected to support the region's ambitious aims for reducing GHG emissions. In February 2011, the EU reaffirmed its commitment to reduce GHG emissions by 80 to 95 percent by 2050, compared with 1990 levels. A subsequent pledge by the EU announced in 2014 set an interim target of cutting GHG emissions by at least 40 percent by 2030.

From 1990 to 2015, the Netherlands cut its GHG emissions by 12 percent, on the way to a 20 percent reduction by 2020. To realize the EU's 2050 goal, however, the Netherlands would have to triple its yearly rate of emission reduction, compared with the 0.7 percentage point annual reduction it averaged in 1990 to 2014.

The apparent need for the Netherlands to accelerate its transition to a low-carbon economy raises some crucial questions. What policy measures, technological advances, and industrial shifts would support a near-total decarbonization of the energy system and the economy? How much spending and investment is needed to pay for those changes? And can the Netherlands achieve economic growth while reducing its GHG emissions to meet the EU targets?

In this paper, we begin to answer those questions by examining the conditions that govern the Dutch energy system, the pathways for changing how the Netherlands generates and uses energy, and the economic impact of those changes. This analysis is not intended to determine the lowest-cost approach to reducing emissions. Rather, we have estimated the costs and benefits for one set of realistic emissions-reduction options to give policymakers and industry leaders a direction for long-term plans.

Although it is subject to uncertainty, our analysis suggests that pursuing the EU's emission reduction goals can also produce economic benefits for the Netherlands. The keys to this approach include setting and following a longer term master plan, reducing costs while capturing potential benefits, and replacing infrastructure and assets at end of life. Following our assumptions, the Netherlands can realize a modest medium term GDP increase of around 2 percent by accelerating its transition to a low-carbon energy system. This impact could be larger if the Netherlands invests in areas with high growth potential, such as electric mobility, sustainable building heating, offshore wind, innovation in energy storage and transport solutions, heavy industry, and (offshore) carbon capture and storage or usage.

We wrote this paper to provide decision makers with a solid fact-base as well as a first view of how the long-term costs and benefits could play out. This paper combines the macro-economic perspectives of our McKinsey Global Institute with the sector-specific knowledge of for instance our Automotive and Chemicals practices. We further have leaned heavily on our proprietary models for the power and energy system, and on the support of many colleagues in our Global Energy and Materials practice.

Making this report would not have been possible without the valuable input of external experts and reviewers ranging from asset owners, energy companies and network companies, and financial institutions, to universities and research institutes.

For the Netherlands, helping to address global climate change could be good for the economy as well as the environment. We encourage those in government and in business to consider this paper and use it to find an economically sensible path towards substantial, lasting emission reductions.

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Executive Summary

The EU has called for cutting greenhouse gas (GHG)[1] emissions by at least 40 percent before the year 2030 and by 80 to 95 percent before 2050. To meet those goals, the Netherlands will have to reduce its emissions at a rate that is three or four times the 0.7 percentage point annual reduction it is set to achieve from 1990 to 2020. Although emissions declined between 1990 and 2014, recent figures indicate that GHG emissions increased 5 percent in 2015 and CO_2 emissions exceeded the level of 1990. This increase in CO_2 was large enough to undo the reductions of the previous 24 years. To realize the EU's goals, the Netherlands will have to return to an emissions-reducing trajectory.

There are limited precedents for how an industrialized country can maintain its high standards of living while reducing per-capita and per-GDP emissions to the levels of countries that are less developed. One thing is certain: Transforming the Dutch energy system in pursuit of high emission reductions will require significant levels of investment. A crucial question for policymakers and business leaders, then, is whether there is a way to minimize these investments and to increase the economic benefits of such investments through increased efficiency and creation of new (export) sectors.

The Netherlands does have advantages when it comes to reducing its emissions footprint. It is a relatively small and densely populated country, where new infrastructure investments can be done economically given high utilization. Energy plays an important role in the Dutch economy and makes a disproportional contribution to GDP compared to other countries. Citizens have picked-up low-carbon technologies steadily, with the Netherlands having the 2[nd] highest penetration of electric vehicles globally. The government has agreed to European and Dutch emission reduction targets, with even a court ruling pushing for higher targets. Hence, the energy transition matters to business leaders, politicians and society at large.

This paper finds that an accelerated but flexible approach to reducing GHG emissions will yield value in terms of GDP and employment. Our approach was to estimate the economic costs and benefits of one set of emission-reduction options for four major sectors: transport, buildings, heavy industry, and power. For simplicity, we considered only one scenario with technologies that are proven today or that appear likely to become workable in the near term. We assumed that some investments would go into emerging technologies such as carbon capture and storage or usage (CSS/U) and large-scale energy storage, though we did not account for the possible emissions reductions of these technologies within the 2020 to 2040 timeframe.

We estimate that investing EUR 10 billion per year between 2020 and 2040 in a low-carbon energy system would generate a positive GDP impact and potentially create tens of thousands of jobs in the long run, with 45,000 installation jobs at minimum in the near term.

1 Greenhouse gas emissions, as reported under the Kyoto protocol, consist of carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4) and fluorinated gases. In order to aggregate the influence of the different greenhouse gases, all emission figures are converted into CO_2-equivalents (e.g., 1 kg of N_2O yields 296 CO_2 equivalents).

Changing energy demand: moving to high efficiency and low-carbon technology

Applying a combination of energy efficiency measures and speeding up the implementation of new technologies could decrease the demand for primary energy by approx. 30 percent. These shifts would roughly double the power sector's share of final energy use from 17 percent today to about 32 percent in 2040.

In the short term, some demand-sectors could launch initiatives that rely on proven, economical, and readily available knowledge and technology. Examples include replacing gasoline- or diesel-powered vehicles with EVs and improving insulation in buildings so they can be cooled and heated with less energy. In other sectors, changes will unfold more slowly or start to accelerate later. Such changes could include replacing heavy-duty vehicles with those powered by hydrogen and phasing out the use of fossil fuels in industrial processes in favor of renewably generated heat and hydrogen.

Decarbonizing the energy supply: one-third less energy, one-third more power

Reducing the energy system's CO_2 emissions while accommodating a 37 percent increase in the demand for electric power represents a major challenge. We have modeled one way of meeting this challenge: by increasing the system's renewable power generation capacity to 80 percent and introducing flexibility measures, such as demand-side management and energy storage. All in all this would lower (energetic) CO_2 emissions by about 55 percent. These changes will require capital and operational expenditures of approx. EUR 10 billion per year. This amounts to some EUR 2.5 billion more than for a fossil-fuel-reliant system.

Compared to a system like the current one, the fully loaded unit cost of electricity[2] will increase from EUR 54 per MWh to EUR 64 per MWh without transmission and distribution costs, and from about EUR 66 per MWh to EUR 79 per MWh with transmission and distribution costs. A power system that runs on 80 percent renewable energy would produce 75 percent fewer GHG emissions than it does today.

Overall, the cost of energy for the Netherlands would come down slightly: from about EUR 23 billion to EUR 22 billion. The higher the oil price, and the lower renewable costs, the larger this difference becomes.

Maximizing the value of investments in the energy transition

Considering that energy transition is so capital intensive, it will be important to invest wisely. We see four major ways in which to increase the efficiency of the investments required:

- By creating nationwide economies of scale through large-scale, planned programs for those technologies that would benefit from central roll out. Attractive areas could include improving building insulation or expanding renewable energy supply, and electrc vehicle charging.

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2 These fully loaded system costs include fuel, operating and maintenance, and capital costs. They can therefore not be compared to the wholesale pricing mechanism which is based on short term marginal costs (i.e. fuel cost and O&M cost only)

- By avoiding investments in less efficient equipment that will require replacement before its technical end-of-life to meet the targets. In other words: avoid investment in equipment that eventually needs to be replaced again with low- or zero-carbon equipment before reaching its economical or technical end-of-life, and leapfrog to low-carbon or carbon-neutral technologies right away.

- By attracting and stimulating new economic activity in “target sectors”, increasing investment in those sectors and capabilities where the Netherlands can build competitive differentiators on a European or global level.

- By transforming adjacent economic sectors. An accelerated energy transition could spur more investment and innovation in supporting fields: it will require changes in technology, business models and financing as well. This could make the economy more competitive as a whole.

Estimating the economic impact of the energy transition, triggering growth

We estimate that investment and spending on goods and services required for the energy transition will generate GDP growth of 2 percent in the short to medium term. Over time this direct effect will slowly fade. In the longer term, further upside can be created. For example, a shift in economic activity away from sectors with lower economic multipliers (like large plants) and towards sectors with higher economic and employment multipliers (like construction) will provide a further net boost to GDP. The Netherlands’ trade balance could be affected positively as the country will need to import less fossil fuel.

The biggest and longest-lasting economic benefits are likely to come from investments in sectors that may generate substantial economic growth and jobs. Examples of attractive areas include:

- **‘New’ transport –** Novel solutions to improve urban transport could be marketed worldwide, particularly as urbanization continues. Such solutions might include innovative city plans, systems for integrating multiple transportation modes, rolling out EVs and other zero-carbon forms of transport on a large scale, and manufacturing vehicles and transportation equipment

- **Sustainable building heating –** The Netherlands as (technology) leader for climate control systems and residential energy management.

- **Heavy industry transformation and CCS/U –** Because chemicals, manufacturing, and other industrial sectors are highly energy-intensive, there are opportunities for improving energy efficiency and pioneering alternative feedstock configurations with innovative processes and technologies. The Netherlands is well-positioned to pioneer advances in carbon capture and storage or usage, because of its unique subsurface characteristics and existing know-how.

- **Offshore wind –** The Dutch and global offshore wind industry is likely to grow to meet rising demand for renewable energy, requiring significant investment and powering industrial development in multiple categories. Enabling cross-border balancing of energy loads through linkage of electricity grids in the North Sea could also be of interest.

- **Integrating renewables with the energy grid –** As solar and wind power grow their share in the energy mix, the energy sector has to consider how to best integrate renewables in energy system. Decentral versus central, intermittent between hours and seasons. The Netherlands can capitalize on this transition by focusing on energy conversion, storage, and transport solutions, given its diverse chemical sector and its extensive energy infrastructure.

Charting a way forward

How these benefits will materialize depends on a myriad of factors: the scale of investment, the pace of change, the development of technology, and the willingness of people and institutions to adapt to name a few. The resulting uncertainty makes it challenging to select options and place big bets on them. Nonetheless, we suggest three considerations for the country to take along in their pursuit of the goals:

- Develop a master plan for each demand sector for how to decarbonize: a fact-based plan that takes the goals of 2050 and translates them into clear decisions and targets for each of the decades inbetween. A long-term outlook on energy supply and demand is critical to unlocking investments that have extended payback periods, because it helps give consumers and businesses more certainty about their investment prospects.

- Use long-term value for the Netherlands as the main variable to optimize emission reduction schemes and GDP stimuli.

- Put public incentives, including tax policies, in perspective of the longer-term challenge ahead and redesign them in such a way that citizens and major energy consumers are encouraged to participate in the overhaul of the energy market.

Energy use in the Netherlands – and the challenge ahead

The member states of the EU have the goal of reducing their GHG emissions by 40 percent by 2030, on the way to a reduction of 80 to 95 percent by 2050. Achieving this goal is widely seen as essential for mitigating the effects of global climate change, in line with the Paris agreement reached at COP21 in December 2015. Acting on these goals will involve extensive change across a number of dimensions – from economics and finance to public policy to technology to culture.

For the Netherlands, realizing the EU's goals will be a formidable task. Although the country has gradually made improvements in energy efficiency and renewable energy use over the past two decades, it remains a heavy user of fossil fuels: only 6 percent of the country's energy comes from renewable sources.

GHG emissions from the Netherlands were 223.8 million metric tons (Mtons) of carbon dioxide equivalent (CO_2e) in 1990. After peaking in 1996, emissions dropped by an average of 0.7 percentage points per year until 2014 (1.5 Mtons/year), when they were 187 million metric tons CO_2e, equaling a total emission reduction of 16 percent over 24 years. An 80 percent emission reduction by 2050, in line with EU-wide targets, would bring the Netherlands' greenhouse emissions down to 44 million metric tons.

This is a very large decrease with major implications. Consider that each person in the Netherlands accounts for approx. 10 metric tons of GHG emissions per year. Reaching a 2050 emissions goal of 44 million metric tons, with no change in population, would require the Netherlands to produce per capita emissions of just 2.6 metric tons. That is a developing-country level of emissions intensity, comparable to Panama or Egypt. Similarly, comparing carbon intensity of the economy, indicates that the Netherlands would need to end up at carbon emissions per unit GDP similar to those currently realized in Zambia.

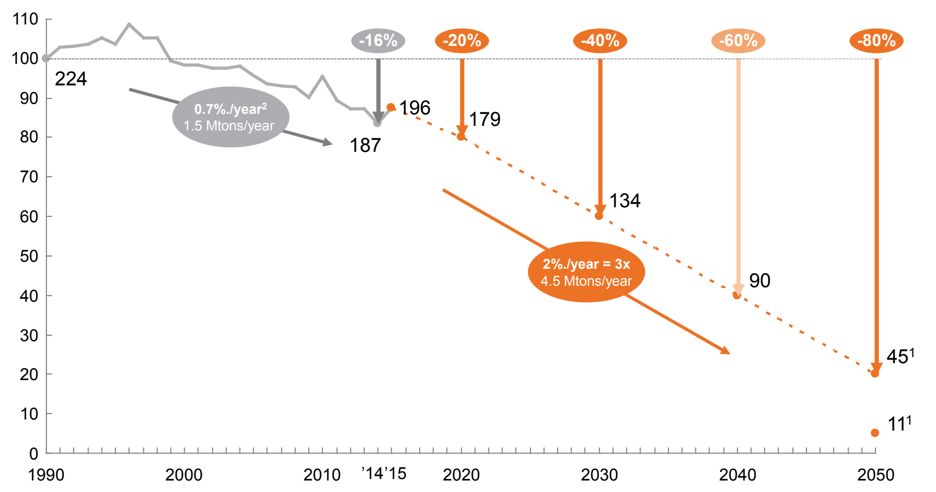
Another way to look at the emission reduction is in terms of the rate of change. To achieve the EU's 2050 emissions goal of 80 percent emission reduction, the Netherlands would need to cut its emissions by at least 2 percentage points (4.5 Mtons) per year, every year compared to 1990 levels – three times the annual reduction it realized between 1990 and 2014 (Figure 1).[3] Computed in compound annual growth rates (CAGRs), a year-on-year change of 4.5 percent would be needed between 2020 and 2050 (signifying even a six-fold increase compared to date). Over the past years, this rate (>4.5 Mton reduction) was achieved in a few years (1996, 1999, 2011), offset by much lower rates or even emission increases in other years.

3 To reach a 95 percent reduction by 2050, the Netherlands would need to accelerate by factor four. Emissions from international aviation and bunkering are not in scope of GHG reduction schemes, but will also have to be addressed at some point. Emissions from the Netherlands' territory amount to 11 Mtons CO_2 from aviation and 42 Mtons CO_2 for bunkering. As a final note, the court ruled in the court case of Urgenda against the state that the Netherlands should aim for emission reduction faster and reach 25 percent reduction (instead of 20 percent) by 2020 – this implies earlier acceleration than signalled here.

Figure 1

To achieve the EU 2050 ambition of GHG emission reduction of 80 percent, the Netherlands would need to accelerate with factor 3

CO_2 equivalent emission (percent change as of 1990)



1 Target CO_2e reduction in 2050 compared to 1990 is 45 Mton for 80% emission reduction and 11 Mton for 95% emission reduction target
2 Assuming the 2020 target of -20% will be met despite the increase in emissions seen in 2015

SOURCE: Rijksoverheid emissieregistratie

The Netherlands would also need to shift its attention to reducing CO_2 emissions in particular. Between 1990 and 2014, 85 percent of the Netherlands' GHG emission reduction has resulted from lowering emissions of methane (40 percent), nitrous oxide (28 percent), and fluoride (17 percent). CO_2 accounted for the remaining 15 percent of the reduction (from 163 in 1990 to 158 million metric tons in 2014). Emissions of CO_2 will have to be reduced 17 times faster than from 1990 to 2014.[4]

There are limited precedents for how an industrialized country with high standards of living can maintain these while reducing per capita carbon emissions to the levels of countries that are much less developed. The Netherlands therefore is faced with two urgent questions. First, what specific changes will result in a low-carbon energy system that supports continued economic growth and a good quality of life for the country's residents? And second, what are the financial and economic requirements and implications of achieving the EU's carbon reduction goals in a country where the energy sector directly accounts for as much as 6 percent of GDP and indirectly for another 5 percent?

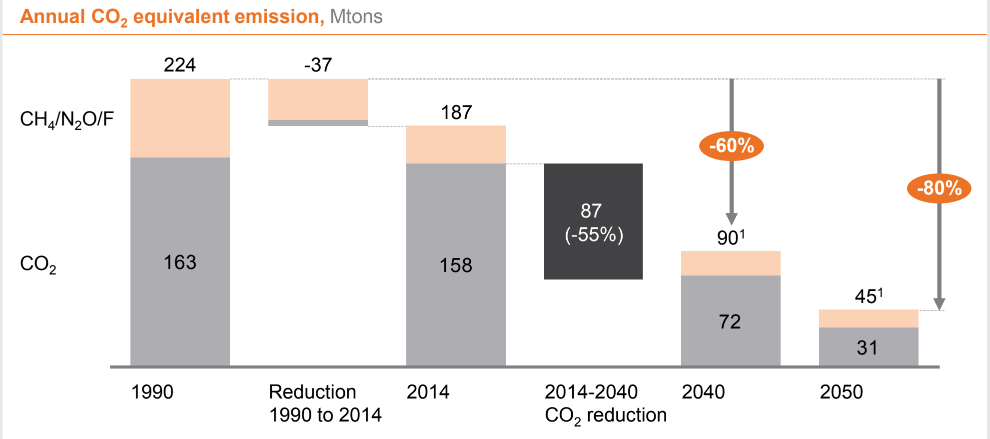
This paper is a first attempt to answer these questions.

4 Between 1990 and 2014, CO_2 was on average reduced by 0.2 million metric tons per year; this has to increase to approx. 4.5 million metric tons per year until 2050 to reach the reduction target of 80 percent CO_2e reduction by 2050. In 2015, CO_2 emissions have gone up again to 167 Mton in 2015, nullifying achieved reductions to date

Our study focuses primarily on the Netherlands for the period 2020 to 2040, a time relevant for current investment decisions. For simplicity, we target an emission reduction of at least 60 percent by 2040 as a step towards an 80 percent reduction by 2050 (Figures 1 and 2).[5] We focus particularly on reducing CO_2 emissions from energy-related activities (149 out of 158 million metric tons (2014))[6]. We identify plausible changes for the medium and the long term, and outline the costs and benefits of all these moves – all against a background of business-as-usual investments. We treat the Netherlands as a stand-alone entity, recognizing that in practice solutions need to be optimized and embedded in an international context. For simplicity, we considered only one scenario with technologies that are proven today or appear likely to become workable in the near term. Technologies including carbon capture and storage or usage (CSS/U), nuclear power and specific large scale storage solutions were left out to simplify the analyses, but in some cases budget was allocated to these areas without making explicit technology choices.

Figure 2

A 55% reduction of CO_2 emission reduction by 2040 would be needed to stay on track for achieving the 2050 emission reduction targets



1 Minimum remaining emissions estimated at about 14 Mtons CO_2e for methane, nitrous oxide and fluorinated gases for 2050. For 2040, we assume 18.4 Mtons remaining emissions following a lineair interpolation between now and 2050.

SOURCE: Kyoto protocol; National Inventory Reports

5 It has been estimated that non-CO_2 emissions from agriculture, industry, and waste can be reduced to a residual level of 14 Mtons CO_2e, beyond which the cost effectiveness and technical feasibility limit further improvement (for more background information, see PBL, 2011). Linear interpolation between current levels (29 Mtons CO_2e) and the 2050 target yields a residual level of 18 Mtons CO_2e for non-CO_2 GHG in 2040. Hence, in order to reach 60 percent emission reductions in 2040, CO_2 emissions have to be reduced to 72 Mtons CO_2.

6 Of the CO_2 emissions, 7 Mtons come from emissions from industrial processes (like cement making) and 151 Mtons from energy-related activities. Also, we assume linear extrapolation of realized emission reductions between 1990 and 2014 (from 9 to 7 Mtons) to 2040 (5 Mtons remaining).

Wherever possible, we highlight opportunities that bring the Netherlands' advantages (such as a progressive offshore wind industry, extensive knowledge of natural gas infrastructure, proven innovation hubs, and ample experience with large-scale projects, such as Delta Werken and the rollout of the gas network) to bear on the challenges of introducing and scaling up new energy solutions and integrating them into the country's energy systems.

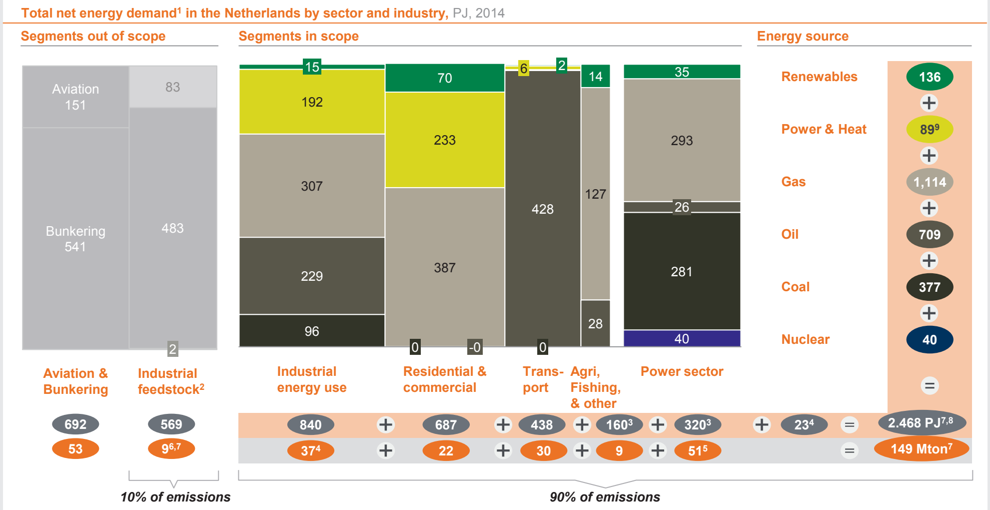
The remainder of this paper follows the logic underlying our analysis. We first define what we see as a plausible, constructive set of changes that could take place in the sectors that account for most of the country's energy demand and use. Next, we interpret those changes for the country's energy generation and distribution system. We conclude by presenting our high-level estimates of the economic and financial impact of the energy transition, in terms of investment requirements as well as effects on GDP and employment.

Changing energy demand: moving to high-efficiency and low-carbon technology

Reducing carbon emissions from energy use enough to reach the 2040 derived target of a 60 percent reduction will require intense, sustained effort across every sector. The Netherlands used 3,039 PJ of energy in 2014, approx. 25 percent of which is primary energy and 75 percent is final energy consumption. Of all demand sectors, industry consumes the most energy, followed by residential and commercial, transport, and agriculture and other. The power sector has a net energy demand of 320 PJ (Figure 3).

Figure 3

Industry, transportation, residential and commercial, and the power sector target 90% of emissions



1 Total net energy demand = final energy consumption (energetic use) + nonenergetic energy use + net use of energy in production of other energy carrying products (including own use energy sector and distribution losses), 2 Including 1.4 PJ feedstock from residential and commercial users, 3 Excluding net power & heat demand (supply) of -7 PJ for agriculture, and -356 PJ of generated heat and electricity in the power sector, 4 Distribution losses (23 PJ), and rounding differences, 5 Energy sector own use for 158 PJ included in Industry and for 2 in power sector, 6 Includes fugitive emissions from fuels (1.7 PJ), 7 2014 total CO2 emissions of 158 Mtons is the sum of emissions from fuels (149 Mton) plus emissions from industrial processes and feedstock (9 Mtons), 8 Total energy use (including feedstock and statistical differences, excluding bunkering and aviation) amounts to 3,039 PJ – subject to statistical and rounding differences, 9 Sum of net heat and power demand and supply – of which 53 PJ net imported electricity and 36 PJ other energy carriers

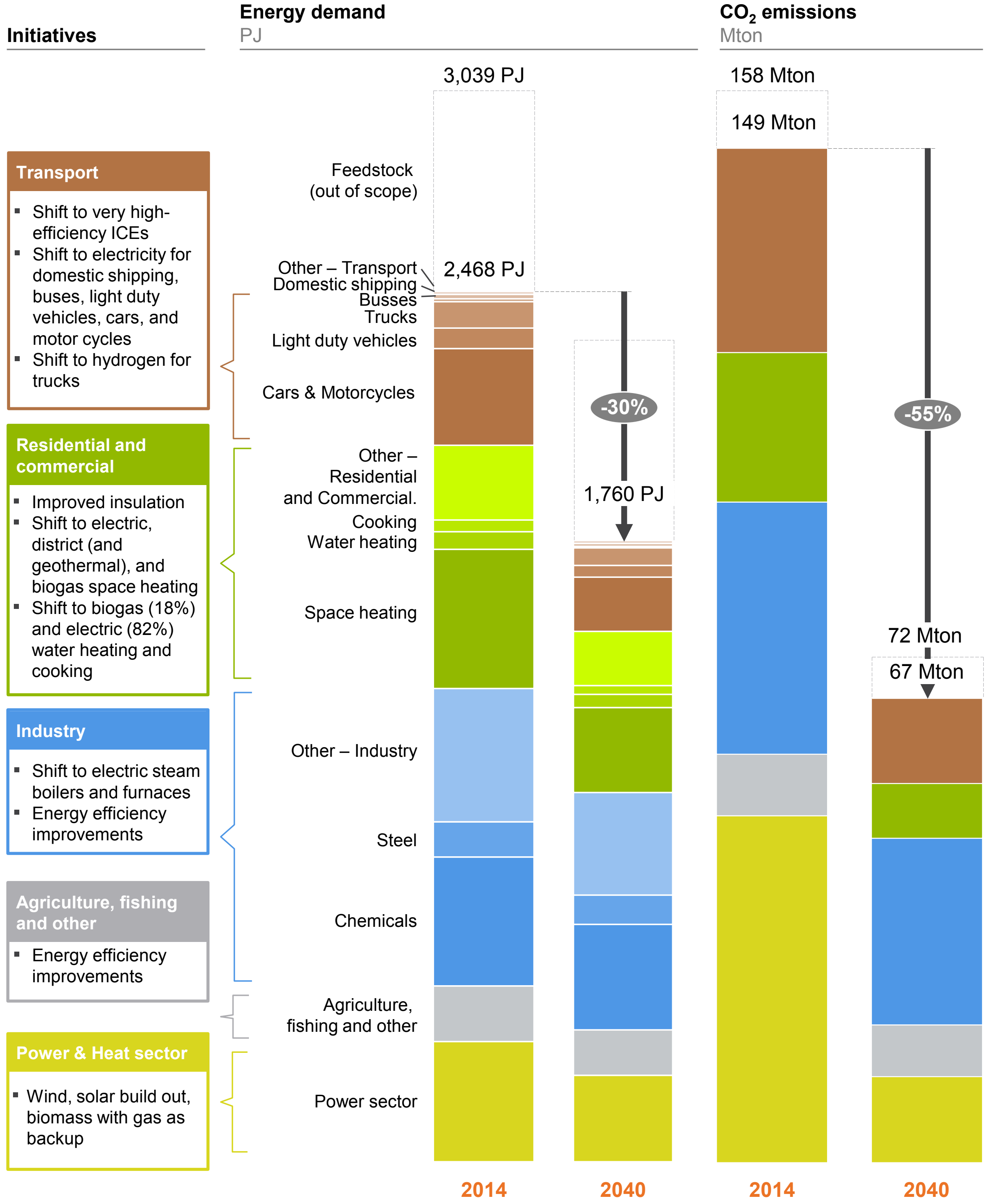
SOURCE: Centraal Bureau voor de Statistiek (2014), "Energiebalans" and "Energieverbruik" databases

We have investigated possibilities for reducing emissions from all modes of transport, from space and water heating in residential and commercial buildings, and from heavy industry (chemicals and steel).[7] We have not sought for "the optimal" solution, but have rather compiled a coherent set of plausible measures. We have calculated investment deltas based on differences in total cost of ownership (TCO) between the low-carbon and the business-as-usual technologies. We have used TCOs with reasonable payback horizons, e.g., a maximum of five years for people who have bought cars; the remaining cost delta is then considered to be the additional investment need.

7 Although we chose to concentrate our analysis on the sectors that account for the vast majority of energy use in the Netherlands, we anticipate that (similar or different) meassures could also be applied effectively in the sectors we did not examine, such as agriculture and fishing.

Figure 4

Energy demand will decrease by 30%, while (energetic) CO_2 emissions are reduced by ~55%

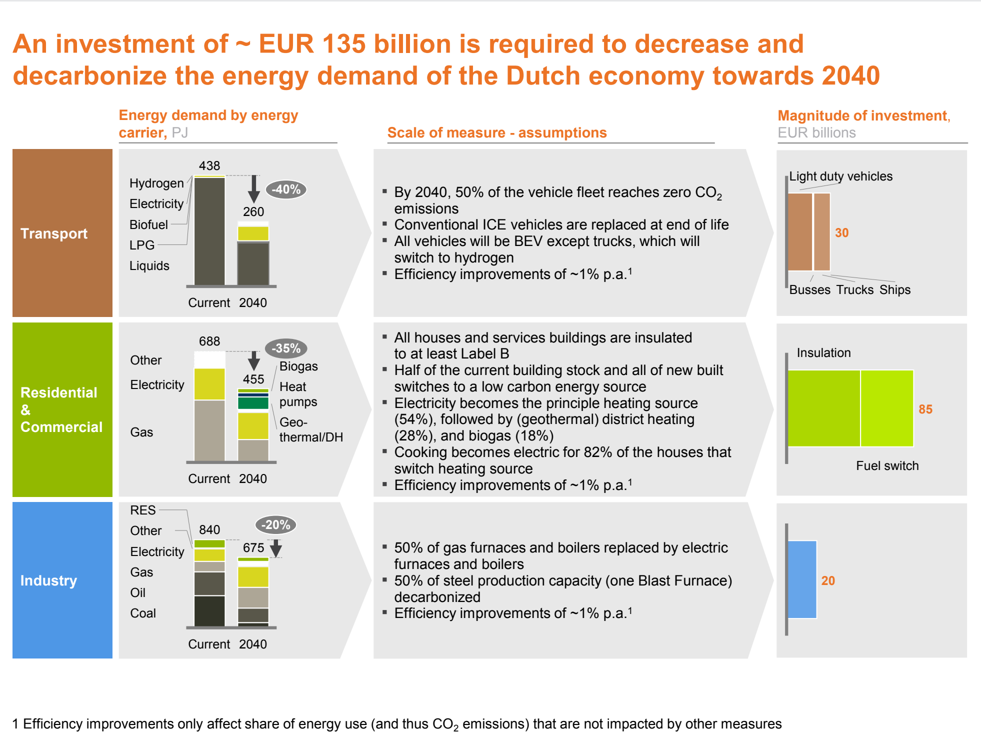


SOURCE: CBS 2014 data

Our analysis suggests that applying a combination of energy efficiency measures[8] and speeding up the implementation of advanced technologies to half of the sectors in question could lower demand for primary energy by 30 percent (Figure 4) – enough to lower carbon dioxide emissions by approx. 55 percent. These changes would also double the power sector's share of final energy demand from 17 percent today to about 32 percent in 2040.

Some demand sectors can begin reducing their emissions in the short term, using proven approaches based on relatively mature technologies. These include improving insulation in buildings and shifting to Electric Vehicles (EVs). In other sectors, changes will unfold more slowly, largely because the necessary technologies are not yet widely available or practical to apply on a large scale. These changes include replacing heavy-duty vehicles with those powered by hydrogen (which requires a hydrogen distribution infrastructure to be rolled out) and phasing out fossil fuels in industrial processes (Figure 5). More information about the assumptions behind our analysis can be found in Annex I – methodological background.

Figure 5



8 Assumed year-on-year efficiency increase of about 1 percent for energy uses that are not covered by other targeted measures. This assumption is in line with or conservative compared to published targets for individual sectors (e.g., "routekaarten industrie" – aiming for 5.7 Mtons CO_2 reduction (90 PJ) by 2030 through energy efficiency and process intensification).

Transport

To prepare a plausible scenario for an energy transition in the transport sector, we assessed a number of potential changes and then selected one change for each mode of transport.[9] Together, these changes would allow half of the transport sector[10] to use almost exclusively renewable energy by 2040, resulting in an emission reduction of 17 Mtons CO_2. The changes mostly evolve around electrification:

Replace light-duty vehicles with EVs – light-duty vehicles account for 76 percent of energy use in transport. We assume the shift from vehicles with internal combustion engines to EVs for 50% of Light Duty Vehicles (LDVs) before 2040. This transition can occur relatively quickly because the TCO of light-duty EVs is closer to that of gasoline- and diesel-powered light-duty vehicles than it is for any other vehicle type, and the gap continues to shrink as battery prices fall. Especially for small(er) cars only limited additional investment is needed (~EUR 1 billion) as the difference in TCO becomes less than 1 cent/km before 2020. Simultaneously, we assume that the remaining vehicle fleet moves towards highly efficient internal combustion engines (ICEs).

Replace heavy-duty vehicles with hydrogen (trucks) and EVs (buses) – these heavy duty vehicles account for 17 and 2 percent of energy use in transport (81 PJ), respectively. We assume gradual conversion from vehicles with internal combustion engines to EVs, vehicles fueled with liquefied natural gas (LNG), and vehicles fueled with hydrogen. In general, fuels with high energy density are advantageous for trucks carrying heavy freight over long distances. For our scenario, we assume that heavy-duty vehicles used mainly for short trips (e.g., less than 100 km, inside cities, such as buses and small trucks) may be replaced with EVs, while heavy-duty vehicles used for longer distances will eventually be replaced with hydrogen-powered vehicles, with some LNG-fueled vehicles as an intermediate solution. We are well aware this may not play out as such if other zero-carbon fuels break through or hybrid solutions suffice (e.g., last mile electric). Again, simultaneously, we assume that the remaining vehicle fleet moves towards highly efficient internal combustion engines.

Replace motorcycles with electric motorcycles or replace engine – rapid conversion to those equipped with electric motors. Such a rapid change was recently implemented in Beijing where engines were replaced, and also in for instance Amsterdam, older nonefficient scooters and motorcycles will be banned from the town center by 2018.

9 As air travel and bunkering are excluded from official calculations of the total energy consumption of the Netherlands, we have omitted them from our analysis.

10 Diverse mobility (including car sharing), increased connectivity, and autonomous vehicles – all will have an impact on the number of cars, the distance travelled per vehicle, and the way in which cars are driven. At the same time, this will also influence the way in and the degree to which public transport is used. For now, we have assumed that the number and mix of vehicles will be similar in 2040 to what it is today.

Replace inland shipping vessels with electric vessels or replace engine – as the distance covered is usually relatively short (e.g., short-distance ferries crossing rivers and canals), traditional vessels will be converted to vessels with electric motors at the end of their life or engine replacement may be favored where possible.

Improve efficiency of trains, trams, and trolleys – Dutch railways mostly run on electricity, so most emission reduction should come from shifting more of the country's generation capacity to renewable power sources. We describe this shift in the following section.

We estimate that the cost of this set of measures will be approx. EUR 30 billion between 2020 and 2040. Our projections are built on a sequenced approach to implementing the changes described above, and are calculated as the difference in TCO between the low-carbon alternative and its conventional counterpart. This calls for implementing the lowest-cost, most advanced technologies now and gradually phasing in technologies that are still relatively expensive or less mature today. The projections also include the costs of installing electric charging stations, hydrogen fuel stations, and other types of infrastructure needed to support a wider array of powertrains.

Diversifying the fuels that power Dutch vehicles would cause the country's energy mix to change as well. Overall power demand would increase by about 60 PJ, and hydrogen demand would increase by about 20 PJ. Fossil fuel demand in the transport sector would decrease by more than 40 percent, resulting in a big improvement in overall energy efficiency and a major reduction in carbon intensity.

Residential and commercial heating

To reduce carbon emissions from heating (space and water) and cooking in residential and commercial buildings, we have considered two areas: enhancing insulation to an economically practical degree, and introducing new heating solutions.

For existing buildings, improving insulation to the standards of Energy Label B (net energy use of less than 1.3 GJ per meter squared) would lower heating energy consumption by approx. 30 percent. New buildings should be insulated up to the standards of Energy Label A (net energy use of less than 1.05 GJ per meter squared).

Half of the existing building stock would shift to low carbon heating sources: 18 percent would switch to biogas, 54 percent to a mix of ground and air source heat pumps, and 28 percent to district heating[11]. We assume that half of district heating comes from deep geothermal sources and the other half from industrial waste heat, incinerators, and other efficient, low-carbon sources. Except for those premises switching to biogas, cooking equipment would also have to change.

11 For alternative heating solutions, we partially follow scenarios developed by CE Delft and use their "15 neighbourhoods" classification with a more aggressive assumption around electric heating, and use these to estimate energy reduction potential and investment need.

We estimate that these changes will require an investment of approx. EUR 85 billion[12]: EUR 50 billion to improve insulation; EUR 33 billion to convert heat sources; and EUR 7 billion to pay for heat pumps rather than gas-fired equipment in new buildings, partly offset by EUR 5 billion of savings for avoided or reduced costs due to demolished buildings. For this sector, we have not taken into account partial recovery of these investments; for instance increased building insulation will lead to lower energy bills. Improving insulation in combination with other energy efficiency measures and changing heating sources in buildings would reduce the demand for fossil fuels by some 240 PJ per year, and roughly increase the demand for power by 40 PJ per year, for biogas by 30 PJ per year, and for district heating by 30 PJ per year.

Heavy industry

In our scenario, we assume that industry will achieve approx. 1 percent improvement in energy efficiency over 20 years, year on year, in line with the sector's own ambitions. In addition, we analyzed the possibilities for further efficiency gains and emission reductions in the chemicals and steel sectors, which together account for 67 percent of energetic industrial energy use today. It is (even) less certain which decarbonization measures or strategies will eventually play out in this sector– with CCS as an example of a technique that could make a difference. Moreover, entirely different products and processes may be used, requiring different energy sources.

Both sectors would focus on improving efficiency and using more electricity instead of other energy sources – except in those configurations where currently extensive waste (fossil) heat sources are used. Effectively, gas furnaces and gas boilers may be replaced by their electric counterparts. For this thought experiment, we allocated a budget for the steel sector for emission reduction. Technological options could include efficiency improvements and process changes such as the HIsarna process[13] – reducing CO_2 emissions by as much as 20 percent (excluding additional benefits from CCS/U, which if implemented could increase reductions to 80 percent). Another existing option is switching from coal-fired blast furnaces to woodchip- or charcoal-fired blast furnaces or to adopt a different steel making process and use biogas to produce direct-reduced iron (DRI), which can then be made into steel in electric arc furnaces. Other often mentioned technologies include electrolysis, hydrogen and 3D printing using scrap. All of which appear not ready for large-scale implementation. Alternatively, the sector could replace its existing furnaces with electric arc furnaces that use only recycled steel – reducing the overall quality of steel produced.

12 We believe this is the upper end of what costs will turn out to be, as learning curves for reducing for instance geothermal costs and electric heat pump costs may be expected and are not taken into account here.

13 In the HIsarna process (developed by Tata Steel IJmuiden), energy efficiency improves (up to 20 percent) due to the omission of certain preparatory steps in the iron making process. Moreover, if this were combined with CSS techniques, it is expected to reduce CO_2 emissions by 80 percent per metric ton of steel.

Implementing these changes in these two heavy industry sectors would require an investment of at least EUR 3 to 5 billion. Depending on specific technology choices and decarbonization targets, this amount could go up substantially. Assuming higher prices for biogas than natural gas and higher prices for electricity than for coal, the sector's annual operating costs would increase. Other options to consider would be to use low cost (excess) power to create relatively low cost hydrogen and steam for industrial processes. Potential changes in operating costs would have to be addressed in the context of international competition. Overall, following these measures, industry would see its energy demand fall by 215 PJ due to efficiency improvements, while increasing electricity demand by 122 PJ and its biogas demand by 33 PJ.

These investments, relative to current profit margins and investment levels and in the light of the international marketplace they operate in, are nearly infeasible without an incentive and investment structure that mitigates some of the negative economic effects on individual plants.

Box I – bunkering and aviation

Bunkering and aviation emissions are reported separately and are not subject to reduction commitments of Annex I Parties under the Convention and the Kyoto Protocol. This is why we have left them out of scope here. However, they represent a considerable share of carbon dioxide emissions supplied for on Dutch territory: Bunkering and international aviation together consume an additional 692 PJ on top of the 3,039 PJ (see Figure 3). For both bunkering and aviation carbon intensity of the energy carrier is relatively high and the corresponding CO_2e emissions amount to 42 and 11 Mtons CO_2e, respectively.

For aviation, the decarbonization pathway that is most often mentioned is biofuels or other liquid fuels (e.g. from renewables). Direct solar also has potential, but is still in its infancy (there is just one solar passenger plane flying). For bunkering, depending on the distance traveled, electrification may play a role. Similar to other heavy modes of transport, LNG may act as (intermediate) solution. Other solutions for longer travel distances (beyond 500 km) include replacement with or cofiring of biofuels and zero-carbon renewable/solar fuels like hydrogen, ammonia, and methanol.

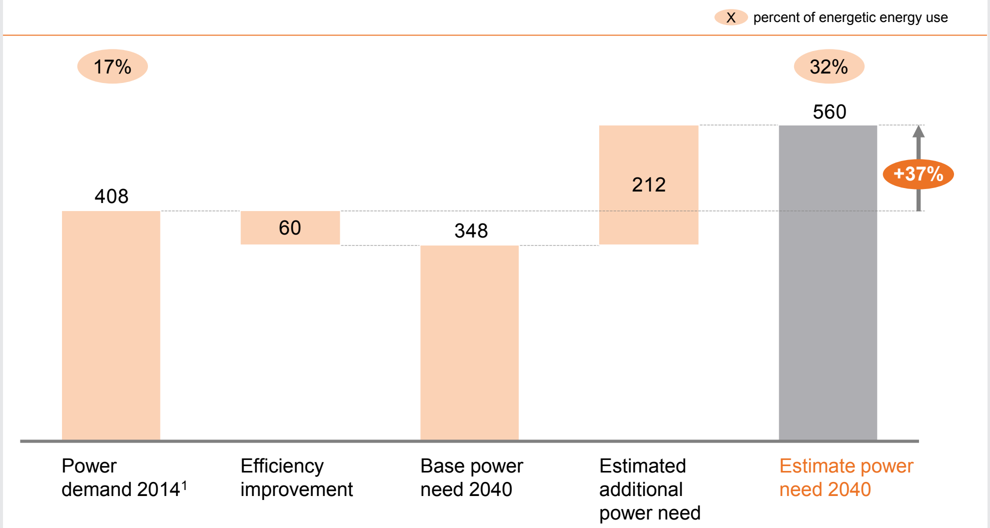
Decarbonizing the energy supply: one-third less energy, one-third more power

Under the scenario described above, the energy demand of the Netherlands would by 2040 be reduced by approx. 30 percent to 1760 PJ (Figure 4), while power demand would increase by 37 percent, to some 560 PJ (Figure 6). The country would also experience higher demand for bio-based fuels and feedstock (240 PJ vs. 117 PJ in 2014)[14] and lower demand for fossil fuels. In this scenario, all three parts of the national energy infrastructure – the electricity grid, the gas distribution network (with a split in high and low caloric gas), and fuel or bunkering stations – would also need to change significantly.

Figure 6

Power demand will increase by 37% to 560 PJ and will almost double its share in the energy mix by 2040

PJ



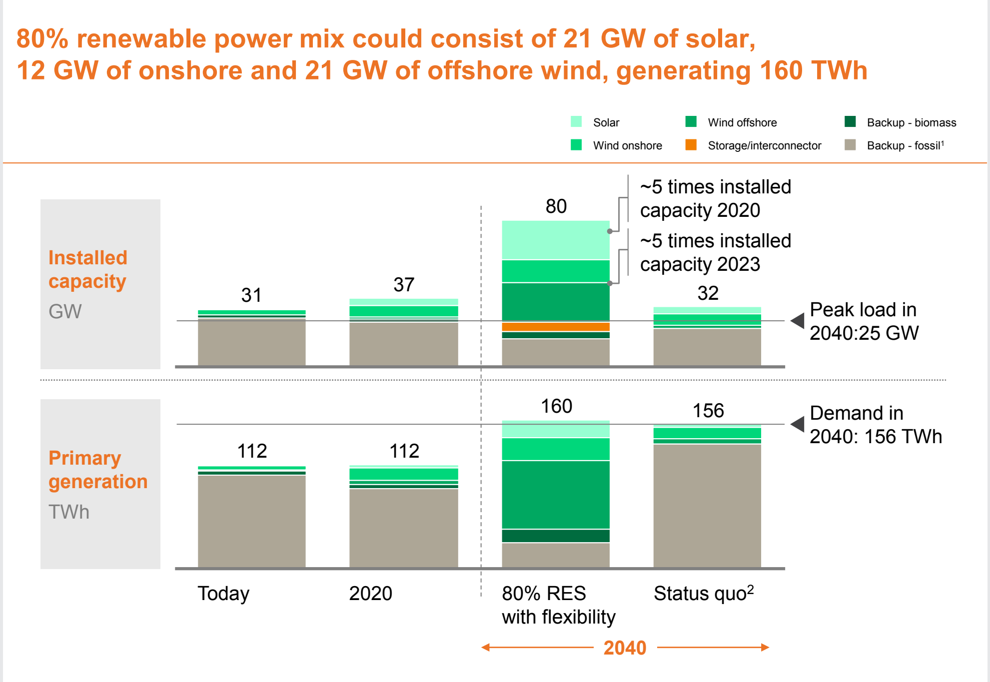
1 Including own use energy sector (20 PJ) and transmission and distribution losses

SOURCE: CBS Statline (2014 data)

Reducing the energy system's CO_2 emissions while accommodating a 37 percent increase in power demand represents a major challenge in terms of technology, economics, and implementation. To ensure decarbonization takes place, the installation of renewable power supply must proceed at the same pace as electrification. A system in which 80 percent of power comes from renewable sources could entail the installation of approx. 36 GW of additional power supply, at an annual cost of roughly EUR 10 billion per year, excluding transmission and distribution costs (Figure 7).

14 It has been estimated that 100 to 300 EJ of biomass can sustainably be produced per year. The Netherlands' "fair share" of this would be about 200 to 600 PJ per year. Hence, our relatively modest assumptions on conversion to biomass (e.g., no bio-based chemicals production yet, modest use of biogas for heating) already bring the Netherlands' biomass level above the lowest estimate.

Figure 7



1 Fossil includes gas, coal, oil, and also nuclear in 2014
2 Reference case covering power need with 2020 mix

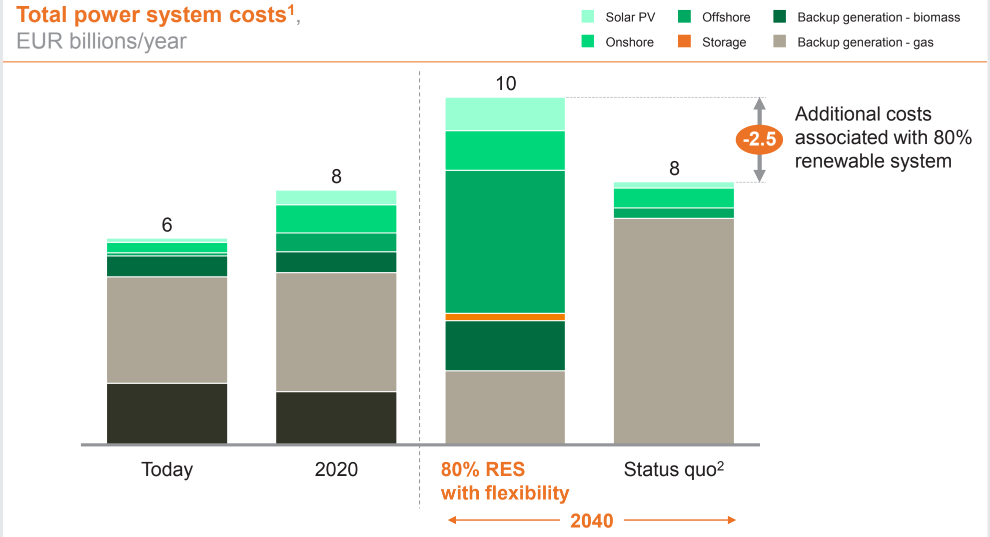
Introducing flexibility measures, however, could create a more cost-effective power system with higher capacity. Such flexibility measures include demand response and demand-side management, energy storage, and conversion of coal-fired backup generators to biomass-fueled ones. To run the electricity grid on 80 percent renewable power, a mix of for instance 33 GW of installed wind capacity and 21 GW of solar PV capacity could work. Some 24 GW of backup or storage capacity would also still be needed to cover residual peak demand. About 15 GW of the backup capacity would be powered by gas; the rest could consist of biomass-fueled capacity and long- and short-term energy storage (Figure 7 and 9).

The capex and opex required to set up the 80 percent renewable generation system described here amount to approx. EUR 10 billion per year, or about EUR 2.5 billion more than a fossil-fuel-reliant system (assuming that the costs of solar PV systems and wind turbines continue falling until 2040 and that oil prices recover to USD 70 per barrel) (Figure 8). Following these sharp price declines, the fully loaded unit cost of electricity[15] will increase from EUR 67 per MWh to EUR 79 per MWh including transmission and distribution. Of course these costs are subject to timing and actual developments in technology pricing.

15 These fully loaded system costs include fuel, operating and maintenance, and capital costs. They can therefore not be compared to the wholesale pricing mechanism which is based on short term marginal costs (i.e. fuel cost and O&M cost only)

Figure 8

Total system costs are 2.5 billion EUR above (fossil-based) status quo

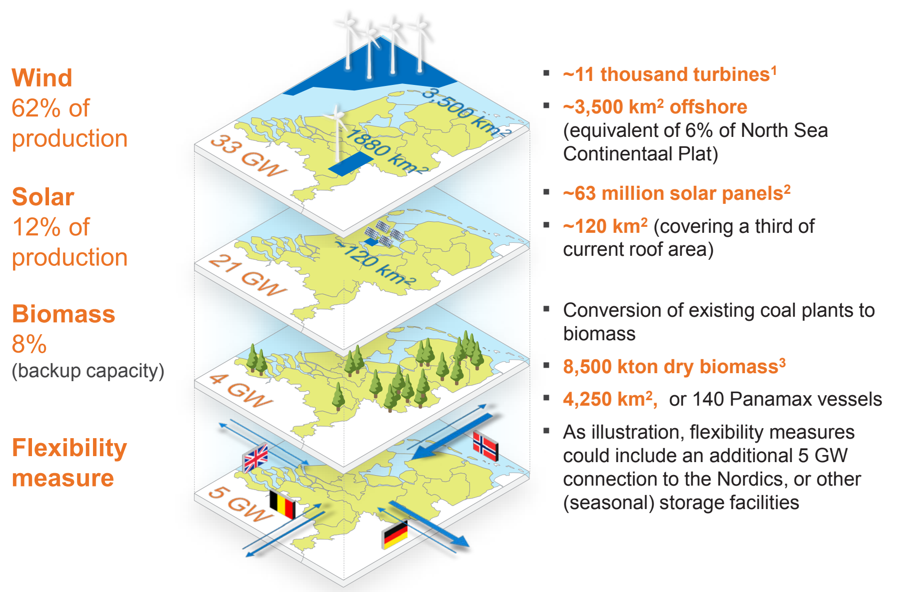


1 Includes capex, O&M, and fuel costs as well as (some) costs for the grid, 2 80% of renewable energy in power fed to the grid, but with high levels of curtailment – introducing flexibility measures improves cost of system
2 Reference case covering power need with 2020 mix

Figure 9

What could this "80% renewable power supply" look like?

EXAMPLE



1 45% capacity factor, turbines of 3 GW
2 1.65 m² per solar panel, 235 kW
3 17 MJ/kg biomass, 2 ktons/km²

Such a system would also result in a decrease in CO_2 emissions: 75 percent less, down from 51 Mtons per year to 13 Mtons (Figure 4, Figures 10 and 11, and 12). Most of the reduction would result from a steep drop in the use of fossil for centralized electricity production, from approx. 600 PJ to 223 PJ.

The resulting power system would also perform and look differently from today's (Figure 9). Its main features would include the following:

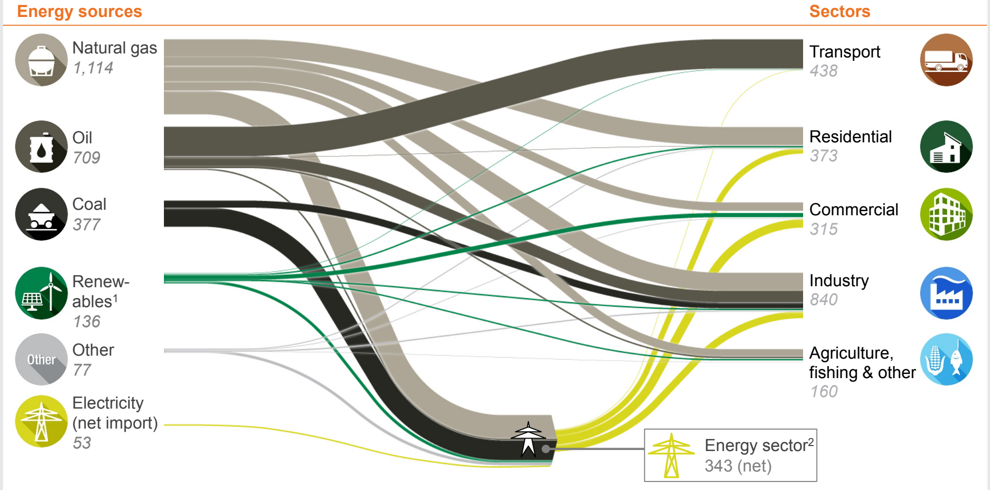
- A reliable, flexible transmission and distribution network capable of delivering the higher peak demand
- Balancing of the loads on the grid, across a "portfolio" of millions of EVs, heat pumps, and other electric power devices using demand-side management technologies
- The ability to store and manage excess power generated by intermittent renewable sources, such as solar and wind
- Consistent delivery of electricity throughout the day and night, throughout the seasons, drawn when necessary from stored energy or shifted moments of demand

The primary risks affecting the implementation of such a system will be related to financing and the need for developing a new market model. Investors will have to accommodate high upfront capital requirements and near-zero marginal costs; intermittent generation of power by wind and solar has to be integrated into the system as a whole; and year-round energy security needs to be ensured through the availability of backup or storage capacity with relatively low utilization rates.

Figure 10

In 2014 the energy system is largely dependent on fossil fuels

Netherlands energy demand in 2014; flow between energy sources and sectors, PJ

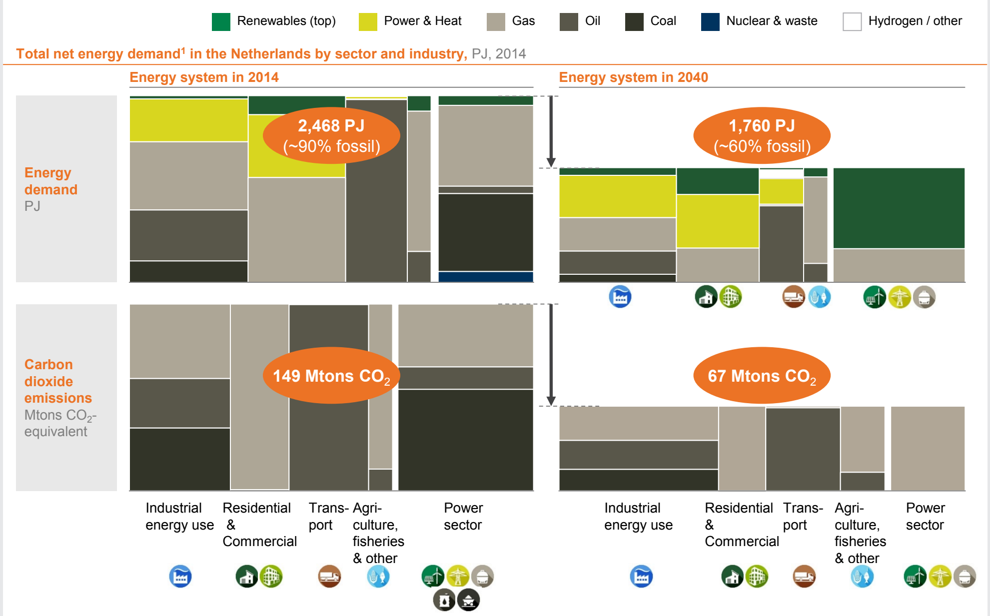


1 Includes: hydro, geothermal, solar, wind, and biomass
2 Only includes net use for central power production (320 PJ) and transmission and ditribution losses (23 PJ); energy sector own use (e.g., oil consumption in refining is included in industry)

SOURCE: Centraal Bureau voor de Statistiek (2014), "Energiebalans" and "Energieverbruik" databases

Figure 12

The new energy system would emit 55% less (= 67 Mton) CO_2

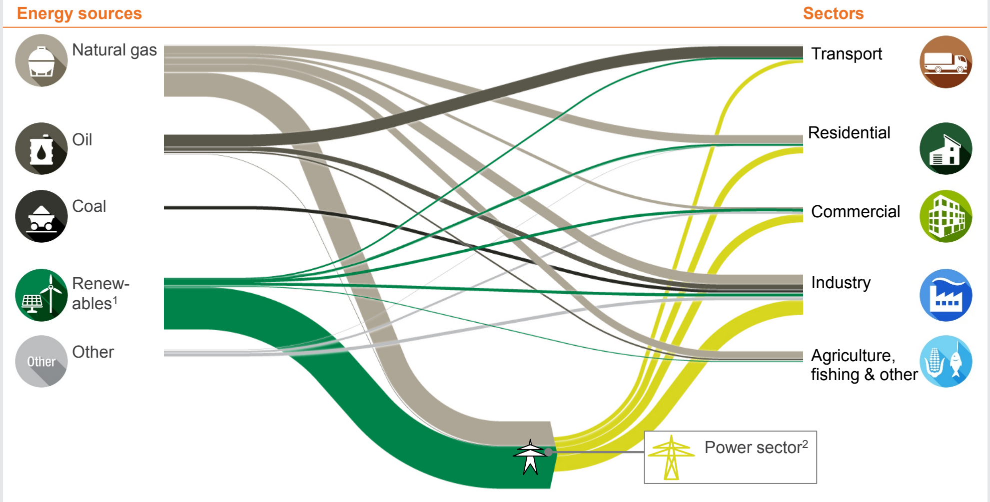


SOURCE: Estimated using: Central Bureau voor de Statistiek "Energiebalans" and "Energieverbruik" databases; National Inventory Report (2014)

Figure 11

In 2040, the energy system would look and function very differently

Netherlands energy demand in 2040; flow between energy sources and sectors, PJ



1 Includes: hydro, geothermal, solar, wind, biomass, and hydrogen
2 Includes net biomass use (94 PJ), gas use (111 PJ) and own use and transmission and distribution losses

Box II – what would happen when aiming for a higher target?

Our estimates of the economic impact of the Dutch energy transition are based on assumptions that the Netherlands will pursue emission reductions of 80 percent. But what if the Netherlands is required to meet the upper limit of the EU's target range: a 95 percent reduction by 2050?

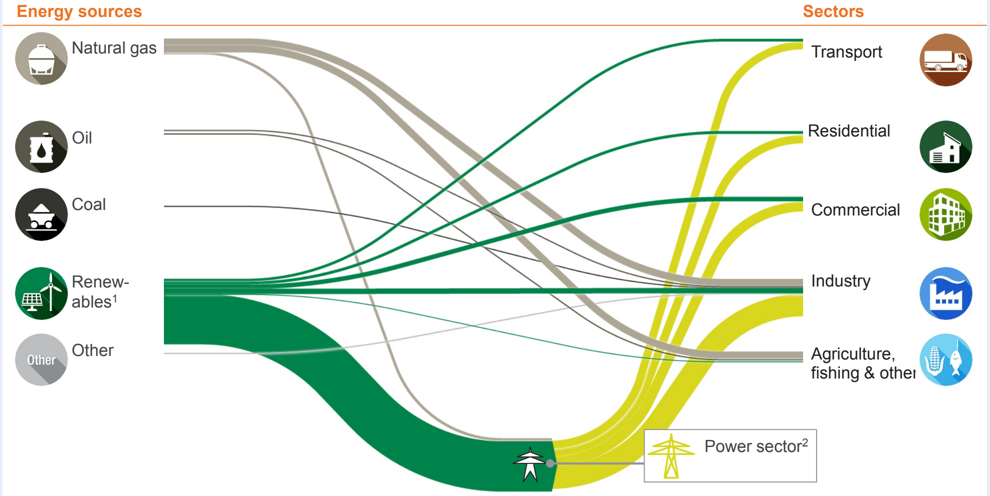
In such a scenario, we would expect that the Netherlands would double its power demand, increase its demand for other carbon-neutral energy carriers, and vastly reduce its dependency on fossil fuels. Funding such a transition would require much more investment, a total of EUR 300 billion by 2040, or EUR 15 billion per year.

The table on the next page summarizes the key differences between the baseline scenario outlined in this paper and the more ambitious scenario for a 80-percent reduction by 2040 (95 percent by 2050).

Figure 1

When striving for 80% reduction by 2040 the role of renewables increases further

Netherlands energy demand in 2040; flow between energy sources and sectors, PJ

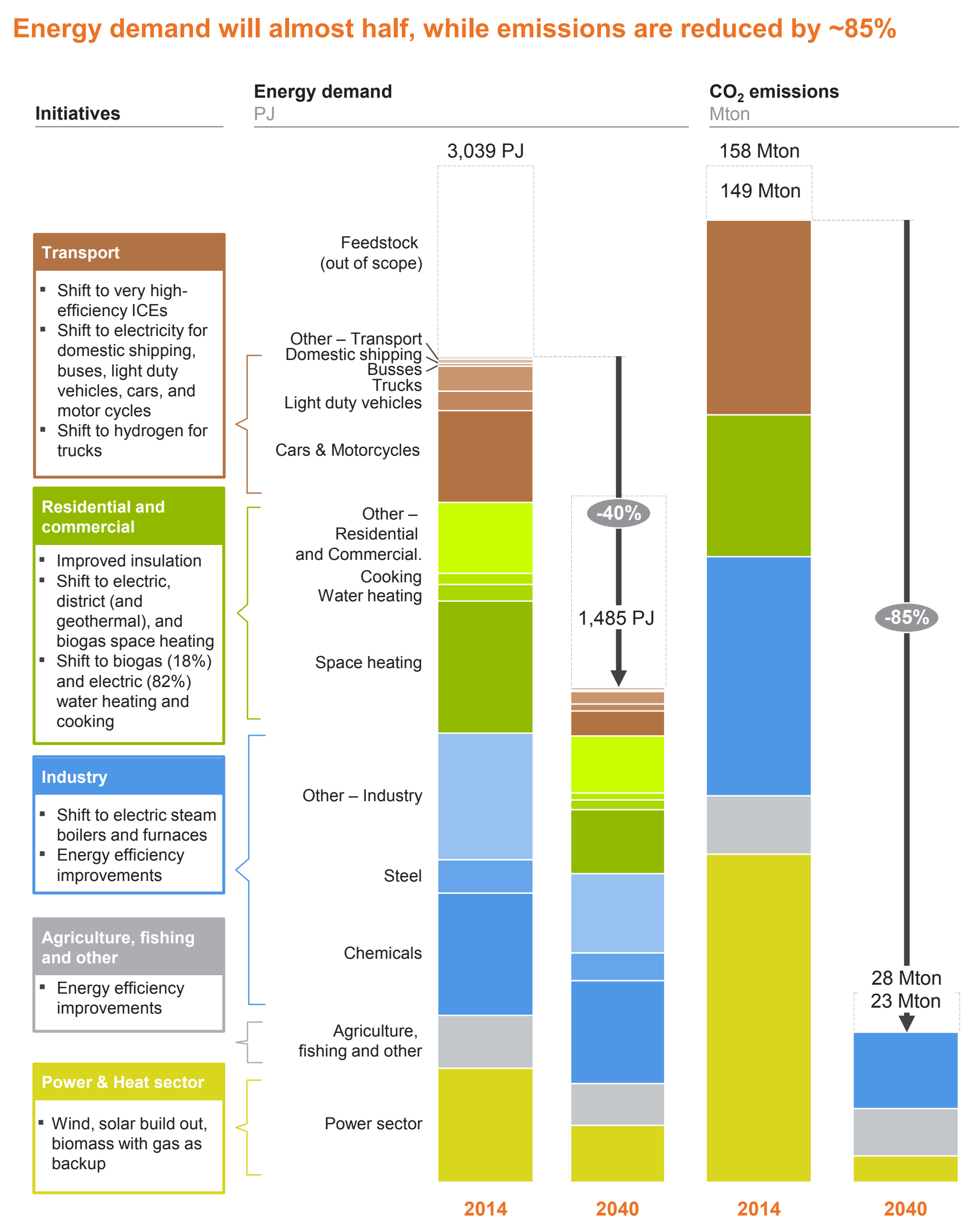


1 Includes: hydro, geothermal, solar, wind, biomass, and hydrogen
2 Includes net biomass use (94 PJ), gas use (37 PJ), and own use and transmission and distribution losses

Figure 2

		Baseline scenario used in the analysis – 80% by 2050	More ambitious scenario – 95% by 2050
2050 emission reduction achieved, total		▪ 80 percent (60 percent in 2040)	▪ 95 percent (80 percent in 2040)
Changes in main assumptions	Transport	▪ 50 percent of LDVs and busses to EV, 50 percent of trucks on hydrogen	▪ 100 percent of LDVs and busses to EV, 100 percent of trucks on hydrogen
	Heating	▪ 50 percent of buildings switch heating source	▪ 100 percent of building ▪ heating switched
	Chemicals	▪ Electrification of 50 percent of furnaces and boilers	▪ Electrification of 100 percent of furnaces and boilers
	Steel	▪ 50 percent of steel production to DRI-EAF	▪ 100 percent of steel production to DRI-EAF
Energy demand in 2040 (reduction vs. 2016)		▪ 1,760 PJ (-28 percent) ▪ 61 percent fossil-based	▪ 1,487 PJ (-40 percent) ▪ 26 percent fossil-based
Power generation capacity in 2040 (percent change from 2016)		▪ 80 percent RES: 78 GW ▪ 156 TWh (+38 percent)	▪ 95 percent RES: 137 GW ▪ 210 TWh (+90 percent), plus 59 TWh curtailment
Investment required, 2020-2040		▪ Total: EUR 200 billion ▪ Transport: EUR 30 billion ▪ Residential and commercial: EUR 85 billion ▪ Industry: EUR 20 billion	▪ Total: EUR 300 billion ▪ Transport: EUR 60 billion ▪ Residential and commercial: EUR 120 billion ▪ Industry: EUR 35 billion
Annual investment required		▪ EUR 10 billion	▪ EUR 15 billion

Figure 3



Maximizing the value of investments

How could we maximize the benefits of these investments? To take advantage of the changes, policymakers and business leaders should look for opportunities to maximize the value of the investments in a low-carbon energy system. We see four major ways in which to increase the efficiency of investments:

By creating nation-wide economies of scale and lowering costs in energy-related industries. A large-scale, well-planned program to decarbonize the Dutch economy should increase demand for low-carbon energy services and equipment, allowing companies to expand production and bring down costs. In the offshore wind sector, for example, capital costs depend heavily on wind turbine prices (approx. 50 percent of the capex), followed by foundation and installation (approx. 25 percent), cabling, and transmission. Equipment, installation, operations, and maintenance costs should all go down as the wind power sector grows larger (IRENA, 2012). Planning of energy projects with foresight of expected developments in demand over the coming decades could also lead to improvements in system design and integration that might reduce overall costs.

By avoiding investments in less-efficient equipment. Leapfrogging to carbon-neutral technologies could result in cost savings because households and organizations will avoid spending money on equipment that eventually needs to be replaced with low- or zero-carbon equipment. Moreover, asset owners would avoid being saddled with inefficient and carbon-intensive assets.

By attracting and stimulating new economic activity in target sectors. Creating a clear vision and road map to build sectors with attractive economic activity. Automakers and battery companies, for example, might find it advantageous to locate factories in a country where people and companies will purchase 200,000 – 400,000 EVs per year. The Netherlands is already home to the biggest assembly factory of Tesla's in Europe. Similarly, the Netherlands could be an attractive location for offshore wind equipment manufacturers and installers, with reliable demand for more than 1 GW worth of turbines per year. Likewise, focus on innovation and R&D around solar/wind fuel development and further integration of renewables in the system could further stimulate economic activity. See Box III for more thoughts on this topic.

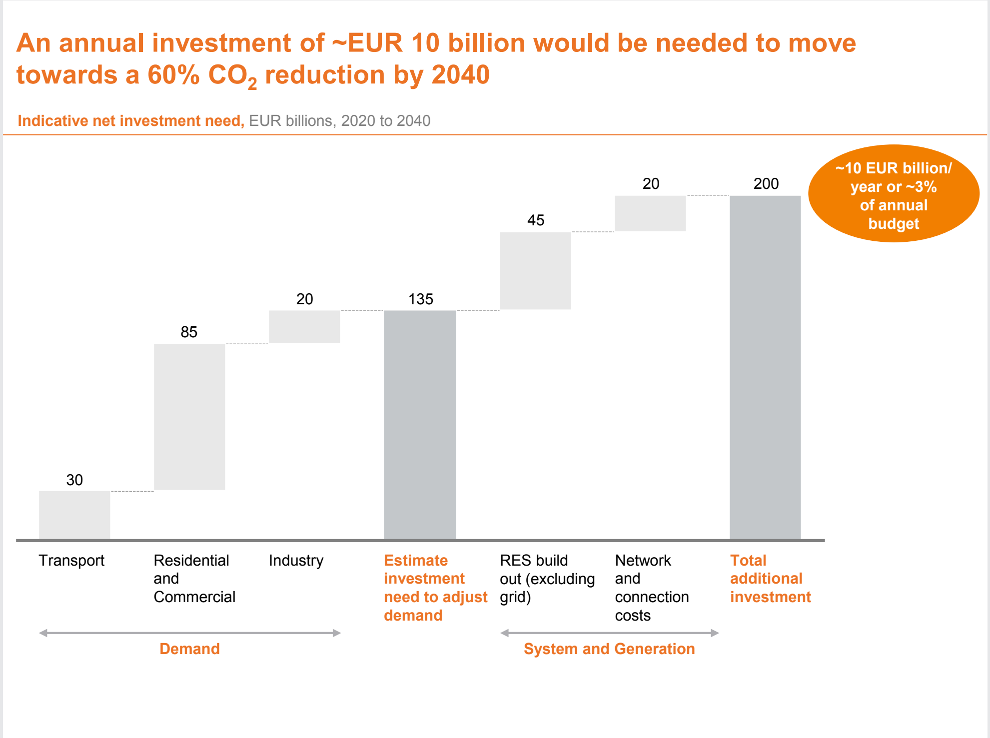
It is important to stress is that the focus of the new economic activity should be on those activities where the Netherlands has the potential to be(come) a differentiator, a leader on European or world-scale.

By transforming adjacent economic sectors. The energy transition could spur investment and innovation in supporting fields such as finance and technology. Financial institutions, for example, might create new deal structures to lower the risk of making large investments in energy assets. Further changes are likely to ripple through additional sectors of the economy, bringing about still more economic gain.

Estimating the economic impact of the energy transition

Our analysis suggests the Netherlands can create economic value by accelerating its transition to a low-carbon energy system. We estimate that this accelerated transition will require annual investments of about EUR 10 billion between 2020 and 2040, or EUR 200 billion in total (Figure 13)[16]. While this is a substantial amount of money – more than the EUR 8 billion per year that the Netherlands now spends on infrastructure and environmental protection – our analysis suggests that the investment could have a positive effect on GDP. This increase would come from three effects on the Dutch economy.

Figure 13



The economic effects of investments. Increasing the level of investment account for the first tranche of the GDP increase associated with an accelerated energy transition. Our initial economic projection, developed using the McKinsey Global Institute's Global Growth Model, suggests that an accelerated energy transition would provide a modest boost to GDP of approx. 0.8 percent (from 1.9 percent growth to 2.7 percent). The final compound impact of new investments in 2040 results in real GDP higher by approx. +1 percent compared to the baseline, assuming that overall investments are spread out evenly over time (10 billion/year). This GDP increase is in line with the earlier estimated GDP change of -0.2 percent and 1.8 percent for the entire EU (ECF, 2015).

16 It should be noted though that potential negative impacts from reduced (global) fossil fuel consumption (e.g. less throughput in the ports, lower revenues for oil majors) are here considered as 'business as usual' - happening in any case if the world moves towards a low carbon world.

Depending on the eventual balance between public and private investments and the corresponding financing structure and associated risk profile, this impact may turn out lower or higher.

Beyond the economic effects that the Global Growth Model accounts for, we see additional economic effects that could lift GDP further, also in the longterm:

- The Global Growth Model does not account for changes in the level of investment across particular sectors. By triggering changes in energy demand and generation, an accelerated energy transition could increase investments in sectors with moderate to high economic multipliers, such as construction (0.96) and vehicle sales and maintenance (1.00). We project that this will, at least in the near term, have an additional positive impact on the overall economy.

- A relative increase in investments in innovation, research, and development often have positive effects on the economy, but have not been quantified as such.

The economic effects of changes in the Netherlands' trade balance. Additional GDP gains should result from the reduction of fossil fuel imports as domestic use of fossil fuels decreases and electricity generation increases. We estimate that the Netherlands will gradually shift from importing 67 percent of its fossil fuels to importing less than 50 percent of them, even when compensating for reducing gas production. Energy costs would decrease slightly overall, and a net benefit of EUR 8 billion can be realized. This would increase GDP by approx. 1 percent (Figure 14). This effect will play out only as long as global trade flows do not change significantly (and the Netherlands thus acts ahead of the curve) and is highly sensitive towards oil and gas price changes.

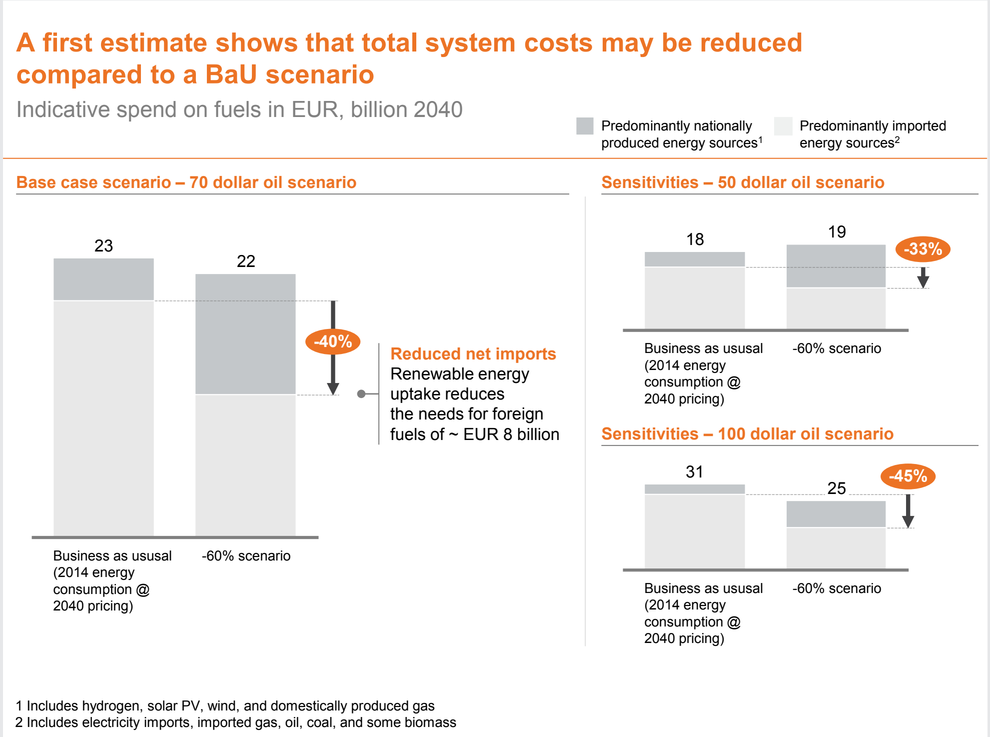
The economic effects of new industrial or other economic activity. Investments in areas as highlighted in Box III should over time produce additional GDP gains and positively impact employment. For example, doubling the current automotive supply business of approx. EUR 9 billion would result in a GDP increase of 1 percent.

The corresponding impact on employment

Impact on employment may overall be seen over the course of three horizons. Realization of course also depends on whether new skills and capability requirements can be met in time.

In the short to medium term, a positive effect will be seen following installation efforts. Overall, we expect the energy transition to create 45,000 or more jobs, all primarily related to installation (Figure 15). These numbers are in line with earlier projections (e.g., from the Energieakkoord where investment of EUR 3.3 billion was supposed to lead to job creation of about 15,000). Some of these jobs would be in companies that will experience heavy demand in the near and medium term (for example, companies that install insulation in buildings). Others will experience most demand in the medium term (e.g., installation of offshore wind, which may continue as power demand continues to rise).

Figure 14

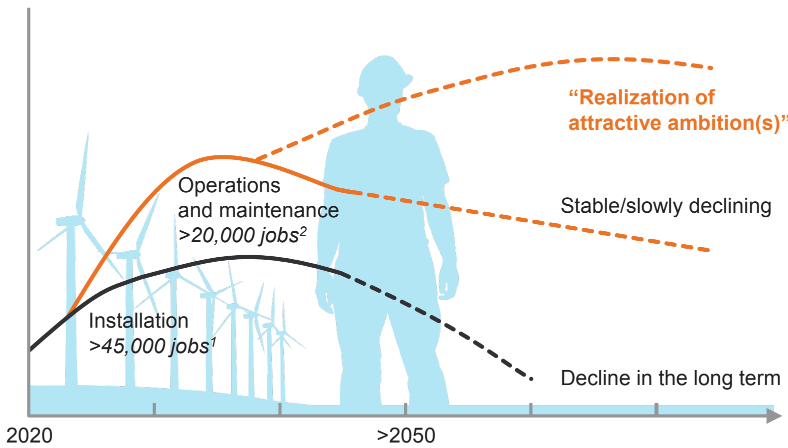


The economic multipliers of particular sectors also influences the effect of investment on short- to medium-term employment. Sectors that are likely to attract more investment during the energy transition, such as construction and automotive assembly, have relatively high employment multipliers and rising demand for low-skilled labor. Sectors that are likely to receive less investment, notably fossil-fuel sectors with high capital efficiency, have relatively low employment multipliers. Accelerating the energy transition should therefore lead to more job creation. For example, we estimate that the automotive sector will add 8,000 jobs and the building sector will add 27,000 jobs as the energy transition takes place.

Over the medium and long terms, operations and maintenance jobs should also multiply. The power sector, in particular, should gain jobs because renewable energy generation requires more jobs per MWh than nonrenewable energy generation. It could take longer for the renewable power sector to add jobs, but those jobs are less likely to disappear. For example, operations and maintenance of distributed solar PV and offshore wind installations should require at least 20,000 additional jobs. And as the operations and maintenance activities of transmission and distribution services companies increase, they will likely need to hire more workers. Employment in other sectors involved in the energy transition could be stable or even decline slightly. EVs, for instance, require less maintenance than vehicles with internal-combustion engines.

Figure 15

Potential job creation: the "real" long-term impact should come from realized ambitions



1 Includes installation of wind offshore, solar PV, improving insulation and replacement of heating equipment; alternative reference: Energieakkoord investment of ~ 3.3 EUR billion/year for a short period is expected to lead to 15,000 extra jobs. Applying similar logic to 10 EUR billion/year investment also gives 45,000 extra jobs/yr. Highest impact expected from installation of offshore wind, followed by building insulation

2 Delta between employment in renewable power generation and fossil generation, corrected for installation job increase. Changes in other sectors not included in this number

In the long term, if the energy transition has the expected effects on the economy, demand for workers should rise, driving up employment and wages. For example, opening a facility the size of Tesla's Gigafactory to accommodate domestic EV demand would add 6,500 jobs. The creation of these jobs could over time offset job losses in fossil-fuel-related sectors, and losses in sectors that experience structural shifts because of higher labor productivity or new technology.

Box III – capitalizing on the energy transition: opportunities for the Netherlands

For the Netherlands, a comprehensive transition to a low-carbon energy system could create ample opportunities for innovation and industrial development. Decarbonizing certain sectors of the Dutch economy will require investment and change on a scale that is as ambitious as some of the biggest and most renowned energy projects in the world. Replacing the Netherlands' entire car fleet with 400,000 cars per year, for example, would require a battery factory the size of Tesla's giga-sized factory, one of the largest manufacturing operations in the world.

In other areas, the Netherlands' energy transition will make a more modest contribution to global activity. Producing enough solar PV arrays to accommodate the Netherlands' needs will add a bit less than 1 percentage point to global solar PV demand.

Perhaps the most promising opportunities for the Netherlands lie at the intersection between its existing capabilities and the requirements of the transition. We see several existing strengths that could give the Netherlands a particular advantage in markets for low-carbon energy technology:

A sophisticated (petro-)chemicals industry, spanning the value chain from petroleum refining to specialty-chemical manufacturing

A well-developed, diverse offshore (wind) industry, with construction and maintenance companies as well as data and analytics providers, oil and gas producers, and utilities companies

A world-class transport and logistics sector that includes the ports of Rotterdam and Amsterdam, and Schiphol airport

A growing and innovative automotive and charging infrastructure business, with ca. 300 automotive supply companies and a revenue stream of EUR 9.2 billion (2015). Several charging infrastructure companies are at the forefront of developments and rollout of charging infrastructure

Innovation and research and development capacity provided by 13 universities, more than 40 institutes of applied science, and public and private R&D centers with an annual budget of approx. EUR 10 billion

Extensive energy connectivity with the rest of Europe, visible in the Netherlands' standing as Europe's second-largest importer of energy and second-largest exporter

High population density (412 inhabitants per km^2) and Europe's highest motorway density (0.06 kilometers of road per km^2), which make the Netherlands an ideal setting for innovation in infrastructure and mobility.

We believe these capabilities and characteristics could position the Netherlands to pursue ambitions in energy-related sectors, including:

'New' transport. Developing the capabilities to meet domestic demand for EVs and other zero-carbon transport could enable the Netherlands to also become a source for goods and services to support electric-powered forms of transport. This could range from batteries and EVs to technology systems required by next-generation modes of transport like autonomous vehicles. The relatively dense infrastructure setting could provide a good testing ground, for instance in developing innovative city plans, and systems for integrating multiple transportation modes.

Sustainable building heating. The Netherlands as a (technology) leader for climate control systems and residential energy management, possibly building on previous experience of rollout of (gas) infrastructure in the 1960s.

Heavy industry transformation and CCS/U. The presence of leading heavy industry such as steel and petrochemicals, can provide an opportunity to support their innovation towards lower carbon production. The depleting (offshore) gas fields and existing dense infrastructure, as well as deep geological expertise together offer a unique starting point for CCS. CCU, where CO is used as chemical feedstock, could go hand in hand with the above mentioned innovation in renewable fuels.

Offshore wind. The Dutch and global offshore wind industry is likely to grow to meet rising demand for renewable energy, requiring significant investment and powering industrial development in multiple categories. This includes pylons, substations, and transmission and distribution lines. The Netherlands could also play a vital role in linking the electricity grids of countries around the North Sea, which would make cross-border balancing of energy loads possible.

Integrating renewables with the energy grid. An innovative chemicals industry gives the Netherlands the potential to advance the creation of energy storage and transport systems. New technologies for converting excess renewable energy to fuels that can be stored and transported could strengthen the role of both Dutch chemicals players as well as transport and storage players.

Charting a way forward – careful planning and coordination

For the Netherlands, an accelerated transition to a low-carbon energy economy could generate substantial economic benefits. Realizing those benefits will, however, require effort and investment on a major scale. It will also require careful planning and coordination. Each economic sector will require its own approach, taking into consideration such factors as the availability of investment capital, the maturity of the necessary technology, the need and opportunity for international collaboration, and the willingness of society to support the transition. Each of these approaches needs clear targets so that investments and efforts can be applied effectively, but also has to be flexible to enable accommodation of new (technical) solutions and opportunities as they arise.

Governments can support the transformations of energy systems in any number of ways, from incentive schemes to direct investments. Three suggestions can help Dutch leaders and officials to design an effective policy program to accelerate the energy transformation:

- **Develop a master plan for each demand sector**. Such a master plan should, at minimum, identify investments and regulations that will enable the private sector and the social sector to support changes in the energy system. To develop these plans, the government might define a vision for 2040/2050 in terms of specific targets and work back from that vision to set intermediate targets and steps. A long-term outlook on energy supply and demand is critical to unlocking investments that have extended payback periods, because it helps give consumers and businesses more certainty about their investment prospects.

- **Use long term value for the Netherlands as the main variable to optimize emission reduction schemes and GDP stimuli.** The Netherlands can structure its energy-transition plans to attract investments and expand the country's economic, industrial, and technological capabilities. This will help the country to capture more economic gains than it might by relying on foreign expertise and imported goods. These plans should account for the real cost of interventions and then factor in business-related matters, such as returns on investment, or policy-related matters, such as taxation. Transition planning should also consider opportunities for the Netherlands to position itself as a global leader in energy innovation, engineering, and product development.

- **Put public incentives, including tax policies, in the context of the master plans mentioned above.** Incentives will have to work within the longer-term horizon of the transition. They should also align the financial, legislative, and physical properties of the energy system with the interests of citizens and major energy consumers.

Annex I – methodological background

Scope of this thought experiment

The scope of this paper is for reasons of simplicity confined to the geography of the Netherlands, but taking into account European energy transport and storage systems, the entire energy value chain (downstream, midstream, upstream), and follows generally excepted prospects (e.g., for technology advancements, price developments and GDP). We do not aim to provide nor advocate a specific solution – but merely look at the implications of a set of design choices around demand and supply. We are excluding CCS as a solution for now, for simplicity. We have not explicitly used a carbon pricing perspective, which could help increase the speed of fuel switching and/or partially co-fund measures suggested. As you will find, this paper builds on previous work around the EU road map 2050 work and does not intend to provide a (McKinsey) forecast or (policy) recommendation.

Assumptions

In general, we follow CBS/PBL outlooks for 2040 for GDP growth (1 to 2 percent p.a.) and population (17.8 million inhabitants) (Manders, Ton (PBL); Kool, Clemens (CPB), 2015) (de Jong & van Duin, 2012) to look at changes in demand. For the part of the energy demand we do not address with specific measures, we subtract a net energy intensity improvement CAGR of 1 percent between 2020 and 2040. For all calculations we assume oil price to recover and stabilize around USD 70/bbl and electricity prices to rise with 20 percent (from 5ct/KWh to approx. 6 ct/KWh).

Transport

In the realm of transport, besides technology switches, three other major trends may play out over the coming 20 years: diverse mobility (including car sharing), increased connectivity, and autonomous vehicles. All of which will have an impact on the number of vehicles, the distance traveled per vehicle and the way in which vehicles are used. In addition, apart from (major) efficiency gains associated with powertrain shifts, further improvements resulting from integration of advanced materials, hydrodynamic surfaces, or system operations are not included here, but will also influence (power) demand. Overall, all estimates are highly dependent on assumptions of battery and hydrogen fuel cell cost developments as well as changes in oil, electricity, and hydrogen pricing.

Switching over from ICE of light duty vehicles, heavy duty vehicles, and ships will have implications for infrastructure, both inside and outside the Netherlands. In the case of 4 million (out of 8 million) passenger vehicles, we assume that 4 million charging stations could and should be sufficient – especially as current car utilization is about 4 to 8 percent leaving plenty of time to charge and the combination of increased connectivity, diverse mobility, and autonomous driving may collectively increase the efficiency of the system. For buses we calculated TCO for opportunity e-buses which aim to minimize the weight of the battery by recharging en route at passenger stopping points. For trucks we took into account domestic infrastructure changes (e.g. hydrogen fuel stations) – no cross-border adjustments or investments.

Residential and commercial

We partially follow scenarios developed by CE Delft and using their "15 neighbourhoods" classification (CE Delft, 2015), with a more aggressive assumption around electric heating and use these to estimate energy reduction potential and investment need. Many factors will influence the choice of application of heating solutions for buildings: age and state of gas network (i.e., in the old city centers these may be up for large-scale maintenance or replacement), building density, type of building, state of the building (including newly built vs. existing), proximity to alternative heat sources, and cost development of other techniques like geothermal. The trend seems to be towards more electric heating though, where a combination of top-notch insulation, triple glazing, electric boilers, air-source or ground-source heat pumps, and decentral solar PV or boilers, leads to low-rise "net-zero energy" homes. For high-rise buildings and in densely populated areas district heating networks may be the more economical solution. We further assume that 100 percent of the new built houses (representing approx. 15 percent towards 2040) will switch to electric. This may be an overestimate as the current trend seems to be district heating for new neighborhoods (e.g., following concessions in Utrecht and Amsterdam). For district heating in the near term waste heat sources may be connected, but as industry will keep focusing on improving energy efficiency and may also switch to renewable sources this heat source may reduce significantly in the long run.

Heavy industry

Our investment estimate is based on the following logic and assumptions: switching upstream heaters (e.g., gas-fired steam boilers and furnaces) to power is in most cases less complicated than switching the heat exchangers downstream. Equipment using fossil-fueled energy covers 10 to 20 percent of installed capex. Replacing equipment at technical end of life or during major overhauls implies that only the delta in investments between the fossil fuel-fired and the electric heating system have to be included. Replacing old equipment with the new equipment during planned maintenance shutdowns cycles (every four years) may help to keep non-running costs down. Operational cost delta is conservatively based on current price delta's between fossil mix used and same consumption level of 129 PJ as electricity.

Impact of investments

On the impact on GDP, we have used our McKinsey Global Institute Global Growth Model to assess the impact of the set of measures on the Dutch economy and looked at multiplier tables (based on input-output tables of CBS) for deep dives on specific sectors. Spillover effects across the wider economy resulting from investment in R&D and innovation have been shown before, and may also play a role in this case, but have not been quantified as such.

Annex II – implications for generation

A first exercise to look at maximizing the share of renewables while minimizing annual cost of system (capex, O&M, and fuel cost) shows that a system with 80 percent renewables would cost about EUR 12 billion/year (Figure 7). We are assuming 90 percent centrally and 10 percent decentrally installed solar PV with decreasing costs to 54 EUR/MWh in 2040. For offshore wind costs are assumed to go down to EUR 51/MWh.

Adding more wind and solar PV generation beyond an approx. 60 to 75 percent renewables scenario inevitably leads to higher curtailment levels and thus cost levels if curtailed power cannot be used otherwise. Introducing flexibility measures like demand side management, storage, and coal to biomass conversion of some of the backup generation would create a more cost effective system, producing more power with more capacity. For biomass we assumed conversion of 4 GW of coal plants running at 35 percent load factor. For the resulting generation of 14 TWh, 8,500 ktons of biomass (filling 150 Panamax ships) is needed (17 GJ/ton). For illustration, longer- term storage could be covered through enhanced connectivity to the Nordics accessing pumped hydro (e.g., a cable of 5 GW). Overall, about 15 GW of (mostly gas-fired) backup capacity would still be needed (vs. 26 GW in 2020). Utilization of the fossil backup will be a lot lower though, generating 15 TWh of primary production vs. approx. 86 TWh today, thus calling for an alternative financing and pricing system. It should be noted that towards 2050, even with increasing renewables share towards 95 percent a higher amount of backup capacity may be needed (28 GW) to accommodate further increases in power demand.

Concerning the other energy carriers: demand for hydrogen will increase by 20 PJ, driven by presumed demand of hydrogen fuel cell trucks. Demand for biogas/biomass comes from build environment shift to biogas/green gas (18 percent of demand; 27 PJ), steel production using DRI (33 PJ), and biomass needed in power generation (converting existing coal plants to biomass plants – 144 PJ).

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