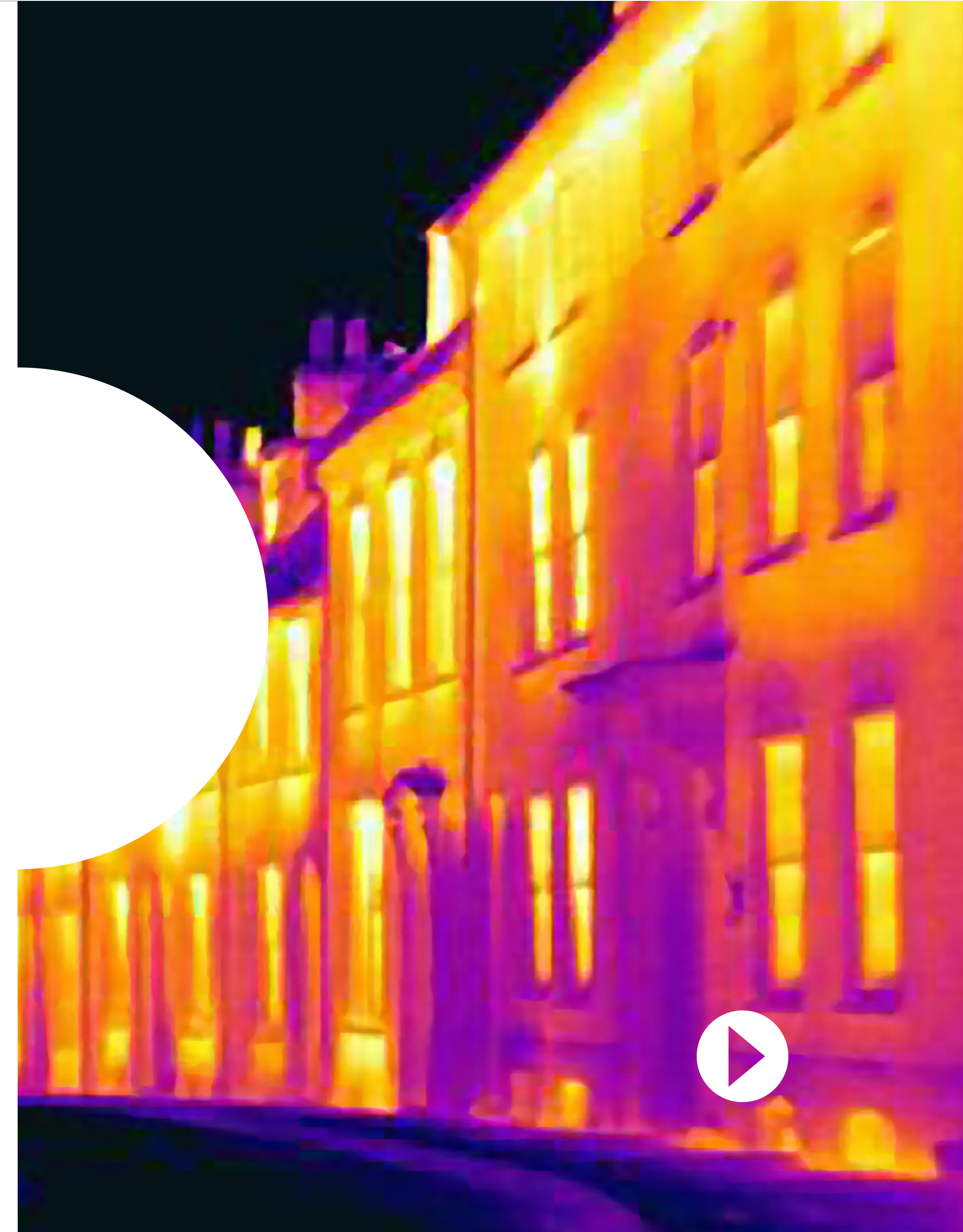
A PROSPEROUS NATION WITHOUT CO_2

TOWARDS A SUSTAINABLE ENERGY SUPPLY BY 2050

SEPTEMBER 2015



Rli Council for the Environment and Infrastructure

About the Council for the Environment and Infrastructure

The Council for the Environment and Infrastructure (*Raad voor de Leefomgeving en Infrastructuur,* Rli) advises the Dutch government and Parliament on strategic issues concerning the sustainable development of the living and working environment. The Council is independent, and offers solicited and unsolicited advice on long-term issues of strategic importance to the Netherlands. Through its integrated approach and strategic advice, the Council strives to provide greater depth and breadth to the political and social debate, and to improve the quality of decision-making processes.

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CONTENT

ADOPTING A NEW PERSPECTIVE IN ORDER TO BRING ABOUT TREND CHANGE

This advisory report was prepared in response to a question that Henk Kamp, Dutch Minister of Economic Affairs, posed to the Council for the Environment and Infrastructure (Rli; 'the Council'): how can a fully sustainable energy supply be realised by 2050? This advisory report accordingly focuses on the period after that covered by the Social and Economic Council (SER) Energy Agreement, which the cabinet and its social partners made in 2013. The goals defined in the latter agreement relate to the period up to 2023, whereas energy policy and investment plans require a longer horizon.

The Council notes that both the energy debate and energy policy have narrowed in recent years to focus on specific sources and sectors. Attention is consistently given to the quantitative input, the means of promotion, or the tools for discouraging use of a given energy source. Such fragmentation often results in strong polarisation of the social and political debate. That in turn leads to protracted discussion – as was the case within the Council itself – which acts as a brake on transition towards a sustainable energy supply. The Council also notes that, since 1990, the CO_2 emissions attributable to energy supply have not fallen, despite the Netherlands having pursued climate policies for at least two decades. In view of those two observations, the Council has opted for a new perspective; a new way of conducting the energy debate and defining energy policy.

The Council proposes directing the energy transition towards a clear, fixed and uncontested goal. The overall national goal should be to cut greenhouse gas emissions by 2050 to a level 80 to 95 per cent lower than the level in 1990. Where the Netherlands' energy supply is concerned, that implies that by 2050 energy-related CO_2 emissions must be between 82 and 102 per cent lower than corresponding emissions in 1990. Hence, the maximum scope for energy-related CO_2 emissions is 30 megatons.

The Council recommends that the government legislates to formalise the reduction goal referred to above. Statutory status would ensure that the goal becomes a strong guiding principle. It would also indicate clearly to the Dutch public and business community that climate change is a serious problem that requires urgent action. Legislation would also yield a clear perspective and ensure that the current administration and future administrations are committed to realisation of the goal. Realisation of the CO_2 reduction goal must take priority, even if that implies major economic and social change in the Netherlands, coupled with high costs and (renewed) debate about the allocation of responsibility.

By international standards, the Dutch economy is relatively energy-intensive. It is also largely fossil-energy based. Consequently, transition to a low-carbon energy supply will involve greater change for the Netherlands than for many other countries. However, that cannot (any longer) justify the Netherlands being reticent about the pursuit of energy transition.

The Netherlands should make definite reduction commitments in the fields where the country can act independently without undermining its international competitiveness. In addition, the Netherlands should commit itself to working in the European and international political arenas to get the goal of a low-carbon energy supply enshrined in European law. That would imply the Netherlands seeking to secure agreements – preferably at the global level but otherwise at EU level or, failing that, amongst forward-looking European countries – under which international industries are obliged to realise emission reductions. The Netherlands has nothing to gain by unilaterally imposing requirements on international industries, because that would simply lead to the relocation of companies and activities. Hence, global CO_2 emissions would be unaffected and the ultimate purpose of Dutch policy would be frustrated. It should also be recognised that the adoption of ambitious goals by the Netherlands, even in the context of international agreements, will necessitate major structural economic changes in the country's energy-intensive industries and energy sector. The realisation of such changes represents a huge challenge, for which support is required in the form of long-horizon result-led innovation programmes.

The realisation of such ambitious aims is possible only if the pathway is monitored by an independent person or body that has no stake in the process. The Council accordingly recommends the appointment of a government commissioner to drive and oversee transition and to ensure continued progress towards realisation, unaffected by governmental succession.

The year 2050 may sound a long way off, but the task in hand is sizeable and the aims are ambitious. Nevertheless, the Council believes that the scale of the technical and social uncertainties preclude detailed definition of a pathway. Again, therefore, an alternative perspective is required: we must stop considering the task from the viewpoint of our current situation and turn our attention to the future. We must also broaden the debate, instead of concentrating on particular sources and sectors. Hence, the starting point of this advisory report is the basic social needs that energy must fulfil and must continue to fulfil in 2050. In that context, the Council has identified four functionalities: i) low-temperature heat for heating buildings and providing hot water; ii) high-temperature heat for industrial purposes; iii) transport and mobility; iv) power for lighting and electrical appliances.

Transition will differ markedly where each of the four energy functionalities is concerned – in terms of the innovations required, the degree of dependency on other countries, the number and nature of the actors involved, and so on. There will consequently be differences in how quickly transition can be realised. We envisage, for example, that transition to the desired low-carbon scenario can be achieved more quickly where low-temperature heat is concerned than where high-temperature heat is concerned. General policy tasks also exist, which transcend the energy functionalities: innovation, market mechanisms, finance, energy awareness, spatial requirements and behaviour. Although the way that such tasks are performed will necessarily differ from one energy functionality to the next, the common nature of the tasks means that general change must be effected.

This advisory report outlines the basic conditions that must be fulfilled in order to bring about the required trend changes. Policy stability is very important for the realisation of transition. The state itself will need to adapt to life in a world with a different energy supply – changes in the income flows linked to the extraction and use of fossil fuels will have budgetary implications, for example. The government's role will be to create appropriate conditions and to work with social actors and the business community to bring about progress. However, scope for innovation must also be allowed. The Council therefore recommends that – in view of the time scale, the uncertainties and the potential for acceleration – the transition should be managed on the basis of adaptive pursuit of a fixed objective. To a large extent, the mechanism for providing such management has yet to be designed and established.

The route to the fixed CO_2 reduction objective will therefore need to be defined flexibly, via four transition pathways. That implies a sizeable challenge for the government, society, the business community, social organisations and knowledge centres. An adaptive innovation policy is required, which enables new directions to be followed, as circumstances demand and as new technology becomes available. Such a programmatic approach will energise the transition, the Council believes. It will create opportunities for new actors, new associations, new finance models, new technologies, new ideas, and so on. All those things are urgently needed for the energy transition and all are things that the Netherlands has an outstanding capacity to provide.

1

BACKGROUND TO AND PURPOSE OF THIS ADVISORY REPORT

Box 1 A sustainable energy supply

The Council defines a fully sustainable energy supply as a low-carbon energy supply that is secure, safe and affordable.

For the Netherlands, that implies that, by 2050, greenhouse gas emissions[1] must be 80 to 95 per cent lower than they were in 1990. That overall national objective is derived from the European Union's emission reduction objective and the internationally agreed aim of limiting the rise in the average global temperature to 2°C (UNFCCC, 2015).

Where the Netherlands' energy supply is concerned, the associated CO_2 emissions must be cut by 2050 to between 82 and 102 per cent of the levels in 1990.[2] Hence, the maximum scope for energy-related CO_2 emissions is 30 megatons (Mt).

Those targets must be achieved without merely displacing emissions and while ensuring that the energy supply can be maintained in the longer term. A sustainable energy supply is an energy supply that supports improved air quality and public health.

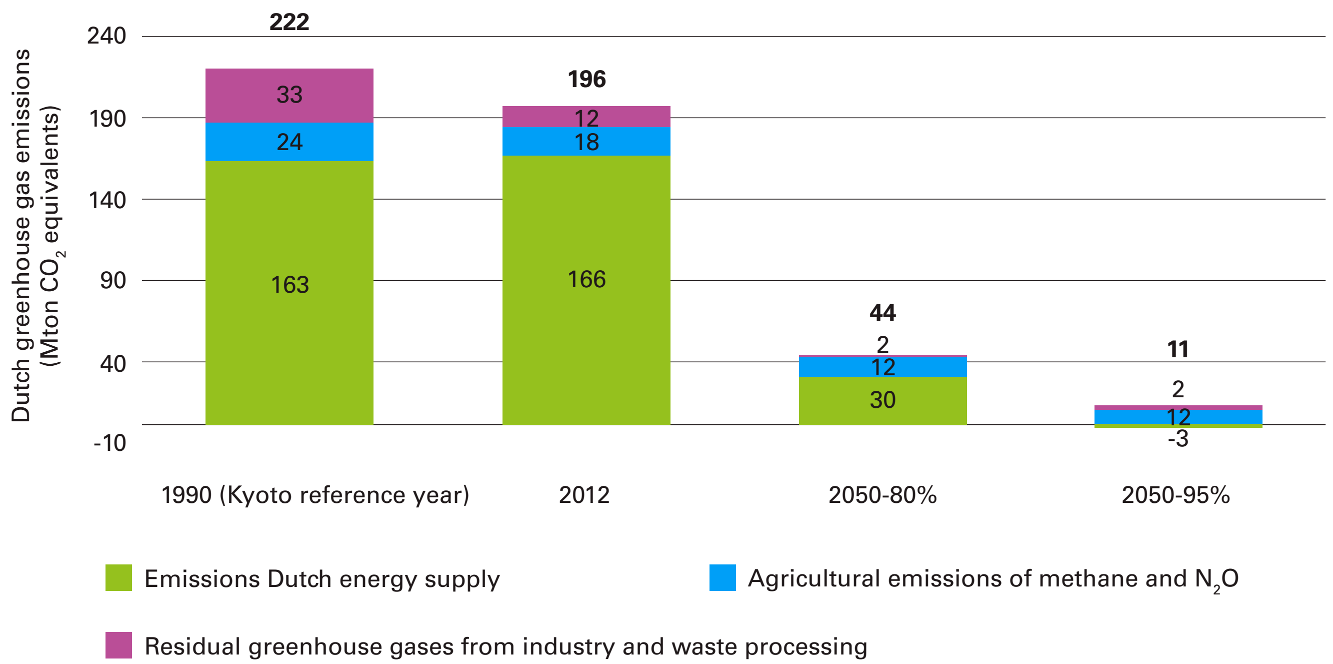
The Council has opted for a definition and goal expressed in terms of CO_2 emissions attributable to the energy supply, rather than in terms of energy sources or technologies. That is because the Council believes that the low-carbon goal for 2050 must remain fixed, while allowing scope for new technological developments that support that goal. The CO_2 goal is illustrated in Figure 1.

Because the objective is fixed, while the road to 2050 is long and surrounded by uncertainty, the Council favours an adaptive approach. That would require the formulation of intermediate supporting objectives regarding certain elements.

There is increasing social and political demand for an integrated strategic vision of the Netherlands' longer-term energy supply. The Minister of Economic Affairs therefore wrote to the Council for the Environment and Infrastructure ('the Council') asking it to report on the 'energy supply in the Netherlands in the medium term, in line with the ultimate objective of achieving a fully sustainable energy supply by 2050' (see Appendix 1). The Council's interpretation of 'a fully sustainable energy supply' is explained in box 1.

1 In the context of this advisory report, 'CO_2' should be interpreted as meaning both CO_2 and CO_2 equivalents.
2 In this advisory report, only those agricultural greenhouse gas emissions that are attributable to energy consumption are taken into account. Other agricultural greenhouse gas emissions are disregarded. It is anticipated that in 2050 the agricultural industry will still be producing some non-energetic greenhouse gas emissions, which cannot be prevented by technical means (PBL, 2011 pp 27-28). It is assumed that the continuation of such emissions has implications for the acceptable level of continued energetic emissions. In relative terms, therefore, the reduction in emissions attributable to the energy supply must be greater than the reduction in emissions attributable to agriculture. The basis of the calculation is explained in Appendix 4.

Figure 1: Greenhouse gas emissions in the Netherlands in 1990, 2012 and 2050, corresponding to reductions of 80 per cent and 95 per cent (Mt CO_2 equivalents)



The ultimate objective is derived directly from the European ambition of realising an emission reduction of 80 to 95 per cent by 2050, relative to 1990 levels (EU Energy Roadmap, 2012). The European Union (EU) has recently defined goals for 2030.[3] In December 2015, the Conference of the Parties 21 takes place in Paris and the global reduction of CO_2 emissions will be on the agenda. In preparation for the discussions in Paris, in June 2015 the G7 agreed that, by 2050, greenhouse gas emissions should be reduced by at least 40 per cent, and preferably by 70 per cent, relative to 2010. In the long term, the G7 is seeking to develop an economy which produces few greenhouse gas emissions. As well as adopting the goals itself, the G7 has invited all other nations to do likewise (G7, 2015).

In Paris, the EU intends to campaign on the basis of a European goal of an 80 to 95 per cent reduction by 2050.

This advisory report outlines how transition to the desired situation is achievable by 2050. Research and calculations demonstrate conclusively that the objective is realisable within that time scale (PBL, ECN, 2011; Kerkhoven et al., 2015; IEA; 2015). It is clear that the Netherlands has more work to do than most countries, and that particular attention must be given to the question of how the objective may be secured while allowing less developed countries scope for economic development. A process of migration to sustainability was set in motion by the SER Energy Agreement (2013). This advisory report looks beyond the time horizon of that agreement. Policies are required that assure realisation of the objective while providing investors and policy makers with greater certainty regarding the future (PBL & ECN, 2011; The Economist, 2015).

This advisory report does not present any detailed scenarios. Too much uncertainty exists to define pathways to 2050 with any precision. Moreover, the Council does not wish this advisory report to use either the current situation or any specific source or sector as a starting point for its reasoning. The Council has adopted an alternative perspective, based on energy functionalities and a fixed objective for 2050.

3 European goals are: EU-ETS -43 per cent and non EU-ETS -33 per cent relative to 2005, at the EU level at least 27 per cent renewable energy and an indicative energy conservation goal of -30 per cent relative to 2005.

Energy transition is linked to international and national economic developments. The major changes required for transition will generate opportunities for a new economy, new industries and new employment. The realisation of a sustainable energy supply in the Netherlands and elsewhere will generate demand for clean technologies and production methods and will promote innovation and new economic activities. Companies and countries that act promptly and appropriately to meet that demand can benefit.

At the same time, transition will cause difficulties, cost money and necessitate substantial investment. Many fossil energy-reliant companies will need to make expensive structural changes to their production processes, for example. Energy companies will need to produce energy on a CO_2-neutral basis. Homeowners and those responsible for office buildings, schools, hospitals and the like will have to take steps to reduce energy consumption. Consumers will need to switch to more climate-friendly products. And much will have to be invested in energy infrastructure.

The contents of this advisory report are divided into three 'blocks':

Block 1 (chapters 2, 3 and 4): the points of departure and the analysis framework
In chapter 2, possible developments in society and in the energy supply are outlined. Chapters 3 and 4 introduce the analysis framework of this advisory report, which is based on four energy functionalities and various transition phases, and illustrate the transition task in quantitative terms (required CO_2 emission reductions).

Block 2 (chapter 5): the Council's advice to the commissioning minister
In chapter 5, the Council presents its advice in the form of the minimum conditions that must be fulfilled in order for transition to be achieved.

Block 3 (chapter 6, 7 and 8): detailed advice
Chapter 6 contains more detailed advice for each energy functionality, while chapter 7 describes the associated general policy tasks. Finally, management of the energy transition is considered in chapter 8.

2

SOCIAL DEVELOPMENTS AND CHANGES IN THE ENERGY SUPPLY

Over the next thirty-five years, the Council expects changes in the demand for energy and major developments and innovations in the way that demand is met and in the way that energy is produced and transmitted or transported. Some developments will happen quickly, while others take more time. Some developments – such as technological breakthroughs – will support attainment of the transition objective, while others will not. Certain developments can be secured only if actively promoted and pursued within the Netherlands, while some will originate elsewhere. There will be both radical changes and the gradual continuation of developments already in progress. The changes foreseen by the Council fall into three main groups: socioeconomic, technical and international developments.

Socioeconomic developments: it is likely that the importance of cities will increase (Rli, 2014a). That will lead to different housing and living requirements and to different forms of travel between home and work. A degree of shift is also anticipated from product ownership to product use (product-service combinations) and to the use of personalised products and services (e.g. medication, food and ICT). Global developments – particularly in prosperity, technology and knowledge – will lead to new patterns of demand, e.g. for food, mobility and domestic and professional products and services. Partly as a result, greater diversity and flexibility will develop in the demand for and supply of energy. Small-scale and individualised energy production will increase, leading to more dispersed energy supply systems. Smarter utilisation of raw materials and the development to a more circular economy will have significant influence on the demand for and supply of energy.

Technological developments: for some decades, everyday life has been changing under the influence of developments in information and communication technology (ICT). That process is certain to continue in the decades ahead. It is likely that virtual reality, further automation, the miniaturisation of IT hardware – e.g. smart watches that provide immediate personal feedback – and the growth of nanotechnology will influence the demand for energy. In the energy sector, a great deal is expected of smart equipment and smart networks in terms of matching the variable supply of energy with the fluctuating demand. The platform economy, where various local and central systems are connected to each other, is forecast to increase in prominence; that may manifest itself in the rise of car-sharing platforms, for example. In the years ahead, important developments are also expected in the field of solar power and storage technologies, such as batteries and hydrogen. Increasing use will be made of conversion technologies that transfer energy from one carrier to another. In the Netherlands, with its mature gas infrastructure and gas expertise, there is particular scope for the development of technologies for the production of green gas or gaseous energy carriers, or for the conversion of electricity into gas. In the transport sector, the vehicle fleet is likely to become much more varied, as electric and hybrid cars enter more widespread use and LNG (liquefied natural gas) is adopted for heavy vehicles and shipping. In manufacturing and the chemicals industry, the demand for energy and raw materials will be met in new ways, such as by using alternative, more electricity-based production methods and biomass-based chemistry. Local production technologies such as 3D printing will facilitate the growth of small-scale manufacturing and influence both the demand for and supply of energy. Dispersed energy generation is likely to play an important role in that context, but it is also possible that new centralised generating technologies will gain ground, such as nuclear technology and perhaps new generations of thorium reactors.

International developments: while the recent past has been characterised by economic globalisation, it appears that we may be about to enter a period in which the emphasis shifts to local communities and geopolitical fragmentation. The latter phenomenon in particular is undermining confidence that, in the long term, energy and raw materials will remain readily available through free international trade. The growing interest in circular economics is driven not only by concern about the finite nature of supplies of energy and raw materials, but also by concern about the possibility of geopolitical tensions threatening their long-term availability. Worries regarding climate change and the desire to be less dependent on imports are combining to persuade many countries to pursue greater self-sufficiency and greater sustainability in the production of energy. That trend is apparent in Europe, partly under the influence of European policy and partly as a result of national policy decisions and technology availability. Where changes to the energy supply are concerned, it is difficult to distinguish cause from effect. In box 2, the Council gives brief examples of events and developments that it sees as having the potential to define the context for and speed of energy transition in the Netherlands. The examples demonstrate the extent of the interdependencies and uncertainties associated with the transition goal for 2050. They also illustrate why the Council believes that an adaptive approach is required on the road to 2050 in order to achieve the challenging fixed objective.

Box 2 Contrasting possibilities: events and developments that may determine the context and pace of transition

Possible event/development	Contrasting possibility
A climate treaty is finally agreed, under which binding commitments are made by the main CO_2-emitting countries, including China, India, North America and Europe.	No climate treaty is agreed and each country makes its own choice between tackling and adapting to climate change.
Solar energy becomes the main energy source in many countries. The breakthrough in the proportion of electricity generated from solar energy radically reduces the demand for coal, leading to a rapid decline in CO_2 emissions after 2040.	Solar energy is not the main energy source in many countries, due to many consumers' lack of purchasing power and the high capital cost for companies.
The ambitions of the European Energy Union, including its climate policy, are realised in all member states.	The European Energy Union is not realised. The pursuit of national energy and climate policies by the separate countries leads to policy competition and new energy borders within in the EU.
After 2030, CCS (carbon capture and sequestration, or the underground storage of CO_2) becomes available on an affordable basis and wins social acceptance, as a result of which the use of fossil fuels is no longer incompatible with a low-carbon economy.	CCS remains unavailable after 2030 and the role for fossil fuels declines substantially.
Geopolitical relations improve markedly and dependency on the import of fuels of various kinds is no longer a concern that influences policy.	Geopolitical relations deteriorate markedly and confidence in the working of international energy markets declines. The preference for domestically generated energy increases sharply.

New (integrated) energy business models result in the emphasis shifting to the sale of comfort that can be supplied to various types of customer by means of various interconnected energy technologies.	The energy technology market becomes fragmented and integration is lacking, requiring the government to intervene strongly to ensure a secure, reliable and affordable energy supply.
Ample affordable electricity storage becomes available, facilitating the development of dispersed energy systems and making it easy to absorb fluctuations in the supply of electricity produced from renewable sources. That in turn accelerates electrification of the energy system.	Electricity storage does not become affordable or available on a large scale, meaning that absorbing fluctuations in the supply of electricity produced from renewable sources remains difficult, limiting the extent to which wind and solar energy can be relied upon.
Thorium reactor technology breaks through, providing an inexpensive and reliable source of energy for large power plants within the energy infrastructure.	Thorium reactor technology does not become viable and nuclear energy falls out of favour. There is consequently less scope for having a few large power plants within the energy infrastructure.

3

THE FOUR FUNDAMENTAL REQUIREMENTS AND FUNCTIONALITIES OF ENERGY

The Council has chosen to base its analysis on the premise that the overall demand for energy derives from four fundamental requirements that energy must fulfil in society, both today and in 2050. The Council has adopted that approach because it makes uncertainties regarding economic structures, energy sources and energy carriers less relevant and means that they are instead incorporated into the outcome of the analysis. When the four social functions of energy are taken as the starting point, the analysis is no longer constrained by our current economic structure and energy supply, or by the associated relationships between sectors, energy carriers and energy sources. That in turn creates scope for new insights and solutions.

In order to satisfy society's four fundamental requirements, energy performs four functions (see Appendix 3 for detailed descriptions and definitions of the functionalities). The four energy functionalities and the social requirements that they fulfil are as follows:

1. Energy is required to fulfil low-temperature heating functions, such as the heating of buildings and the provision of hot water (e.g. for bathing and food preparation). This is referred to as energy's low-temperature heat functionality.
2. Energy is required to fulfil high-temperature heating functions, such as manufacturing and high-temperature industrial processing. This is referred to as energy's high-temperature heat functionality.
3. Energy is required to fulfil transport and mobility functions, enabling the movement of people and goods. This is referred to as energy's transport and mobility functionality.
4. Energy is required to fulfil lighting and appliance functions, such as powering lights, electrical and other appliances and ICT equipment. This is referred to as energy's lighting and appliances functionality.

3.1 A quantitative picture of the energy supply in 2050

There is little to be gained by attempting to translate the uncertain future and all the ways that it may differ from the present into a quantitative picture of the Dutch energy supply in 2050. Nevertheless, a few illustrative figures can make it easier to picture future developments. While retaining sight of all the ifs, buts and maybes associated with information about a date some way in the future, the Council has referred to published scenarios to obtain a quantitative picture, reflecting what the Netherlands' energy supply may look like in 2050. The data presented by the Council below are based upon the IEA ETP scenario (IEA, 2015) and the Energy (R)evolution Scenario (Greenpeace International et al., 2013).[4] On the basis of those scenarios, the energy demand and CO_2 emissions associated with each of the four functionalities have been calculated for the year 2050 and compared with the reference year 1990 (Warringa & Rooijers, 2015).

In addition, a number of recurring (and therefore robust) scenario study findings identified by meta-analyses have been incorporated into the qualitative picture (see box 3). The robust findings provide a firmer basis

4 Numerous energy scenarios for 2050 have been published. The Council has opted to use the two good quality scenarios named because they are based on data published by the International Energy Agency (IEA). In addition, the Energy (R)evolution Scenario goes further, meaning that a certain spread of results is obtained.

for predictions about the future energy supply and can therefore facilitate policy decision-making in the Netherlands.

Box 3 Recurring scenario study findings

A number of frequently recurring findings emerge from studies and meta-analyses of multiple published scenarios for a low-carbon energy supply in 2050.

The scenario studies and meta-analyses* consulted by the Council show:

- A low-carbon energy supply in 2050 is feasible and affordable.
- Considerable effort must be made to improve energy efficiency in order to curb the growth in the total demand for energy (and the cost of migration to sustainable means meeting that demand). Energy consumption will remain substantial in the long-term.
- The proportion of the energy supply obtained from renewable sources will increase sharply. Wind energy, solar energy and biomass will all have to be harnessed. Globally, the demand for gas and/or nuclear energy will also increase, even in a low-carbon scenario. The total share of fossil energy – energy from coal, gas and oil – in the global energy supply will decline.
- Electricity will become a more prominent energy carrier and account for a larger proportion of the energy supply.
- By 2050, nearly all electricity will have to be generated from renewable sources. Consequently, there will be stronger fluctuations in the supply of electricity, as weather-dependent sources displace fossil fuels. The electricity market must therefore adopt more flexible supply-side and demand-side solutions, such as flexible energy storage options, demand response and demand management.
- The availability of biomass will be limited (due to the application of sustainability criteria). Biomass will therefore be used mainly in areas of the economy where it is difficult to use other renewable sources (e.g. aviation and long-distance heavy goods transport).
- Depending on the success of energy conservation and energy efficiency initiatives, more nuclear energy or CCS is likely to be a feature of a low-carbon energy supply.

* Sources: Knopf et al., 2013; TNO, Copernicus Institute of Sustainable Development and ECN, 2013; IEA 2014a, 2014b, 2015; Greenpeace and EREC, 2013

A reduction of between 82 and 102 per cent in the Netherlands' energy-related CO_2 emissions by 2050, relative to 1990, implies scope for the continued annual emission of between 30 and 0 Mt CO_2 from the consumption of energy (see Appendix 3 for details).[5] Greenhouse gas emissions that are not associated with the energy supply are outside the scope of this advisory report.

Quantitative profiles of the four energy functionalities in 2050 have been compiled for the Council on the basis of calculations (Warringa & Rooijers, 2015) made using the IEA Energy Technology Perspectives scenario (IEA, 2015) and the Greenpeace Energy (R)evolution Scenario (Greenpeace

5 An alternative concept is the carbon budget, where figures are calculated from the total remaining scope for CO_2 emissions over the entire period. In the context of this report, the Council uses the concept of the carbon flux: the annual amount of CO_2 that may be emitted, because it is easier to operationalise and develop tools for, and because it is more consistent with the existing policy debate.

International et al., 2013). The figures calculated for primary energy use and CO_2 emissions should not be interpreted as (and are not intended for use as) absolute targets for the energy functionalities. Both the underlying scenarios and methods used to derive functionality-specific figures involve significant uncertainties. Figures 2 and 3 show the approximate levels for each functionality in 2050. For each energy functionality, both demand and CO_2 emissions have been considered. From the calculated data, it is apparent that, where all the functionalities are concerned, making the necessary energy savings and achieving sustainability will be major undertakings. Because the Energy (R)evolution Scenario assumes that the remaining scope for emissions in 2050 will be 24 Mt CO_2, while the Netherlands's scope for emissions assigned on the basis of IEA ETP 2°C is 42 Mt CO_2, the scope calculated for each energy functionality covers a range of emissions. For further information about the differences in the scenarios, see Warringa and Rooijers (2015). The total scope for emissions associated with the goal proposed in this advisory report is a maximum of 30 Mt CO_2 in 2050 (assuming an 80 per cent reduction in emissions at the national level). For each functionality, the scope for emissions in 2050 is likely to be somewhere in the range indicated.

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Figure 2: Primary demand for energy for the four functionalities in 2012 and 2050 under the IEA ETP 2 degree Celsius scenario and the Greenpeace Energy (R)evolution Scenario (on the basis of calculations by Warringa & Rooijers 2015a).

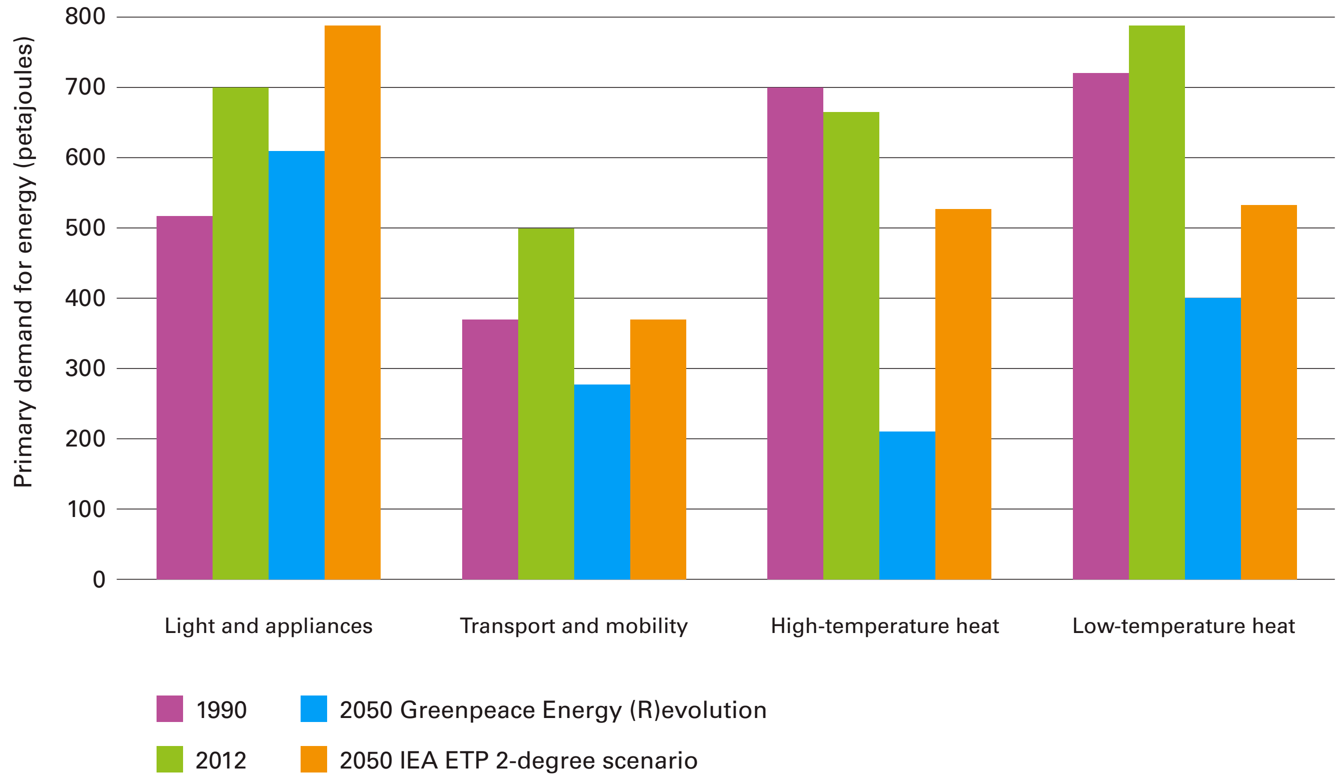
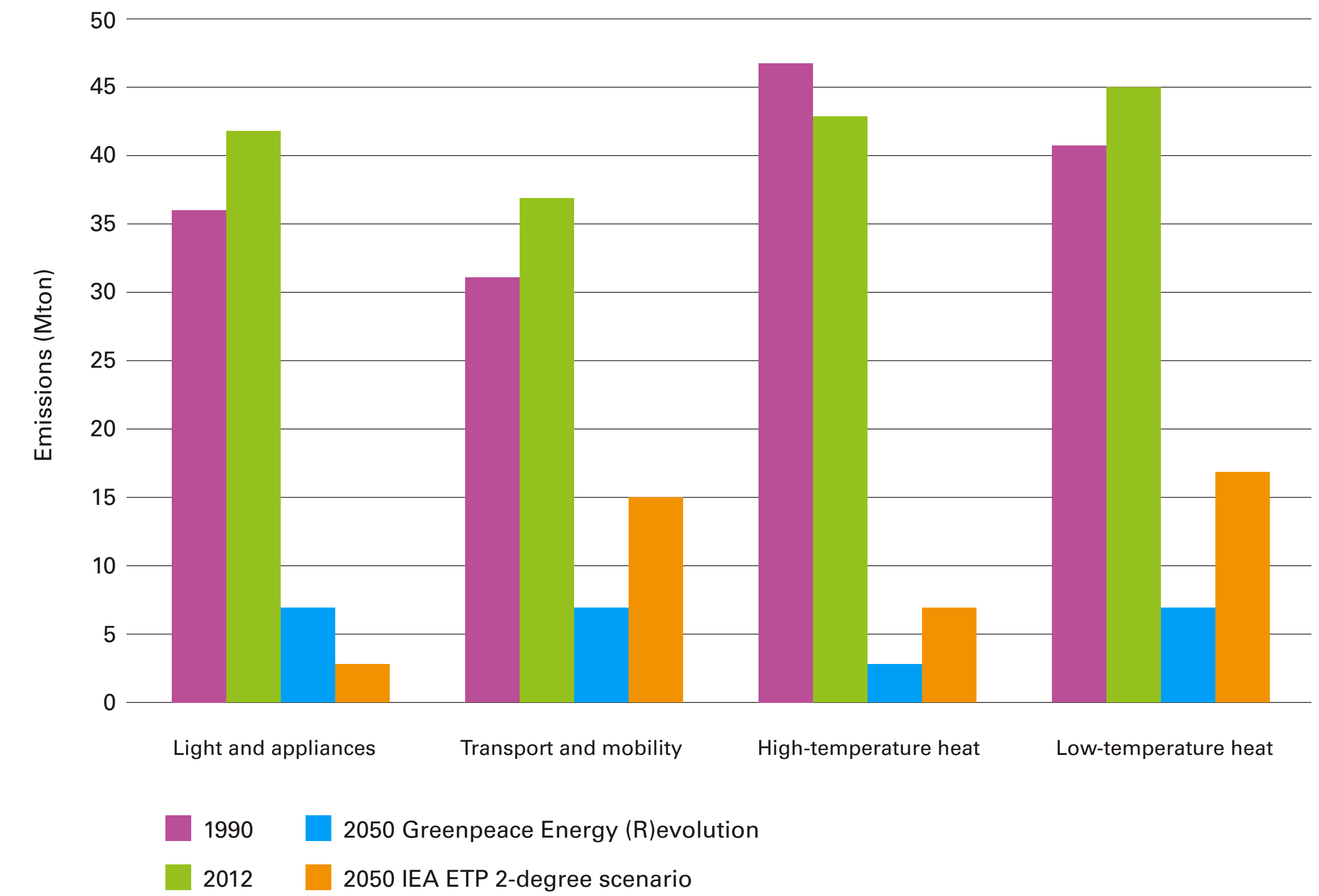


Figure 3: CO_2 emissions for the four functionalities in 2012 and 2050 under the IEA ETP 2 degree Celsius scenario and the Greenpeace Energy (R)evolution Scenario (on the basis of calculations by Warringa & Rooijers 2015a).

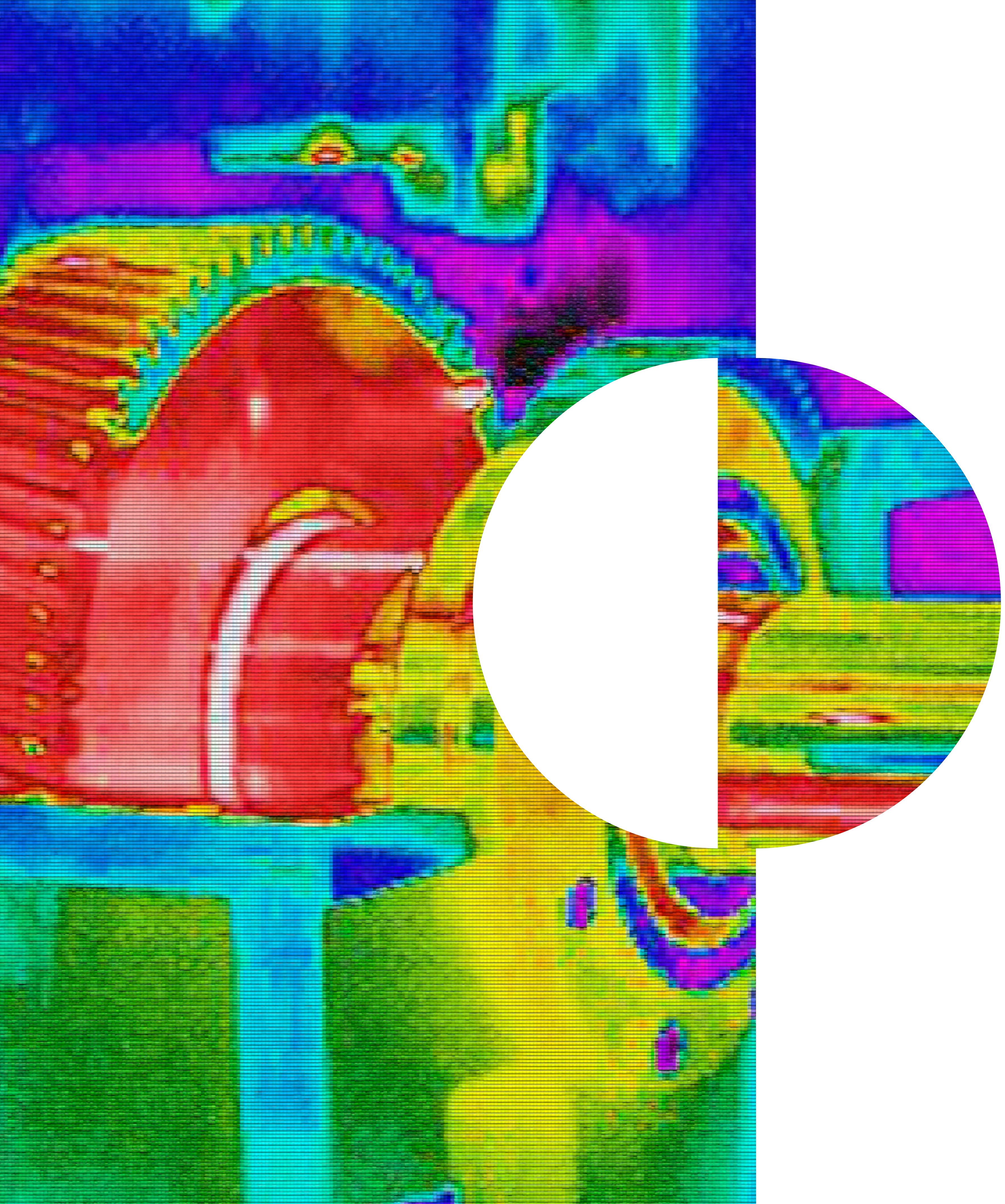


3.2 What will the energy supply be like in 2035?

Because realisation of the defined objective is such a large undertaking, and because the realisation date (2050) feels rather remote, it is necessary to sketch a picture of the medium-term situation (2035) before a dynamic process is set in motion.

In a period of twenty years, a great deal can change; and in this context a great deal will need to change. By 2035, cleaner production methods will account for a greater proportion of the energy supply than at present, while some existing technology remains in use. Certain new technologies will have become commercially viable and made the breakthrough into use, but other very promising technologies will not have come on line. By about

2035, it should be clear what the current drive for innovation has yielded and which technologies have the potential to make a real contribution after 2035. Solar energy will have broken through as a rapidly growing source of energy and may already account for several per cent of the total energy supply. Looking at the electricity supply in isolation, solar energy's share will of course be much greater. Wind energy may also be expected to be making a substantial contribution. In 2035, gas will continue to play an important role in the Netherlands, for industrial purposes, for local power load balancing and for heating. Nevertheless, the total demand for gas will have declined considerably due to the use of other energy sources and carriers. Hence, gas will have changed from being a base-load source to being a peak-load source (see glossary for explanations of terms).



4

THE TRANSITION TASK

Transition to a sustainable energy supply is such a large and fundamental undertaking that it will require systemic change. In other words, it will involve changes in the way energy is produced and used, coupled with changes to the associated infrastructures. Such changes will cause shocks and disruption. Furthermore, there will be an extended period during which 'old' and 'new' must coexist. Transition is therefore a complex undertaking, but is nevertheless achievable.

4.1 Periods and waves

To facilitate analysis, the Council has broken down the complex transition issue on the basis of the four energy functionalities referred to earlier and two time periods. The first period is from the present day to 2035, encompassing the Energy Agreement for the period to 2020/2023, the EU targets for 2020 and 2030 and the associated policy and implementation processes. Adoption of the year 2035 allows for further adjustments relative to the EU 2030 targets. The second period runs from 2035 to 2050. Naturally, energy transition will not simply end in 2050. Also of relevance in this context is the analysis by Lester and Hart, which identified three waves of innovation (box 4). The Council's breakdown of the task and the three-wave model yield a rough framework, within which the manner and time-line of transition may be described in general terms for each functionality.

Box 4 Three waves of innovation

On the basis of a detailed case study in the US, Lester and Hart (2012) outline three waves of innovation:

1 Energy conservation, improvement of energy efficiency and improvement of the capabilities and deployment costs of sustainable technology

2. Rollout of existing technologies and the incremental improvement of their efficiency

3 Long-term implementation of radical new technologies requiring long development lead times and therefore prompt initiation.

4.2 A different approach to transition for each functionality

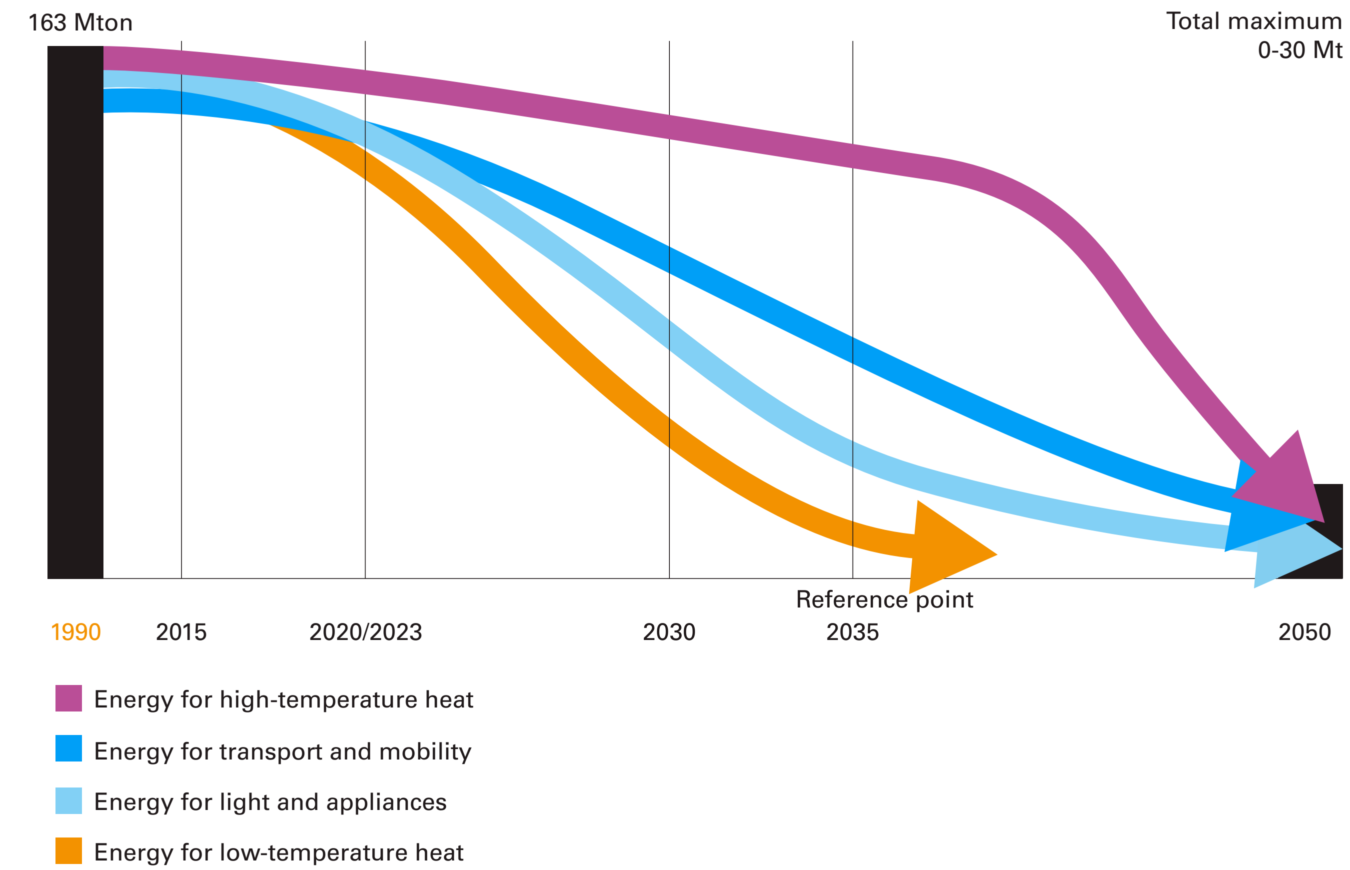
A different approach to transition will have to be taken for each functionality or sub-functionality, reflecting factors such as the availability of the necessary technology, the financial viability of investment and the need for international collaboration.

Nevertheless, the transition pathways for the four functionalities share an important characteristic: in the first period, great strides must be made in terms of energy conservation and the improvement of energy efficiency, while also investing in the development of new technologies for subsequent rollout. That implies both working to make existing technologies more efficient and cheaper, and developing new technologies suitable for larger-scale application after 2035. Progress in both fields will be non-linear: there will also be conjunctions between the innovations and technologies that follow incrementally converging lines of evolution (e.g. cars: combustion engine > hybrid > plug-in hybrid > full electric). In this first phase, the definite European commitments for 2020 and 2030, including targets for renewable energy and energy conservation, will also play an important role.

In all periods, innovation will play an important role, but there will be differences across the various energy functionalities in terms of how radical the required innovation must be. Where low-temperature heat is concerned, the main need is for social innovations, process innovations and learning by doing, while in the field of high-temperature heat fundamental technical innovations will be required. Certain sequential conditions must also be fulfilled. The supply of domestic heat, for example, depends on the availability of an infrastructure capable of delivering the heat in the desired form. There will be a need not only for technical innovations, but also for economic, political (management) and social (behavioural) innovations. Progress will depend on the combination of various forms of innovation.

Figure 4 illustrates broadly how the energy transition for each functionality is likely to progress in terms of CO_2 emissions. Where some functionalities, particularly low-temperature heat, are concerned, early progress will be both necessary and possible, and the required transition will take place mainly in the period up to 2035. By contrast, the transition pathways for functionalities such as high-temperature heat will be characterised by substantial progress in the period from 2035 to 2050, on the basis of technology that needs to be developed or refined in the nearer future.

Figure 4: The transition task for each function of energy (turning points in the arrows are indicative).



5

RECOMMENDATIONS REGARDING CREATION OF THE CONDITIONS REQUIRED FOR TRANSITION

The Council concludes that achievement of the cabinet's stated goal of a fully sustainable energy supply in the Netherlands by 2050 depends on various trend changes being effected. This chapter sets out ten recommendations regarding creation of the basic conditions required for realisation of the ultimate objective. Implementation of the recommendations can expedite the process of transition.

The government has the explicit task of creating and maintaining the conditions necessary for energy transition. The government should therefore provide clarity regarding the transition playing field and the rules that apply. A large number of actors, including government bodies, private individuals, market players and social organisations, must then work to bring about the transition to a sustainable energy supply.

The assumptions and reasoning that underpin the Council's advice are set out in the previous chapters of this advisory report. In this chapter, the Council makes ten material recommendations to the cabinet, each relating to a condition that must be fulfilled in order for a fully sustainable energy supply to be achieved by 2050. In chapters 6, 7 and 8, the various recommendations are fleshed out with information about the transition required for each energy functionality, the general policy tasks that transcend the energy functionalities and finally management of the transition process.

Recommendation 1. Legislate to formalise the national CO_2 reduction goal of 80 to 95 per cent by 2050 (relative to 1990).

The Council recommends that legislation is brought forward to formalise the national goal of an 80 to 95 per cent reduction in greenhouse gas emissions relative to 1990. That would provide a basis on which more specific period and sector goals could be set and a management plan defined (regarding the latter, see chapter 8). Translated to the Netherlands' energy supply, the overall goal implies that that by 2050 CO_2 emissions must be limited to between 0 and 30 Mt. Political assurance of the energy transition policy should be reinforced by establishing a system of periodic energy reporting, with the reports requiring parliamentary adoption.

The problem of climate change is sufficiently grave to warrant the goal being enshrined in the constitution. However, constitutional amendment is a prolonged process and the climate change question requires urgent action. The Council therefore recommends taking another route. Nevertheless, in view of the uncertainties that exist regarding the transition period, coupled with the social impact of the desired changes, solid political and administrative support for the energy transition is essential for long-term consistency of policy and for the necessary investments to be made. General political support will prevent the transition process being halted by conflicts of interests and resistance to change.

The approach adopted in neighbouring countries, such as Denmark, Germany and the UK can serve as inspiration for the Netherlands.

Those countries have defined long-term goals and incorporated ambitious climate change goals into their energy policies.

Recommendation 2. Pursue the CO_2 reduction goal for 2050 on an active and adaptive basis

The adoption of a fixed CO_2 emission-reduction goal enables the definition of a clear and definite pathway to 2050. In consultation with its social partners, the government should set district, task-defining intermediate goals for each energy functionality. The realisation of such goals should be mandatory. At the end of each period, the intermediate goals for the remaining period(s) can be confirmed – if necessary following re-specification – with a view to ensuring that the ultimate objective is secured. If an intermediate goal is not secured, the government must take steps to enforce realisation. Where new possibilities emerge or unexpected problems arise, the course may be adjusted, but always with retention of the ultimate objective. Such an approach will also assure the reliability, affordability and safety of the energy supply throughout the transition process. The Council also recommends the appointment of a government commissioner to oversee transition, as described in chapter 8.

Recommendation 3. Be decisive and increase the speed of CO_2 reduction in the Netherlands

The Council believes that the pace of CO_2 reduction needs to increase in order for the stated ultimate objective to be realised by 2050. The rate of progress must be raised and action taken immediately in fields where the Netherlands can act independently without detriment to its international competitiveness and where the necessary technology is available. That implies introducing stricter rules and more targeted sustainability incentives, particularly in connection with functionalities such as low-temperature heat. The Council recommends working to make urban areas energy neutral by 2035 – substantially sooner than provided for by current policies. Progress in certain segments of the Dutch transport sector could also be accelerated, e.g. by means of tax incentives and environmental zoning.

Recommendation 4. Enter into regional coalitions in Europe where EU-wide agreements cannot be secured quickly enough

The Netherlands should commit itself to work with companies, governments, network operators and supervisory authorities to secure binding agreements regarding international industries, preferably at the global level but otherwise at EU level[6] or, failing that, amongst forward-looking European countries.[7]

By international standards, the Dutch economy is relatively energy-intensive. It is also largely fossil-energy based. Consequently, transition to a low-carbon energy supply will involve greater change for the Netherlands than for many other countries. The CO_2 reduction goal must nevertheless take priority, despite the possible economic and social repercussions, (re-)distribution issues or high transition costs for the Netherlands. Such

6 Regional approaches increasingly have the support of the European Commission; see for example (Boot, 2014).
7 The Pentalateral Energy Forum is an example of this approach. The forum was originally an initiative by five countries (Benelux, France, Germany) and has since been expanded to include a further two countries (Austria, Switzerland).

considerations cannot (any longer) justify the Netherlands being reticent about the pursuit of energy transition. The Netherlands has nothing to gain by unilaterally imposing requirements on international industries, because that would simply lead to the relocation of companies and activities. Hence, global CO_2 emissions would be unaffected and the ultimate purpose of Dutch policy would be frustrated.

Recommendation 5. Assure the opportunities for innovation provided by flexibilisation in the energy market

Ensuring that anyone can obtain the amount and form of sustainable energy that they want at any given time is not only a challenge, but also emphatically an economic opportunity. There will be opportunities in fields such as conversion (transferring energy from one carrier to another: e.g. power to gas or power to heat), transmission (smart grids), demand management and energy-related services (ICT). With its well-developed physical infrastructure, geographical location, enterprise culture and knowledge base, the Netherlands is well placed to utilise such opportunities.

The growth of sustainable, dispersed energy options will increase fluctuation in both the supply of and demand for energy. For the next few years, the existing market mechanisms and energy infrastructure will be able to absorb the increasing levels of fluctuation.[8] However, for the supply to remain secure in subsequent years as well, it will be necessary to develop an extensively integrated and particularly flexible energy system. The system should feature flexibly deployable production capacity, conversion and storage facilities, and greater elasticity in the demand for energy from private and corporate consumers. With a view to promoting flexibility in the system, the government should adjust network tariffs and tax rules so as to create both supply-side and demand-side incentives. See subsection 7.3 for a fuller description of the policy task in this field.

Recommendation 6. Establish large-scale, task-focused, long-horizon innovation programmes

The Council considers large-scale, task-focused, long-horizon, internationally oriented innovation programmes vital for realisation of the ultimate objective to the highest possible quality standards.

Innovation is essential if the objective for 2050 is to be secured on a cost-effective basis. The nature of the innovation required in connection with each functionality is different. For example, where low-temperature heat is concerned, the technology is already available and it is largely process innovation and social innovation that are required. In the field of high-temperature heat, by contrast, more fundamental technical innovations will be needed to modify production processes. Each innovation programme should have a remit, such as to develop technology that enables a given material to be produced using no more than X GJ of energy per tonne.

Innovation will also yield competitive benefits for the companies involved, create employment and increase export potential. The global demand for

8 See, for example, TenneT's capacity documents.

products and services that support the transition to a sustainable economy is growing all the time. Structural increases are required in corporate commitment to sustainability and in the subsidies made available by government in order to ensure the future flow of affordable technologies. It is essential to have a targeted innovation programme for each functionality, established with input from the business community, the scientific community and government. The task-focused, long-horizon innovation programmes should also feature fundamental research. Furthermore, it is important to collaborate with other countries, so that knowledge acquired elsewhere is available to the Netherlands. See subsection 7.1 for a fuller description of the policy task in this field.

Recommendation 7. Recognise the power of social innovation and the impact of local initiatives, and provide full support

The success of the energy transition depends on securing broad social support. That will be facilitated by enabling enthusiastic and active citizens and enterprises to participate and giving them the opportunity to produce their own energy or run joint energy conservation schemes. Such initiatives will not only contribute to CO_2 reduction, but will also create a vanguard, which in turn will help to mobilise more widespread support. Sharing best practices is one way of encouraging and supporting private initiatives.

One important added value of local projects is that they make energy transition tangible and involve people directly in the subject. Regulatory, financing and implementation obstacles should be removed. Private energy generation by citizens must be made financially attractive on a structural basis. The impact that private generation has on the energy system (load balancing, grid capacity) must be reflected in the cost. See subsection 7.3 for details of the related policy tasks.

Recommendation 8. Share responsibility and make actors accountable

The existing approach to energy transition is unsatisfactory. A new way of managing the process is essential if a trend change is to be effected and the pace of progress accelerated, while also adaptively directing developments towards the fixed emission reduction goal for 2050. At the heart of the new approach is differentiation on the basis of the four energy functionalities, with the assistance of the relevant stakeholders. The approach that the Council recommends for management of the energy transition is divided into four stages: definition of the ultimate objective, definition of intermediate objectives for the various functionalities, framing of task-defining agreements and making arrangements for each functionality with the responsible parties (e.g. CO_2 emitters and consumers). A regime of increasingly coercive incentives and regulations that come into effect in the event of failure to realise (intermediate) objectives without justification is an essential feature of the approach. The possibility of subsequent enforced compliance must be present from the start. That is the only way to make real progress while sharing responsibility. Everything must be subject to independent monitoring and supervision of adherence to the agreed transition pathways. At all stages of the process, the approach will differ significantly from one energy functionality to the next.

Where low-temperature heat is concerned, for example, responsibility is shared by citizens, network operators and government bodies. In the context of high-temperature heat, responsibility lies mainly with manufacturers, (inter)national players and – where the knowledge infrastructure and political involvement in international forums are concerned – the government. Responsibility for making energy for transport and mobility more sustainable rests partly within the Netherlands (e.g. with the parties to the SER's Fuel Vision) and partly at higher levels (EU and global). Finally, where energy for lighting and appliances (almost entirely electricity) is concerned, responsibility is shared by consumers, SMEs and electricity producers. For details of how transition should be managed for each functionality, see also chapters 6 and 8.

Recommendation 9. Ensure appropriate pricing and tax rules

In order to harness social forces to aid realisation of the CO_2 emissions goal of the energy transition, energy prices must support that goal. In practical terms, CO_2 emissions must carry a price. The social costs associated with, for example, security of supply and the flexibility and stability of the system must also be reflected in energy prices.

At the European and global levels, the pricing of emission allowances (within Europe's emissions trading system for greenhouse gases, the EU ETS) is in principle a good approach. However, the price of emission allowances has so far been too low to provide sufficient economic incentive for strong reduction measures. It is not yet clear whether the price of emission allowances in the revised EU ETS for the period 2020 to 2030 will be sufficient to drive the desired energy transition. If the price does not adequately support the ultimate objective, the Council recommends that the Netherlands raises the issue, or at least calls for a substantial reduction in the total emissions allowed (a lower emissions ceiling). At present, the emissions trading system is also flawed insofar as emissions from (subsidised) renewable energy are not automatically deducted from the total emission allowances available for trading. Consequently, if for example additional wind-powered and solar-powered capacity is installed, that creates downward pressure on emission prices and therefore no overall reduction in emissions. The Committee also believes that consideration should be given to reducing the number of excepted industries within the EU ETS. That could be achieved by reaching agreements with likeminded (Northwest) European countries. The European Energy Union is a potential vehicle for regional collaboration.

As part of the desired general overhaul of the tax system, the Netherlands needs to make its energy-related taxes greener and link them to CO_2 emissions. The energy tax tariff structure and the exemption of large consumers need to be addressed, for example. The changes need to incentivise CO_2 reduction by making investment in energy conservation and sustainable energy attractive to private individuals and businesses. Tax policies should avoid seeking to influence the transition process at the detail level e.g. by incentivising particular measures or particular technologies. Although the Netherlands already leads the way within Europe, insofar as 10 per cent of its total tax revenue is derived from green taxes (Vollebergh, 2014), that is no reason for not doing even more. What matters is realising the intended CO_2 reduction.

Recommendation 10. Allocate sufficient financial resources to energy transition

Realisation of the energy transition will require substantial public and private investment. The Council recommends that the government makes more explicit plans for managing the budgetary issues surrounding energy-related tax revenues. The multi-year budgetary estimates already allow for the decline in income from natural gas extraction. However, further financial provisions will have to be made if the write-off of gas extraction income is accelerated or if some or all of the income is hypothecated for energy transition. Making energy-related taxes greener by linking them to CO_2 emissions may initially result in increased revenue, but such revenue flows will dwindle as transition progresses.

The private financing of energy projects is a complex field. Within the Social and Economic Council (SER), the government has been working with the relevant parties to explore possible ways of facilitating appropriate forms of investment. A number of finance-related policy issues are considered more closely in subsection 7.4.

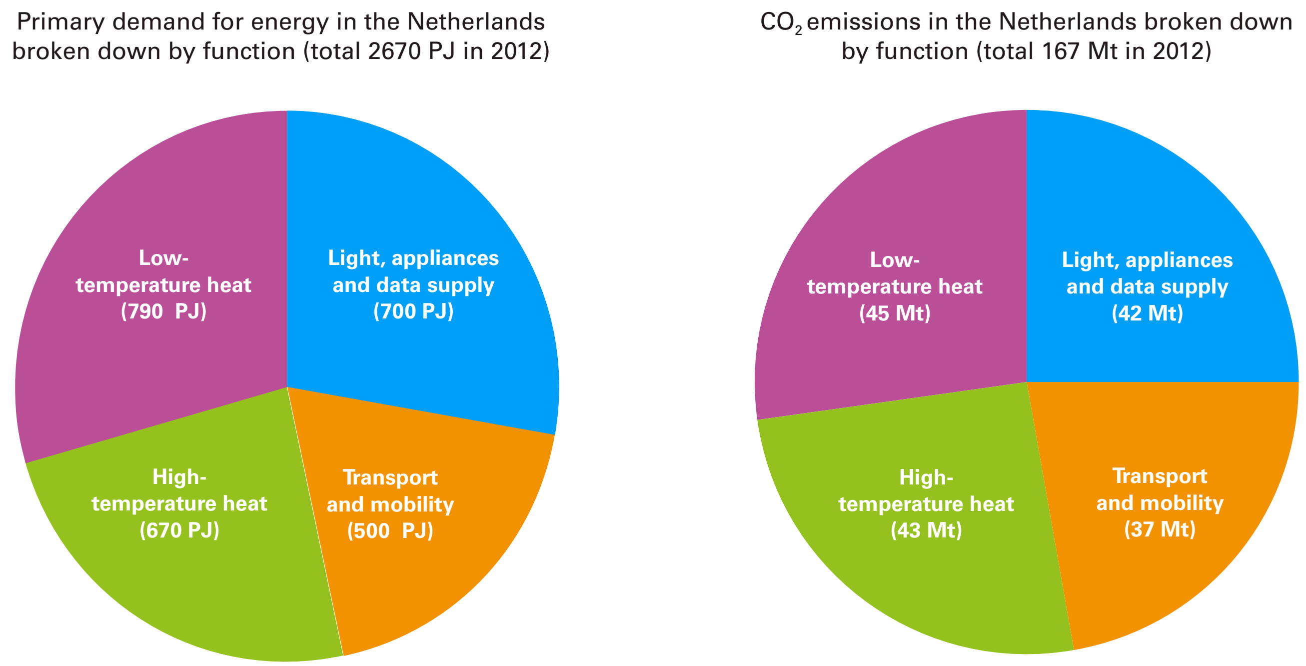
6

DETAILED TRANSITION PATHWAY FOR EACH FUNCTIONALITY

In this chapter, the recommendations about the conditions required for the energy transition are fleshed out in relation to the four energy functionalities. Figure 4 illustrates the size of the four functionalities in 2012 in terms of primary energy use and CO_2 emissions.

In chapter 7, the main policy tasks that transcend the energy functionalities (the 'general policy tasks') are considered. Those tasks relate to policy issues associated with innovation, spatial integration, energy market organisation, finance, behaviour, support and the production side of a low-carbon energy supply.

Figure 4: The primary demand for energy (in PJ) and CO_2 emissions (in Mt) associated with the four energy functions in the Netherlands in 2012



6.1 Energy for low-temperature heat

What is the transition task?

Energy is used for low-temperature heat – spatial heating, tap water – in the urban environment, for greenhouse horticulture and, to a lesser extent, in industry. A detailed breakdown is presented in Appendix 3.

The transition task is to arrive at a situation by 2050 where the low-temperature heat functionality is fulfilled within a CO_2 budget of 7 to 17 Mt (Warringa & Rooijers, 2015) and relies much less on natural gas. In 2050, the energy required for low-temperature heat may be provided by gaseous sustainable energy carriers, heat networks, electricity-heat pump combinations and a residual amount of natural gas. Many of the necessary technologies are already available. Integrated conservation solutions, solar panels and sustainable low-temperature heat are additionally needed to make existing buildings more sustainable (Tigchelaar & Leidelmeijer, 2013; IEA, 2013a; IEA, 2013b). In the low-temperature heat market, international competition plays no significant role (except in greenhouse horticulture and, to some extent, in industry). The Netherlands can therefore pursue independent policies in this field.

The Council recommends pursuing rapid transition to sustainability in the supply of low-temperature heat for the urban environment, so that a low-carbon supply is already in place by 2035. The most cost-effective available solution must be determined separately for each district, city or region. Transition will require coordination between the various stakeholders and the conditions necessary for successful transition will need to be created. The conditions required to bring about energy conservation differ from those required to achieve sustainability, as detailed below. That is important mainly because the existing systems must remain available until transition in a given area is complete.

How

The optimum balance between energy conservation and (integrated) sustainable fulfilment of the residual demand for energy will differ from one region, municipality or district[9] to the next. There will be similar variation in the options for a sustainable fulfilment of the residual demand for heat, and in the optimum balance between the various energy carriers, the associated infrastructure (where relevant) and the cost. It is also important to take account of the increasing scope for converting electricity into gas (e.g. hydrogen) and vice versa, enabling the use of solar and wind energy[10] for various functionalities, for example. The scope for realising greater energy system integration needs to be considered in the context of the choice of system. Nevertheless, the depreciation periods for existing infrastructure will have to be adjusted to support the changes sought. Shorter depreciation periods for infrastructure increase the adaptiveness of the system.

Energy conservation

The technical conservation potential is estimated to be 260 PJ for low-temperature heat (Schepers & Aarnink, 2014). Both the general public and the business community have yet to be adopt many viable conservation measures. The Energy Agreement includes provisions regarding various goals that support transition to a low-carbon energy supply by 2035, such as the target of ensuring that, by 2030, all existing homes and utility buildings have an average rating of at least energy label A. An approach that differentiates between various key target groups – landlords, tenants, letters, utility building owners and horticulturalists – is desirable in the Council's view. However, the agreements made to date are insufficient for realisation of the ambitious goal recommended by the Council. A much higher rate of progress with energy conservation is required. An energy tax, a higher tax on gas, can significantly incentivise energy conservation. Such a tax would reduce the payback period for energy conservation measures. If the imposition of a high tax on gas proves insufficient to drive energy conservation, compulsion should be considered (e.g. compulsory changes to buildings whenever they change hands).

Fulfilling residual demand

There will consequently be increasing variety in the heat supply for urban areas, and a combination of central and distributed systems will be used, including heat grids, geothermal heat, green gas, electricity and hydrogen.

It is important that decisions regarding the installation or phasing out of the required infrastructure can be taken at 'smart' junctures for entire areas (districts, cities). Obstacles to the growth of sustainable heat include the

9 The may be differences even at the neighbourhood level (Schepers & Aarnink, 2014).
10 Such as solar fuels, i.e. fuels produced directly from solar energy.

existing heat supply market model and the financing model (funding by market actors themselves) for the required heat infrastructure (House of Representatives, 2015c).

Who

There is strong interaction between national, regional and local initiatives. It is therefore necessary that individual households, landlords, housing corporations, market actors and network operators are all involved. The interests at stake in the utility building market differ from those at stake in the housing market.

Time line and management

Design of the institutional framework that will identify the optimum means of supplying sustainable low-temperature heat in each region and will decide how to bring about transition is an important issue.[11] Because of the technically and financial-economically complex and compelling nature of the transition to a situation where the residual demand is met sustainably, a governance framework is required. That framework must be developed by means of a process in which all stakeholders are involved (to ensure support) and must subsequently be legitimised democratically. A heat plan in which the various options (heat pumps, thermal energy storage) are compared on an integrated basis should form part of the framework.

The existing urban environment can be made carbon-neutral by 2035. Achieving carbon-neutrality will be a major undertaking and will necessitate a trend change, but it is possible. Responsibility for the urban environment is shared across numerous levels. That complicates the process of reaching agreements and making the arrangements needed for attainment of the goal.

6.2 Energy for high-temperature heat

What is the transition task?

The demand for high-temperature heat (temperatures exceeding 100-120°C) comes mainly from industry, where there is a need for process heat. By international standards, Dutch industry is relatively large, energy-efficient and energy-intensive. In 2012, roughly 25 per cent of overall primary energy consumption in the Netherlands (approximately 670 PJ) was for the production of high-temperature heat. That energy consumption resulted in 43 Mt of CO_2 emissions (Warringa & Rooijers, 2015). Industrial products are used in all spheres of everyday life. The demand for such products will continue and energy will therefore still be required for their production in 2050. It is estimated that, by 2050, the amount of energy required for the production of high-temperature heat will be between 210 PJ and 530 PJ. The transition task is to arrive at a situation where, by 2050, that energy is produced on a low-carbon basis, resulting in emissions of 3 to 7 Mt of CO_2. The industrial products whose production requires high-temperature

11 If a given district is close to a heat source, the decision may be taken to connect the properties to a heat grid, for example. For cost reasons, choosing a given energy carrier will generally imply not building or maintaining infrastructures for other energy carriers (gas, heat pumps, thermal energy storage).

heat are traded on international markets and energy costs represent a substantial proportion of the total production costs. There is also a risk that manufacturing companies will relocate from countries with strict emissions policies to countries with more lenient policies. That can make it harder to secure international climate goals. In pursuit of the emission reduction objective for the generation of high-temperature heat, the Netherlands must therefore take account of the European and global contexts.

How

Energy conservation and technological innovation in the form of production processes that are less reliant on high-temperature heat are the 'transition keys' for energy-intensive industries. In its Energy Technology Perspectives of 2014 (IEA, 2014b), the IEA indicated that energy savings of around 20 per cent are attainable in many industries on the basis of technologies that are already available. Every effort must be made to realise that energy conservation potential. It was agreed in the Industrie routekaarten (Industrial Roadmaps, RVO, 2013) that such energy conservation potential would be utilised. The Council believes that such agreements must provide for accountability and sanctions, in addition to monitoring.

Fundamental innovations in production technologies, processes and methods are necessary in order to further reduce CO_2 emissions. Examples include the introduction of biochemical technologies (e.g. producing high-grade chemicals with enzymes, rather than by conventional chemical processes), membrane separation and advanced extraction techniques (instead of distillation, which requires a lot of heat) and the clustering of industrial plants to facilitate the exchange and use of residual products and residual heat. With its existing chemicals industry clusters and knowledge centres, the Netherlands is well placed to play a prominent role in driving innovation in this field (House of Representatives, 2015c). Fundamental production process innovation takes considerable time. The Council therefore emphasises the importance of long-horizon innovation programmes to facilitate the necessary trend changes and utilise the economic opportunities for the Netherlands. In view of the size and complexity of the innovation task, collaboration is desirable at the European level or with countries pursuing similar goals.

Many industrial companies that use high-temperature heat are required to participate in the European emissions trading system. However, the price of emission allowances is currently too low to serve as an incentive to improve efficiency and seek innovation. In chapter 7, the Council considers how the European emissions trading system can be reinforced and what the Netherlands can do in that regard.

The residual demand for heat in 2050 (estimated on the basis of the two reference scenarios to be between 210 PJ and 530 PJ) must be met by low-carbon, sustainable means. Appropriate options are currently under development. Technologies that may be useful in that context include very deep geothermal energy extraction, CCS and the use of hydrogen. The Netherlands Enterprise Agency (RVO) indicates that various technologies are already ready for larger-scale testing (RVO, 2013). The Council recommends that industrial companies and the government should initiate such testing as soon as possible.

Who

The private sector and the government share responsibility for encouraging innovation. Together, they must organise a large-scale innovation programme as quickly as possible in order to ensure that new technologies rapidly become available well before 2050. Efficiency improvements can be secured using existing technologies; the use of such technologies should immediately be promoted by means of stricter energy conservation policies. Primary responsibility for the transition to a lower-carbon industrial economy lies with companies active in manufacturing and industrial processing. The responsibility of governmental bodies (at the global, European and national levels) is to create the (international) conditions within which such companies can effect that transition without losing out to competitors that continue to operate on a less sustainable basis.

Time line and management

Energy conservation and the improvement of energy efficiency must immediately be prioritised and pursued with vigour. Fundamentally different production processes require innovations that are unlikely to enter general use quickly. In the first phase of the transition, i.e. the period up to 2035, a large-scale innovation programme must therefore be established and maintained, so that appropriate technologies are available and enter use in the second phase (2035 to 2050).

In the management of the high-temperature heat transition, the EU ETS will need to play an important incentivising function, and the Netherlands must work within the EU to have the EU ETS reinforced. Furthermore, much can often be done to promote innovation and conservation through public-private consultation between government and industrial companies. Regional management is also relevant: the potential offered by the clustering of companies to facilitate the cascading and utilisation of residual heat can be realised only if regional decision-makers pursue the creation of such clusters.

6.3 Energy for transport and mobility

What is the transition task?

In 2012, approximately 500 PJ of primary energy was used to meet the demand for transport and mobility, resulting in the emission of 37 Mt of CO_2 (Warringa & Rooijers, 2015). From the two reference scenarios, it appears that the amount of energy required for transport and mobility in 2050 will be between 280 and 370 PJ. The transition task is to meet that energy requirement while limiting the associated emissions to between 7 and 15 Mt of CO_2.

How

Of the four functionalities, mobility and transport is the most reliant on high-density energy[12], which is currently provided by fossil fuels. The transport sector is very varied, involving a wide variety of modes of short-distance and long-distance transport for people and goods, including aviation, shipping and long-distance road haulage. Each of those modes will need to undergo its 'own' transition.

A document was published by the SER in 2014, setting out a sustainable fuel vision developed by more than a hundred contributors, including fuel producers, vehicle manufacturers, hauliers, shippers, umbrella organisations, knowledge centres and social organisations (SER, 2014). The Council believes that that vision can serve as a good basis for transition of the transport and mobility functionality, since it is built around energy and climate change goals and additionally takes account of related factors, such as air quality goals and economic opportunities. Furthermore, the vision proposes the adoption of an adaptive approach to realisation.

With regard to the agreements contained in the Sustainable Fuel Vision, the Council believes that the scope for proceeding at different speeds in the various fields should be utilised. In some areas – such as the reduction of CO_2 emissions from domestic personal road transport, rail transport, water transport and bus/light-rail passenger transport – the Netherlands can act independently and is therefore able to accelerate transition. That could involve measures relating to modification of the fuelling/charging infrastructure and other infrastructures, the award of public transport concessions, tax policy and emission zones in cities.

The Netherlands has less influence over the CO_2 emissions associated with European freight transport or over aviation and shipping inside and outside Europe. The Netherlands should adopt a pioneering role in the relevant international forums[13] and press for stronger policies to bring about major reductions in CO_2 emissions. Those policies might include the introduction of even stricter and more progressive CO_2 emission standards for the engines used in cars, goods vehicles and aircraft, and extending the scope of the EU ETS to include European aviation, sea shipping and inland water transport. The EU ETS must therefore be improved, as described in recommendation 9. Far-reaching, binding international agreements must be pursued regarding emissions from international aviation and shipping (bunker fuel-related emissions), which currently fall outside all regulatory systems. If agreements prove elusive within the international forums referred to, the Netherlands should seek collaboration and make agreements with other forward-looking countries.

Both where overall CO_2 reduction is concerned and where the contributions of the various technologies are concerned, the situation may change significantly as a result of technical breakthroughs in the years

12 Liquid fuels have a high energy-density per unit volume (compared with batteries, for example), which is a vital characteristic for a mobile energy source.

13 The revision of the standards and policies is the responsibility of the International Maritime Organization (IMO) where shipping is concerned, and the International Civil Aviation Organization (ICAO) where aviation is concerned. Policy on inland water transport is directed from Strasbourg (The Central Commission for Navigation on the Rhine (CCNR)) and Brussels (EU).

ahead. If, for example, it becomes possible to make 'solar fuels' (i.e. fuels synthesised directly from sunlight), the nature of the transition task will change considerably.

Time line and management

The Council recommends following the approach set out in the Sustainable Fuel Vision and the related implementation agenda (House of Representatives, 2015a). If the approach proves successful, it can serve as a template for use in the period running up to 2030 and beyond. Depending on other developments in the energy supply, the stated goal of limiting emissions to a maximum of 12 Mt of CO_2 by 2050, a stricter goal may need to be adopted.

International transport is rationally cost-focused. Where international shipping and aviation are concerned, it is appropriate to pursue agreements in UN forums (ICAO and IMO). Where personal transport is concerned, European standardisation would appear the best method of securing progress on matters such as the rollout of electric vehicles, since such vehicles are traded on the European internal market. National and regional policy can play a supporting role, e.g. in relation to the integration of such vehicles in the domestic infrastructure, parking policy and the cost of acquisition and use.

6.4 Energy for lighting, appliances and ICT

What is the transition task?

The amount of primary energy required for lighting, (electrical) appliances and ICT is 700 PJ (Warringa & Rooijers, 2015a). At the moment, that demand is met almost exclusively by electricity. The expectation is that the functional demand for energy for lighting and appliances will increase in the years ahead, due to growth in the number of appliances in the urban environment (e.g. electrical appliances and ICT equipment in homes and businesses) and due to increased energy use in the tertiary sector (energy for information, communication, health care and leisure activities). On the other hand, lights and appliances will become more energy-efficient (energy conservation). The demand for energy for this functionality can therefore be kept broadly stable, as increased use is offset by increased efficiency. On the basis of the two reference scenarios, the primary demand for energy is forecast to be between 610 and 790 PJ in 2050. The associated CO_2 emissions must be limited to between 2 and 7 Mt. Where this energy functionality is concerned, there are both demand-side and supply-side tasks to be accomplished. On the demand side, substantial energy conservation and efficiency improvements must be secured. On the supply side, the task is to bring about a situation in 2050 where the principal energy carrier, electricity, is produced on a fully carbon-neutral basis. Hence, the role of wind energy and solar energy must increase considerably. In short, the electricity market faces profound change.

How

The energy efficiency of appliances is governed by the European Eco-design Directive.[14] That directive, whose provisions become stricter over time, has so far proved effective (Ecofys, 2014). Tightening the efficiency standards for appliances reduces energy bills for private consumers and businesses. The effect of the standards needs to be reinforced by outlawing the least efficient appliances. Because non-EU manufacturers have to meet the same standards if they wish to sell their goods in the EU, European manufacturers are not disadvantaged.

Who

It is important that in Brussels the Dutch government presses hard for further progress, e.g. in talks on the European Commission's multi-year Eco-design Working Plan and in the technical standardisation committees.

Time line and management

By 2050, all energy for lighting, appliances and ICT must be produced on a low-carbon basis. Immediate steps must be taken to realise major reductions in energy consumption during the first phase of the transition (the period up to 2035). With that aim in mind, the Netherlands should press for stricter European standards on appliances and for the least energy-efficient electric appliances to be phased out.

14 The directive covers both products that use energy (except means of transport) and other products that influence energy consumption (e.g. windows, insulation materials and taps).

7

GENERAL POLICY TASKS

This chapter identifies a number of important policy tasks that transcend the four the energy functionalities. Most of the tasks relating to innovation, space, infrastructure, support and finance considered in this chapter differ considerably from one functionality to the next.

7.1 Innovation

Where the mobility and transport functionality (particularly aviation) and the high-temperature heat functionality (particularly steelmaking and refinery) are concerned, the technologies and processes required to reduce the CO_2 emissions sufficiently at a socially acceptable cost are not currently available. The ability to store power generated using wind energy and solar energy for later use is vital for the realisation of transition to a sustainable supply of electricity for those functionalities. The possibility that by 2050 solar panels will be capable of generating electricity for 2 to 4 euro cents per kWh is encouraging (Fraunhofer ISE, 2015), but further product development is required.

Innovation is vital for the energy transition:

- New, clean technologies and processes are required. Particularly where the mobility and transport functionality and high-temperature heat functionality are concerned, the existing technologies and processes are not capable of reducing CO_2 emissions sufficiently on an economically competitive basis within the current market and policy context. This advisory report therefore anticipates further innovation. Refinement of technologies and processes makes them more efficient, cheaper and more user-friendly.[15]
- Innovation, particularly in fields where the Netherlands has a relative advantage and the potential to generate earnings, also creates economic opportunities.
- Social change is both encouraged and supported by innovation. For example, ICT enables consumers to continuously optimise their choice of whether to car-share, travel by public transport, work from home, or combine some or all of those options. In the current energy system, the supply adapts to the demand. So, for example, a gas-fired power station will generate more electricity when the demand for electricity increases. In the future, the demand for energy will have to become more dependent on the supply. Thus, energy use will rise when a lot of energy is available (when the sun is shining and the wind is strong, for example).
- Institutional innovations are vital for encouragement and management of the dispersed activities that are vital for attainment of the objectives of the energy transition. In the field of energy conservation and generation, there remain many split incentives, which can be corrected by new institutions, new industries (energy service companies, or ESCOs) and possibly a different market model.[16]

15 There are promising signs that renewable energy will become cheaper per kilowatt-hour than electricity generated using fossil fuels and that electric cars will become easier to use and more desirable than fossil-fuel-powered alternatives, making them not only more sustainable but also superior products. Such factors are important drivers of increased market penetration.

16 A split incentive is a phenomenon where, for example, the cost of a conservation measure has to be met by someone other than the party that benefits financially from the measure. Energy service companies (ESCOs) are companies that take on both the cost and the benefits of a measure, so that the incentive is no longer split.

Innovation is vital in all stages of the energy supply chain: production, transport and transmission, storage, conversion, trade, earning models and use. The Council wishes to highlight the need for innovation in the following domains:

- Technological domain: attainment of the ultimate objective depends on the availability of new technologies and processes. In addition, the refinement of technologies and processes is necessary to make them more efficient, cheaper and more user-friendly. Particular opportunities exist in this domain for the Netherlands. Collaboration with international partners is essential.
- (Business) economics domain: the rise of sustainable wind energy and solar energy (at low marginal cost) and the growth of dispersed initiatives will necessitate new market and earnings models.
- Social domain: given the speed at which the energy transition must be realised, it is important to develop new forms of collaboration and ways of approaching target groups. Examples include energy cooperatives and innovations in the rollout of energy conservation concepts to the urban environment. Social change is both encouraged and supported by innovation.
- Administrative domain: institutional (administrative and regulatory) innovations are equally necessary, e.g. in response to the increasingly dispersed nature of the energy transition and in order to guarantee attainment of the ultimate objective (see chapter 8).

The Council believes that the cuts to the Ministry of Economic Affairs' innovation budget planned for the years ahead (2015b) are a mistake. Strong support for energy innovation is what will enhance the position of the Dutch business community and scientific community. Furthermore, because of its size, economy and (knowledge) infrastructure, the Netherlands is an ideal 'testbed' for innovations such as a biomass-based economy, energy conversion measures, smart grids and smart energy services (Delft University of Technology et al., 2015).

A particular problem is that the current innovation budget is not sufficient to support the innovation needed in the longer term. The budget needs to be increased in order to bring through innovations such as smart grids, new process technologies, CCS and biomass and biochemistry-based technologies. Too much of the current innovation budget is targeted on the short term, when it is investment in longer-lead-time innovations that has the potential to bring down the total cost of the energy transition.

The Council recommends supporting the lines of innovation referred to above by means of thematically organised programmes with long horizons (ten to fifteen years), through which all phases of innovation can be supported. Such programmes need to be tailored to the four energy functionalities. For example, the low-temperature heat energy transition depends mainly on social innovations and process innovations, whereas the high-temperature heat energy transition requires mainly fundamental, technical innovations.

The business community, the scientific community, social actors and the government need to work together to bring about the required innovation.

There is already collaboration through the Top Consortiums for Knowledge and Innovation (Dutch initials: TKIs). It is also important that there is adequate scope for experimentation. It has to be possible to try out new technologies and concepts, first on a small scale and later on a larger scale. For the development of smart grids, for example, it is sensible to follow-up the small-scale experiments that have taken place with a larger-scale trial (Powermatching City II, 2013).

The development of radical new technologies that are further from the market takes considerably longer and requires a multi-year approach, involving the establishment of demand-led programmes geared to specific goals. Box 5 gives a number of examples of technical-scientific challenges that could be addressed by performance-oriented innovation programmes. In this field too, public-private partnerships involving the business community, the scientific community and the government can provide a good basis for success. In order to maximise the prospect of new concepts progressing through all stages of the innovations chain and thus to market, it is necessary to provide greater certainty that support will be available at each stage. The tools currently used to promote energy innovation appear to be somewhat stage-specific, and continuity is therefore lacking.

Such programmes depend on a structural increase in the resources allocated to innovation by the private sector and the government. The Council believes that investment needs to rise to between 200 and 300 million euros. In view of the size of the innovation task, participation in European programmes will be necessary. By making programmes result-focused, a wide range of developments can be encouraged.

Different performance criteria apply at each successive stage, by reference to which the performance of the consortiums (companies, knowledge centres and governments) can be assessed as a basis for deciding whether support should be made available for the next stage.

Box 5 Examples of technical-scientific challenges that could be addressed by performance-oriented innovation programmes

- New materials, technologies and processes for the high-efficiency conversion of sunlight into electricity and (subsequently) into chemical compounds (such as H_2, NH_3, CH_4)
- Concepts for biomass cascading and bio-refinery
- Development of cheaper drilling techniques to facilitate the use of geothermal energy
- Lighter and stronger materials for advanced rotor blades, new maintenance concepts for wind turbines and new foundations for offshore wind turbines
- Development of new catalyser concepts for industrial applications and process intensification: new, more compact process routes for industry
- Development of new concepts for nuclear reactors and for the processing and reuse of nuclear waste
- New materials for increasing the storage capacity of batteries, reducing the cost of batteries and reducing the charging times for electric car batteries

- New materials and new designs for drastically reducing energy use in the urban environment
- Technology for optimising management of energy production and use and smart grid applications
- Systems for affordably collecting and sequestrating (or, better still, reusing) CO_2
- ICT for the integration of energy systems
- Innovations directed towards eliminating the use of precious metals
- Innovations directed towards improving efficiency in transport (lighter vehicles, lighter ships, lighter containers, new transport systems such as maglev trains and road-powered electrical vehicles for freight transport)

7.2 Energy transition and space

What is the transition task?

The exact size of the spatial task associated with the energy transition depends on how much of the national energy requirement is met using domestic sources. That is ultimately a political choice. Regardless of what is decided in that context, the energy transition will pose a considerable spatial task involving the accommodation of many thousands of plants and structures and the associated infrastructure. Social acceptance of the resulting changes to the physical environment, sometimes literally next door, will require considerable input from the public, politicians and administrators.

Depending on the technologies used, creation of the required renewable generating capacity will involve the erection of between two thousand and eighty thousand onshore wind turbines and between two thousand and twenty thousand offshore wind turbines, plus more than three hundred square kilometres of solar panels on hundreds of thousands of roofs and in solar power stations. More than a thousand bio-energy plants will be needed, as well as hundreds of geothermal plants and hundreds of thousands of thermal energy storage plants (PBL, 2013). All such plants and structures have direct spatial impact (the space that they actually occupy) and indirect spatial impact (perception, noise, odour, visual impact, shading and impact on the landscape). The large-scale use of biomass will also have considerable spatial impact, in the Netherlands or elsewhere. Production of biomass for energy can easily lead to spatial competition with food production, recreation or biodiversity. Of the various renewable energy options, onshore wind power has the greatest indirect spatial impact: wind turbines can be audible more than a kilometre away and visible more than twenty kilometres away.

Spatial policy issues to be addressed

If the spatial potential of the Netherlands is utilised, it is technically possible to produce quite a large proportion of the required renewable energy in the Netherlands. Spatial accommodation of renewable generating capacity will, however, meet social resistance. Such resistance often comes from people living close to a proposed development ('not in my back yard'), but can also come from other stakeholders or organisations within the community. Securing social support for the accommodation of a renewable energy supply will be a considerable challenge.

It will be necessary to combine two apparently conflicting perspectives: the bottom-up perspective, based on small-scale developments and social initiatives, and the technocratic top-down perspective.

1. The first perspective relates to 'human scale' developments: Consumers become prosumers of energy, local initiatives drive progress, local air quality is more important than climate, and buildings, districts, cities and regions are energy neutral. Small-scale initiatives not only contribute to attainment of the emission reduction goal (many little pieces ultimately making up something very big), but also promote wider social consolidation of and support for realisation of the energy transition. The active involvement of citizens in their own energy supply leads to a more widely supported energy policy and greater acceptance of changes to the landscape.
2. The second perspective relates to climate change, (sustainable) energy potential, large-scale installations and space claims, infrastructure of national importance and landscape development. In such fields, the transition task is so large and complex that decisions need to be made at the national level (and, where necessary, imposed on a top-down basis) in the interests of good spatial planning and the achievement of a proper economic balance between social costs and benefits.

Only by careful combination of the two perspectives can spatial accommodation be achieved. An example of an approach which does that is 'designing research'[17], where interaction with the environment is pivotal. The Council recommends giving that approach more emphasis and using it more widely.

In this context, two policy questions are of particular importance:

1. Are local initiatives preferable, because both the costs and the benefits are felt locally, leading to greater social acceptance?[18] Or is it better to concentrate wind turbines and solar generating capacity at a limited number of locations, with a view to achieving optimum spatial integration?
2. What is the best division of responsibility between the national government and the lower tiers of government, given the current trend towards the decentralisation of spatial policy, particularly in the context of the Environment Act and the Environment Vision? Will the collective ambitions of twelve provinces or four hundred municipalities drive the energy transition adequately, or does the energy transition require central management in view of its national importance?

The Council recommends prioritising the energy transition within national spatial policy and giving explicit consideration to the transition when formulating the Environment Vision. The Council additionally recommends that provinces and municipalities similarly prioritise the energy transition in their spatial plans and take account of the national tasks when developing those plans. It will help if provinces and municipalities maximise support

17 An example of this approach: College van Rijksadviseurs (Board of Government Advisors, Cra), 2015.
18 Promising examples of such constructions include financial participation by private individuals in local energy projects and the reinvestment of income from community projects in the immediate locality.

for local initiatives (e.g. by adopting a policy of approval as the default response), and if politicians and administrators stress to their communities that spatial change is essential and that their province or municipality is not exempt.

7.3 A low-carbon energy supply and market structure: capacity, flexibility and (European) integration

What is the transition task?

The need to effect an energy transition, and therefore to increase the use of sustainable energy sources and change the way sources and carriers are utilised in order to realise a low-carbon energy supply, translates to increasingly strict requirements regarding the energy-system and its regulation. The existing energy system and its regulation are inadequate. The market structure – the playing field and the rules governing investment, trading and consumption – must therefore be reconsidered.

Policy issues

The Council believes that regulation should have the explicit goal of promoting the transition to a low-carbon energy supply. Naturally, a reliable and affordable supply of energy must also remain assured.

Three closely interrelated topics are of particular importance: flexibility of the energy system, production capacity and the energy-infrastructure. The three topics are considered more closely below.

Flexibility of the energy system

In the years ahead, the electricity market will come under further pressure. The major growth expected in the importance of weather-dependent wind-powered and solar-powered generating capacity will require transition to a more flexible energy system in order to ensure the continuous availability of energy.

At present, many market actors have insufficient (price) incentives to immediately respond to fluctuations in supply or transmission capacity availability. An efficient market would give appropriate price signals, so that supply and demand remain permanently in balance. Both the amount of energy produced and the timing of production are critical in that context. The price signal given by the wholesale price is in practice weakened by fixed consumer supply tariffs, static network tariffs, taxes and surcharges. End users, acting increasingly also as producers (prosumers), must become fully fledged energy market players.

Box 6 Demand-response and demand-bundling, storage, conversion and back-up

The following actors can increase the flexibility of the system:

- *Flexible end users (by demand-response)*
  Electricity demand is currently almost entirely inelastic. In other words, power consumption remains almost constant, regardless of the price at a given time. Greater elasticity could have major prosperity effects in the form of lower prices and reduced need for (capital-intensive) investment in new production capacity. Industry, commerce and households should be able to increase or reduce their demand, depending on the supply (and price) of electricity at a given time. 'New' applications, such as electric vehicles and heat pumps, would then add flexibility to the electricity system.
- *Suppliers and other service providers*
  ESCOs can offer bespoke contracts to businesses and households, covering not only energy consumption, but also daily or seasonal flexibility. Under such contracts, for example, prosumers receive backup guarantees assuring them of supplies when their own generating capacity is insufficient to meet their own demand. By combining local generation, smart appliances and storage (e.g. in electric cars), flexibility can be bundled and offered to the market in aggregated form.
- *Storage facility providers*
  Short-term balance shifts in electricity production can be absorbed using batteries and thermal energy storage. In the long term, storage systems will also be needed to improve the absorption of seasonal variations in electricity consumption. Against that backdrop, solutions based on energy conversion, such as power-to-gas (hydrogen) and power-to-heat require further development.
- *Flexible producers*
  For some time to come, thermal power plants will remain necessary to accommodate fluctuations in the consumption and production of electricity. However, if the emission objective for 2050 is to be secured, they must be deployed on a very flexible basis, they must be very efficient in terms of fuel consumption, and their greenhouse gas emissions must be very low (due to use of biomass, CCS). Alternatively, large wind-powered and solar-powered plants must limit output when demand or network capacity is insufficient.

Production capacity

In 2050, and also during the transition, there must be sufficient production capacity to assure security of supply. The market must provide appropriate investment incentives to assure an adequate energy supply in the longer term. The existing market structure does not provide such incentives. The capital costs associated with the production of electricity from renewable (e.g. wind energy, hydro-energy and solar energy) are high, but the operating costs are low, mainly because there are no fuel costs. The strong growth in the production of electricity from renewable sources is driving thermal power plants with high fuel costs from the market. However, such plants can be necessary as backups for times when there is little wind or solar energy available and other flexibility provisions (storage, demand management) cannot fully absorb the fluctuations.

Investing in backup plants, including storage and conversion systems, is viable only if market prices peak during the brief periods that such plants are deployed. To prevent major price fluctuations, some neighbouring countries price the availability of flexible production capacity separately through 'capacity mechanisms' (German Federal Ministry for Economic Affairs and Energy, 2015).

Another dilemma is that long-term market prices at times when ample electricity is available at low marginal cost (solar power, wind power, hydro power) are so low that there is little incentive to invest in renewable capacity. That is another reason why market prices need to be more representative of the underlying production cost structures, including system costs (e.g. grid costs and balancing costs) and the costs arising out of external impact, including the contribution to CO_2 emissions and air pollution. Taxation and tariff structures need to address such issues more actively.

Also where low-temperature heat is concerned, the market structure will be problematic as natural gas becomes a less automatic choice. In relation to transport and high-temperature heat, key questions include how the biomass market will develop and whether the supply of energy from renewable sources will be sufficient. The Council expects that sustainable biomass will be so scarce that it will be used only where other sustainable options are very difficult to realise or very expensive. Part of the solution to the capacity challenges may be the further integration of markets and market segments within the energy system. Power-to-gas conversion and power-to-heat conversion allow energy to be stored when there is a surplus. Another part of the solution may be continuing European integration of the energy supply. The expansion of international interconnections and market linkage provide for a more stable supply of energy. Upscaling also leads to more efficient pricing. Such developments do, however, make increased supranational coordination desirable. The Netherlands must therefore strive for further development of the European Energy Union.

Energy infrastructure

Reliable infrastructure is essential for the continuous availability of energy (security of supply). The characteristics of the available infrastructure also influence the scope for using various energy carriers and the associated technologies.

Infrastructures for various energy carriers need to complement each other in order to take full advantage of the variety in the available energy sources, the physical geography and the local (weather) conditions. Electrification of the low-temperature heat functionality (heat pumps) and the mobility functionality (electrical transport) will increase the demand for electricity and the load on transmission networks, particularly at the local level. In practice, infrastructures can also have a mutually exclusive effect ('lock-in effect[19]), because the creation of a transport or transmission network is expensive. For example, the large-scale rollout of gas networks across the Netherlands since the sixties has held back the development of collective heating networks. By contrast, Denmark – which has no natural gas of its own – has since the oil crisis of the seventies committed itself to the development of its own collective (residual) heat supply system, which is consequently one of the country's dominant infrastructures. In view of the high cost and long lead times, energy infrastructure investments need to be initiated in plenty of time if they are to contribute to the energy transition. It is important that no infrastructure is created or renovated, if it is not subsequently going to be compatible with the new sustainable energy supply.

The network operators (operators of primary and distribution networks for electricity, heat and gas) act as providers of the required transmission capacity. Network operators have a role to play in, for example, the development of flexibility options by realising sufficient transmission capacity. With a view to bringing about the desired energy transition, the government should reassess whether the network operators' statutory duties are (still) compatible with that role. In the context of the energy transition, not only must each network's capacity requirement be separately determined, but also the merits of various networks must be compared. Where should networks be retained or decommissioned; where should a new network be created and how will that be decided? It would seem illogical and expensive to have three networks (for electricity, heat and gas) competing with each other. A clear long-term plan for the realisation and maintenance of infrastructure is therefore vital. Insight into the cost of expanding, replacing and upgrading networks and into possible ways of reducing those costs is best obtained at the regional and local levels. The task is particularly great where the low-temperature heat infrastructure is concerned.

The realisation of sustainable mobility and transport will require the vigorous continued rollout of infrastructure. A network of charging points for electric cars that provides adequate coverage will be required, as will the integration of that network within the electricity grid; hydrogen filling stations and LNG stations will also be needed for freight transport. Where shipping is concerned, the number of LNG supply points and bunkering stations must be increased further.[20]

19 A lock-in effect is an inherent advantage that an established product, service or network has over a newly introduced rival product, service or network.
20 Within the EU, efforts are being made to create a pan-European infrastructure through the Clean Power for Transport Directive.

7.4 Availability of public and private finance

What is the transition task?

Major investment will be needed to bring about the energy transition. The challenge is therefore to mobilise enough private and public capital to fund the necessary investment projects. In the context of the financing task, distinction must be made between the long-term cost of the energy system and the cost of bringing about transition. Initial calculations made using the Energy Transition Model (ETM) also demonstrate that the cost structure is changing: whereas the current energy supply system involves relatively high fuel costs (plus the associated uncertainties) and relatively low capital costs, the target situation is characterised by relatively high capital costs and relatively low fuel costs. The ultimate costs are to some degree dependent on which endpoint scenario is actually realised (Kerkhoven et al., 2015).

Investment is needed at all levels. Householders will need to modify their homes. They will need to invest in energy conservation (floor and roof insulation), in new central heating boilers if they have to switch from using (natural) gas to heat their homes to using (residual) heat from a heat network, or in electric cookers. Businesses will also have to make their buildings energy-efficient. Moreover, they will need to invest in fundamentally different production methods in order to conserve energy, or they will have to start using different materials that can be processed without expending so much energy. And energy companies will have to produce energy in very different ways from at present. Both private and publicly funded innovation are necessary to bring out the energy transition.

The national budget

The national government faces a particular budgetary challenge in connection with the income from and expenditure relating to fossil energy. The state derives tax revenue from the extraction of natural gas (and a small amount from the extraction of oil), as well as from VAT, taxes and duties on fossil energy carriers. The income from extraction is declining, because the gas reserves are beginning to run out. That process is independent of the energy transition and the decline in revenue has already been factored into the government's long-term budgetary estimates.

The problems with seismic activity in the province of Groningen increase the likelihood that, in the period ahead, even less natural gas will be extracted than anticipated.

The state must decide how to cope without the annual income of more than forty billion euros that it derives from the use of fossil energy, which will diminish considerably as the use of fossil fuels declines. If the government wishes to continue generating that revenue from within the energy sector, the tax on the dwindling amounts of fossil energy used will have to increase. Alternatively, renewable energy will need to be taxed by the unit, much as fossil energy carriers are currently taxed. However, that would not be a sensible strategy to adopt during the transition phase. The transition approach must therefore include a tax plan that addresses such dilemmas.

Ensure the availability of the necessary capital

Financiers indicate that enough private capital is potentially available to fund sustainable energy projects (SER, 2015). Nevertheless, such projects are difficult to finance, due to issues such as the amount of capital required (particularly for large-scale projects), the long payback horizons, the technical risks and the uncertainties that exist regarding future policy. Expectations regarding future energy prices and the price of CO_2 emission allowances are of course important too. If prices are expected to fall and new sustainable technologies are expected to emerge, investments are liable to be deferred, even if they are desirable for realisation of the required emission reduction. In order that incentives are not split, it is important that investment decisions are based on the total cost of ownership (TCO). That implies that the total emissions burden associated with both the capital cost and the operating costs are included in the analysis and therefore inform the decision-making. That is particularly relevant in the urban environment, where users often do not own the buildings in which use takes place.

Financiers make investment decisions on the basis of detailed business plans. However, it can be difficult, particularly for SMEs, to provide business plans for renewable energy projects that contain enough detail to persuade a financier. Additional support, e.g. in the form of a development subsidy, may help in that regard. Banks generally want securities, which may not be readily available during a period of transition, when enterprises cannot provide evidence of cash flows, proven technologies and demonstrable creditworthiness.

Alongside subsidisation, the combination of public and private finance may open up new funding opportunities. Through public-private finance schemes, sustainable energy projects can be supported with guarantees, loans or stocks. However, any government that wishes to interest a private entity in fund management or direct (co-)investment must accept the implications. The benefit of private sector involvement will not be secured if the government seeks to restrict the private actor's freedom of movement by attaching conditions to subsidies or insisting on certain technical solutions, instead of focusing on a particular project result or (social) outcome. Conversely, private actors must accept that the use of public resources has implications for the conditions governing management or project finance.

Finally, there are alternative sources of finance. When small-scale sustainable energy projects are bundled, as with solar panels on homes, finance can be obtained from conventional routes or crowd funding. Where obstacles to such initiatives are identified, steps must be taken to find solutions.

7.5 Energy awareness, influencing behaviour and support[21]

Energy awareness

Energy awareness is generally fairly low amongst the general public, politicians and administrators. In other words, many people lack knowledge about the cost of energy or the level of CO_2 emissions associated with an aeroplane journey, a car journey to the supermarket, a year of running a refrigerator, having a light on every evening, or eating a kilo of vegetables or beef. If someone at a dinner party brags that he has so many solar panels on his roof that he can already generate all his own energy, he is probably talking only about electricity, which actually represents a small proportion of all the energy that the average person uses. The potential of new energy technologies is often overestimated as well. Greater understanding of energy, promoted by the government and others, will contribute to a balanced debate about the value of and the need and scope for energy transition.[22]

Influencing behaviour

Public information campaigns and financial incentives (e.g. subsidies and tax concessions) are not the only things that influence people's behaviour. Promoting change is much more complex than using those two tools, and it is important to consider what else can be effective. The complexity of behaviour and of exercising influence over behaviour is illustrated by following research observations. People may be encouraged to behave in a climate-friendly way by what other people are doing. 'Bad' behaviour is often the product of habit, meaning that the habits that lead to unwanted behaviour need to be broken before more desirable behaviour can become established. Making energy-saving behaviour more attractive and easier promotes energy conservation (so, for example, instead of merely offering subsidies for home insulation, it is helpful to offer a package of support services, such as loft clearance help, so that it is very little trouble to get the job done).

The energy transition can be promoted by making better use of knowledge about how people behave and about the determinants of individual behaviour. All parties that wish to promote energy transition need to make use of such knowledge. Governments can use various physical, technological, legal, economic and communicative tools to influence behaviour. In practice, the various tools are mutually reinforcing. Furthermore, different forms of intervention tend to work with different groups of people.

Social support

The energy transition will proceed more quickly if broad social support can be secured. Three factors are key to securing social support. First, the (general perception of the) division of social and private costs and benefits. Second, the confidence that people have in innovators, the government

21 This subsection is based largely on Rli's advisory report *Influencing Behaviour: More effective environmental policy through insight into human behaviour* (Rli, 2014b), which presents an analysis framework for understanding the determinants of behaviour.

22 The Royal Netherlands Society of Engineers (KIVI) has, for example, compiled a useful booklet, which explains the significance of energy: *De rekening voorbij: ons energie verbruik voor 85% onzichtbaar (The hidden cost: 85 per cent of our energy consumption is invisible*, 2014).

and scientists. Third, the extent to which people are involved and participate in decision-making (Steg et al., 2015). If the people who bear the costs of energy transition are not the same people who stand to gain, that is likely to be considered unfair. Naturally, the size of the costs and benefits makes a difference in that regard.

People are more likely to accept energy policies and changes to the energy system if they have the sense that they can exercise influence over the policy process and if they feel that that process is democratic. There must be involvement at all levels. That implies accurate information being made available from the beginning. Furthermore, decision-making and the underlying reasoning need to be transparent and consistent, rather than retrospectively communicated and explained. Clear commitment from politicians and administrators has a positive effect, while forms of public involvement or participation that have no influence on the process have a negative effect (Steg et al., 2015).

8

MANAGING THE ENERGY TRANSITION: ADAPTIVE PURSUIT OF THE PRIMARY OBJECTIVE

One element of the central question addressed by this report is how to adaptively manage progress towards the fixed emission reduction goal for 2050. Energy transition is not only a substantial and complex process, but also a process that implies far-reaching changes in the social, economic, administrative and technical domains. Existing interests and structures need to be dismantled. Numerous bodies, companies, lobby organisations, private citizens, consumers and governments have a role to play in the transition. Obstacles will need to be removed, including market imperfections, obstructive institutions and unhelpful regulations. New technologies, institutions and regulations will have to be developed or designed. Scope must be created for initiatives that make a positive contribution. The transition is going to necessitate major investment and give rise to significant financing issues. Policy consistency will be required in order to reduce uncertainty for everyone involved. However, policy must not be inflexible: there has to be scope for adjusting course where circumstance dictates. The whole energy transition will take place in a European and global context. At the same time, the changes associated with transition provide opportunity and inspiration.[23]

Notwithstanding the size and complexity of the energy transition itself, a solution must be found for what the Netherlands Scientific Council for Government Policy (WRR) describes as the 'time inconsistency problem of politics and administration' (De Goede, 2015).[24] In a nutshell, that involves politicians and administrators (like people in general) attaching greater importance to short-term interests than long-term interests. In order to realise adaptive management of progress towards the fixed emission reduction goal for 2050, a way must be found of setting and maintaining a course towards that goal within the democratic process. Policy must be predictable and consistent, while also being adaptable to circumstance.

In our modern network society, chains and networks are the organising principles, rather than individual organisations. Management consists primarily of calling on and activating the self-organising capabilities of such chains and networks.

The Council recommends basing management of the transition on six principles:

1) The statutory emission reduction goal in 2050 should be actively pursued, but the pursuit should be adaptive.

The ultimate objective is fixed and expressed in completely technology-neutral terms. As indicated earlier, the Council favours statutory adoption of the national goal of reducing greenhouse gas emissions by 80 to 95 per cent by 2050, relative to 1990, and the associated goal for energy-related emissions. Formalisation of those goals in law would serve as a powerful

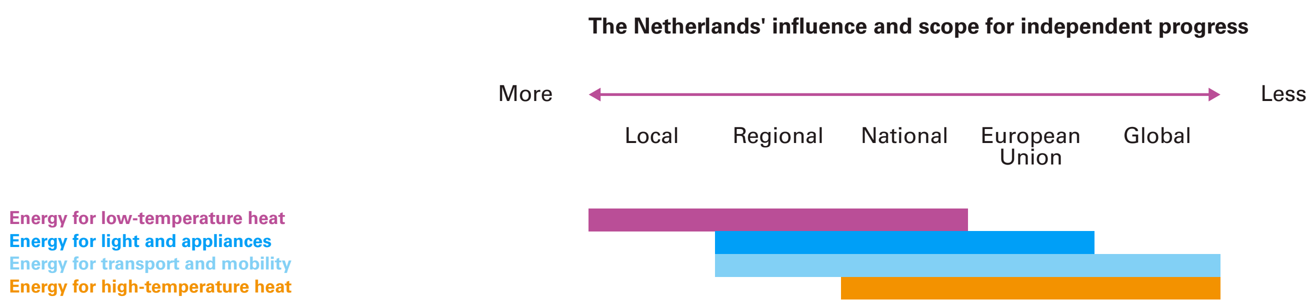
23 The Council wishes to point out that the uncertainties associated with energy transition have important positive effects as well. Taleb introduced the word 'antifragile': 'to deal with black swans, we indeed need things that gain from volatility, variability, stress and disorder.' His point is that there is much to be gained from unexpected events, from volatility, variability, stress and the resulting disorder. In the context of this report, that is important not only in relation to innovation, but also within the social domain.

24 According to the WRR (2015), politicians and administrators are 'time inconsistent' and often more concerned with short-term interests than long-term interests. That is a response to factors such as the threat of electoral penalisation, media pressure and a national budgetary system which revolves around annual income and expenditure. The discount rates applied when calculating the value of future benefits which must be paid for in the present also play a role.

signal to the political community and to wider society that the Netherlands is committed to their realisation. It would provide greater certainty than if the goals were merely stated in successive coalition agreements, since a coalition agreement is valid only for the duration of one political administration. Furthermore, the formulation of the goals in terms of CO_2 emissions will make technology-neutral management possible, thus maximising the scope for innovation. That in turn will help to optimise the private and social cost-benefit balance over the whole period. The year 2050 is a long way off, meaning that considerable uncertainty exists regarding the course that developments may take between now and then. The ability to adjust course along the way is therefore essential, but always with a view to securing the stated emission reduction goal for 2050.

2) The approach should be differentiated for the four functionalities.
Transition must be realised in a different way for each functionality. Explicit differentiation is therefore required in management of the transition, based on the functionalities, not on the energy sources, carriers or sectors. The

The Netherlands' scope for exercising influence and independently pressing ahead with transition



approach should differ particularly in terms of the level of management, the speed of transition, the management organisation, the secondary goals, the result levels (spatial, administrative), the current availability of technical solutions and the need for social and technological innovation. The figure below shows the level at which management issues need to be addressed for each energy functionality and how much scope the Netherlands has for independent action. The scale level influences the management methods that are appropriate and the Netherlands' scope for independent progress.

Increasingly, the energy transition involves multiple organisational levels, from local (e.g. heat grids and dispersed energy generation) to European (e.g. emissions trading and European standardisation). The shift from a predominantly centralised energy system to a more dispersed one means that lower tiers of government, such as city and provincial governments, are more involved in decision-making and coordination of the energy system. Responsibility for the realisation of a given component of the energy transition should lie at the level where that responsibility can be exercised most effectively and efficiently, while central system tasks remain with the central government.

The scale levels also differ from one functionality to the next. Direction needs to be provided at various scale levels, e.g. at the international level for European appliance efficiency standardisation, at the national level for mobility and transport tax incentives, and at the local level for heat grids. Harmonisation and interaction between the levels are important.
Where decision-making proves difficult (e.g. where international consensus

is needed) or its tempo does not match the need for progress, it is desirable to switch to a different level. That may be appropriate where the emissions trading system is concerned, for example.

The functionalities also differ in terms of the number of actors involved. In the field of low-temperature heat, there are numerous actors (households, institutional and private landlords, housing corporations, suppliers and installers), while the high-temperature heat functionality involves a much small number of less varied actors.

3) Task-defining agreements and arrangements should be made, with provision for accountability.

The rules that apply in the context of the adaptive working method advocated by the Council need to be clear, so that all actors understand who is responsible for what and are answerable for their individual contributions to the ultimate objective. The availability of more compelling legislation and regulations must be made explicit from the outset when negotiating agreements and arrangements, so that no one is in any doubt that their fulfilment is not optional, but vital for realisation of the ultimate goal.

The agreements and arrangements must also reflect the following principles (Weterings, 2010):

- Collaboration should be effected across the technical, economic, social and administrative domains in order to realise solutions. That is important, for example, in the context of innovation programmes that need to take account of social factors. The rollout of smart meters or smart appliances may encounter opposition, for example, if insufficient account is taken of privacy-related issues.
- Interested organisations should be helped to organise dispersed energy projects and energy conservation projects, which have an important role to play in the transition.
- Links should be established between short-term activities and experiments and long-term objectives (learning by trial and error).

Scope must be provided for social initiatives with the ability to activate forces of change and to maintain the motivation of social actors.
The framing of the desired change must therefore be aligned with the interests and value structures of the relevant public and private stakeholders. The various frames must nevertheless be mutually consistent, since the ultimate objective is always the same. Providing scope implies also allowing for experimentation and for making errors, i.e. for learning by trial and error.

4) Impose an increasingly compelling regime of incentives and legislation where necessary.

The form taken by that responsibility will change from management by a central government to management on the basis of governance. Management by the government must enable each component of the network to contribute optimally to the general goal.

That implies that the government must promote ties between actors, provide encouragement, build trust, remove obstacles and involve itself in deliberations. With those aims in mind, general goals should be defined and promoted (giving meaning and branding), the organisational capabilities of actors involved in transition should be reinforced, coproduction should be encouraged, assessed, stimulated and rewarded, and learning effects should be organised.[25] The government requires a clear understanding of the society's capacity for self-organisation if it is to harness that capacity and make targeted (minor) interventions.

Where all such matters are concerned, the government retains ultimate system responsibility – its role being to assure public interests. That implies imposing an increasingly compelling regime wherever that proves necessary for the transition. The prospect of compulsion must be in view from the outset, in order to minimise the likelihood of compulsion ultimately proving necessary.

5) The political and administrative processes should be made resilient. The WRR (De Goede, 2015) has identified a number of possible ways of reinforcing management in the long term. The Council recommends explicitly incorporating the identified possibilities into the management model:

- Depoliticisation of management of the energy transition is vital for realisation of the required trend changes and attainment of the goal for 2050. Management of the energy transition can be depoliticised by establishing an administrative organisation that is not under direct political control. The WRR (De Goede, 2015) suggests that the independence of the central bank can serve as a model. The officials who run the central bank are appointed for long periods by the government and their decision-making is not therefore influenced by the need to secure re-election or reappointment. That means that they can take a long-term view of matters such as price stability and are not deflected by day-to-day political turbulence.
- Subsequent revision of climate policy can be made more difficult, e.g. by making less use of escape clauses, or by requiring that any subsequent revision has qualified majority support. Explicit linkage of national legislation and international treaties can also make policy more resilient.
- Responsibility for supervision and enforcement in connection with the emission reduction goal for 2050 and the secondary goals should be given to an independent organisation. (See also principle 6, below.)
- In the development of policy, intelligent use can be made of positive dependencies on the pathway to the future, providing that progress is incremental, so as to retain the ability to make course adjustments in the event of circumstantial changes.
- The existence of an apolitical, independent energy transition organisation can help to promote relevant issues on the political agenda and to escalate them where necessary. Everyone should be able to raise energy transition issues with the energy transition organisation.

25 Sometimes referred to as 'betweenness centrality' (attributed to Freeman, L.C. (1977)).

6) A form of organisation should be explicitly selected for monitoring and acceleration.

The Council believes that it is important to have a form of organisation that can determine whether transition remains on course and what the causes of delays are, and can accelerate the process where necessary. The form of organisation must be capable of encouraging actors, holding them to account, adjusting their course and, in the final resort, penalising them. The organisation must also serve as a reference centre, to which people can turn when they have questions, ideas, opportunities and problems.

For inspiration, the Council suggests looking to Denmark and the UK (Notenboom, 2015) (Notenboom & Nielsen 2015). In Denmark, the goal of achieving a fossil-fuel-free energy supply by 2050 is stated in a widely supported agreement (2012-2020). Policy coordination is provided by the Ministry for Energy, Climate and Utilities, which has responsibility for all energy functions except for mobility. The UK has framework legislation (the Climate Act) stating that, by 2050, the government is obliged to reduce CO_2 emissions to a level at least 80 per cent below the 1990 level. Compliance with the act is monitored by a Committee on Climate Change (Committee on Climate Change, 2015).

The Council recommends that the organisation form should be selected in accordance with the five preceding principles.

The Council also wishes to make the point that the pursuit of ambitious goals by the Netherlands at home and in international forums will lead to major structural changes in the economy. The great challenge facing the nation can be successfully undertaken only if the transition is overseen by an independent person or body with no direct interest in the process. That also has implications for the detailed implementation. The Council accordingly proposes the appointment of a government commissioner to drive and oversee transition and to ensure continued progress towards realisation over a long period of time, unaffected by governmental succession.

Like the emission reduction goal, the organisation form should be specified by legislation, because that is the only way to ensure that duties and responsibilities are clearly defined from the very start of the transition to 2050, before agreements and social arrangements are made for each of the energy functionalities.

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APPENDICES

1. REQUEST FOR ADVICE

Council for the Environment and Infrastructure
F.a.o. H.M. Meijdam
PO Box 20906
2500 EX THE HAGUE

Date: 09 dec 2014

Subject: Request for Rli advice in connection with the Energy Report 2015

Dear Mr Meijdam,

I am writing to ask the Council for the Environment and Infrastructure (Rli) to produce an advisory report to form the basis for the Energy Report 2015.

Background
In the long term, the definite (EU) ambition is to realise a fully sustainable energy supply by 2050 at the latest. As well as being sustainable, the energy supply has to be affordable for consumers and businesses, and reliable, with assured national and international security of supply. The Energy Agreement for Sustainable Growth (2013) was intended to help build wide social support for practical action aimed at securing the Dutch sustainability goals for 2020/23. Furthermore, in October 2014, the European Commission has defined the European climate and energy goals for 2030.

Meanwhile, there are short-term tensions in various fields: conflict in the Middle East and Ukraine, with implications for security of supply; seismic activity in the province of Groningen and the safety of local residents; price differences with countries inside and outside Europe and the competitiveness of business; the efforts to establish a European Energy Union while member states individually define their own energy mix; the rise of intermittent energy sources and the associated pressure on the electricity system; the decline in Dutch gas production and the role of gas in our energy supply; dispersed sustainable generators and uncertainties about financial support; the (spatial) accommodation of high-voltage pylons, wind turbines, gas storage and shale gas and the social resistance to them. Those are just a few of the many issues that require practical policy action and have long-term implications. It is also pertinent to consider whether current policy lines will be sufficient in the long term to go on assuring a sustainable, reliable and affordable energy supply in a changing world.

With so many developments, objectives and ambitions, there is a (political) need for a new integrated and strategic vision for the energy supply in the Netherlands. In the Energy Report 2015, the cabinet will outline the energy policy and a robust policy agenda for the short and medium term.
The report is expected to be published in late 2015.

Request for advice

The Council for the Environment and Infrastructure (Rli) is asked to produce an advisory report containing the following:

1. A number of trend and development-based scenarios for the energy supply in the Netherlands in the medium term, which are consistent with the ultimate objective of achieving a fully sustainable energy supply by 2050.
2. Dutch, European and international policy tasks for the period to 2035, based on the scenarios referred to above and taking account of the inherent uncertainties and identifiable opportunities and dilemmas.

The Council is asked to submit the advisory report no later than August 2015. The arrangements made in consultation with your Council regarding the organisation of the reporting process are set out in the appendix to this letter. The appendix also highlights a number of important trends, developments, uncertainties and dilemmas

H.G.J. Kamp
Minister of Economic Affairs

Appendix

Organisation of the reporting process

RLi will establish an advisory committee chaired by Mr Meijdam to prepare the advisory report that will serve as input for the Energy Report. The advisory committee will include one or two RLi members, plus roughly six external members with knowledge of the energy domain (research, technology, administration, market, finance).

The advisory committee will organise an open process, in which stakeholders from the energy world have the opportunity to contribute to the advisory report. The aim of the process will be to ensure that the advisory report ultimately produced enjoys support and recognition.

The advisory committee will organise the information exchange and interaction with the Ministry of Economic Affairs and other departments on the most efficient possible basis, in order that optimal use may be made of the available (policy) knowledge and that the advisory report lends itself to translation to the Energy Report 2015. Throughout the reporting process, the Ministry will make the necessary personnel and resources available.

Detailed arrangements may be made regarding additional funding for advising on and extrapolating the scenarios and policy lines, e.g. by commissioning ECN, PBL, CPB or other experts.

Trends and developments

Within the energy domain various developments may be distinguished. It is pertinent to ask which trends can be influenced and which cannot. Examples:

1. **Consumption.** Global energy consumption is increasing strongly; it is expected to grow by a third in the period to 2035. However, consumption in OECD countries is stabilising. Indeed, since 2004, energy consumption by final consumers in the Netherlands has been falling slightly.
2. **Availability.** Globally, ample energy sources are available. The Dutch energy supply is sensitive to developments in other countries. The relatively high gas price (compared with USA) has implications for competitiveness, particularly of bulk consumers.
3. **CO_2 emissions.** CO_2 emissions from emerging economies are increasing strongly. China 28%, USA 14%, Europe 10% of global CO_2 emissions; per capita: China 7.2 tonnes of CO_2, Europe 6.8 tonnes.
4. **Energy mix.** Renewable energy will become a more substantial component of the European energy mix. Gas consumption and gas production in the Netherlands will fall further in the years ahead. Between 2025 and 2030, the Netherlands will go from being a net exporter to being a net importer of natural gas. Electricity generation from coal will initially rise, but decline later. The Netherlands (and Europe) will become more and more dependent on imported energy. In the EU, most nuclear power plants will be phased out towards 2040.
5. **Space.** Energy generation and infrastructure will require more of the already scarce space.

6. **Energy bills.** The cost of energy to the end user is rising. Significant factors include: higher extraction and transport costs, investment in infrastructure, higher price of renewable energy, cost of climate policy and accommodation of flexible electricity production.
7. The **economic significance of renewable energy will increase.** Global investment in renewable energy has risen from $60 billion in 2000 to $250 billion currently (by way of comparison: fossil energy-related investment is $ 1100 billion). The cost of renewable energy is also falling. However, renewable energy will only become viable in the long term. Gas revenues currently provide nearly 10% of the government's income.
8. The **gas revenues** will decline as production continues to decline.
9. The increasing use of intermittent, renewable energy sources for production will put strain on the **electricity system**. Low wholesale prices undermine the earnings models of (traditional) market players. The transmission grid will have to become more flexible. Storage and demand management will become more important.
10. The greater tradability of energy will attract **other players** besides energy companies and energy consumers, including index investors, capacity managers and prosumers.
11. In many countries, **government involvement** in the energy domain is increasing. The role of national oil companies and subsidies for renewable energy are examples of such involvement.

Uncertainties and dilemmas

a. **Support.** Rising (final) prices and the increased spatial requirements may undermine social support for energy policy and projects.
b. **Technological development**. What the energy mix will be in 2050 is uncertain, because technological development in the fossil fuel domain and other domains is inherently difficult to predict. Consequently, the impact on spatial development, the central-dispersed split, the energy system, the market organisation, willingness to invest, security of supply, etc is unclear.
c. All **energy options** have drawbacks in terms of reliability, affordability or sustainability. Options such as nuclear energy, CO_2 storage and renewable energy appear to be essential if the goal for 2050 is to be attained. Meanwhile, fossil fuel use can lead to lock-ins.
d. **Competitiveness.** The Netherlands has a relatively large and energy-intensive industrial sector. Technological development, energy prices and climate policy have major impacts on the competitiveness of our industrial companies. It is not clear whether such companies can make the necessary changes or reinforcements.
e. **Energy conservation.** In many cases, energy conservation is economically attractive, yet the investments needed to realise the savings are not being made. At the same time, increased energy efficiency does not necessarily lead to less energy consumption (rebound effect).
f. **International.** The key energy policy issues and climate policy issues are European and global, and interdependencies are increasing. The playing field and politics are very varied, creating uncertainty as to the level of collaboration in Europe and beyond.

Composition of the Rli Energy Report Committee

Henry Meijdam (Chair)
(Rli Chair)

Marjolein Demmers
(Rli member, Director of Sustainability DHV RH)

Coby van der Linde
(Director CIEP (Clingendael), international knowledge and network)

Tim van der Hagen
(Professor of Reactor Physics (Delft University of Technology), member of the Advisory Council for Science, Technology and Innovation (AWTI)

Paul Schnabel
(Professor of Social and Cultural Policy, ex SCP)

Michiel Boersma
(Former CEO of Essent. Former figurehead of the energy top sector)

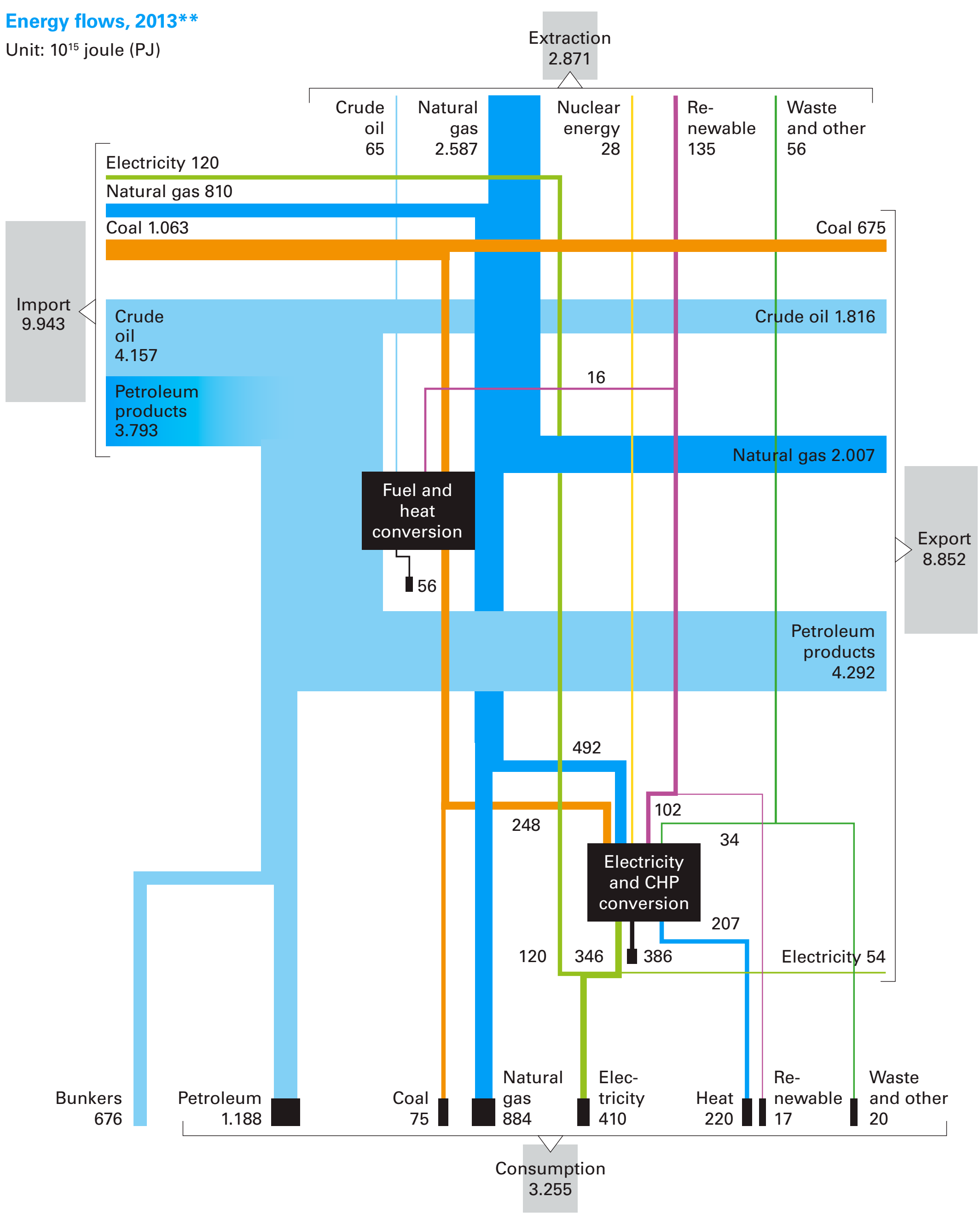
Manon Jansen
(CEO of Ecofys. Current figurehead of the energy top sector)

Marga Hoek
(Sustainability, Groene Zaak)

2. ENERGY FLOWS IN THE NETHERLANDS

Figure 2-1 is a flowchart ('Sankey diagram') illustrating the energy supply in the Netherlands in the form of energy flows. The diagram shows energy imports and extraction in the Netherlands, together with energy exports and consumption. The flows are depicted in petajoules (PJ) and include non-energetic use of energy sources.[26] The various illustrated flows are considered in the body of this appendix.

Figure 2-1: Dutch energy consumption in 2013, broken down by source[27]



N.B. The sum of the black blocks is the total energy consumption (final consumption and conversion balances). The figure disregards various pieces of data.

Source: Statistics Netherlands

26 Consumption as raw material is the consumption of energy carriers to make products that are not themselves energy carriers but in which the energy is stored, e.g. the use of petroleum as a raw material for the production of plastic. Such use is also referred to as non-energetic final consumption.

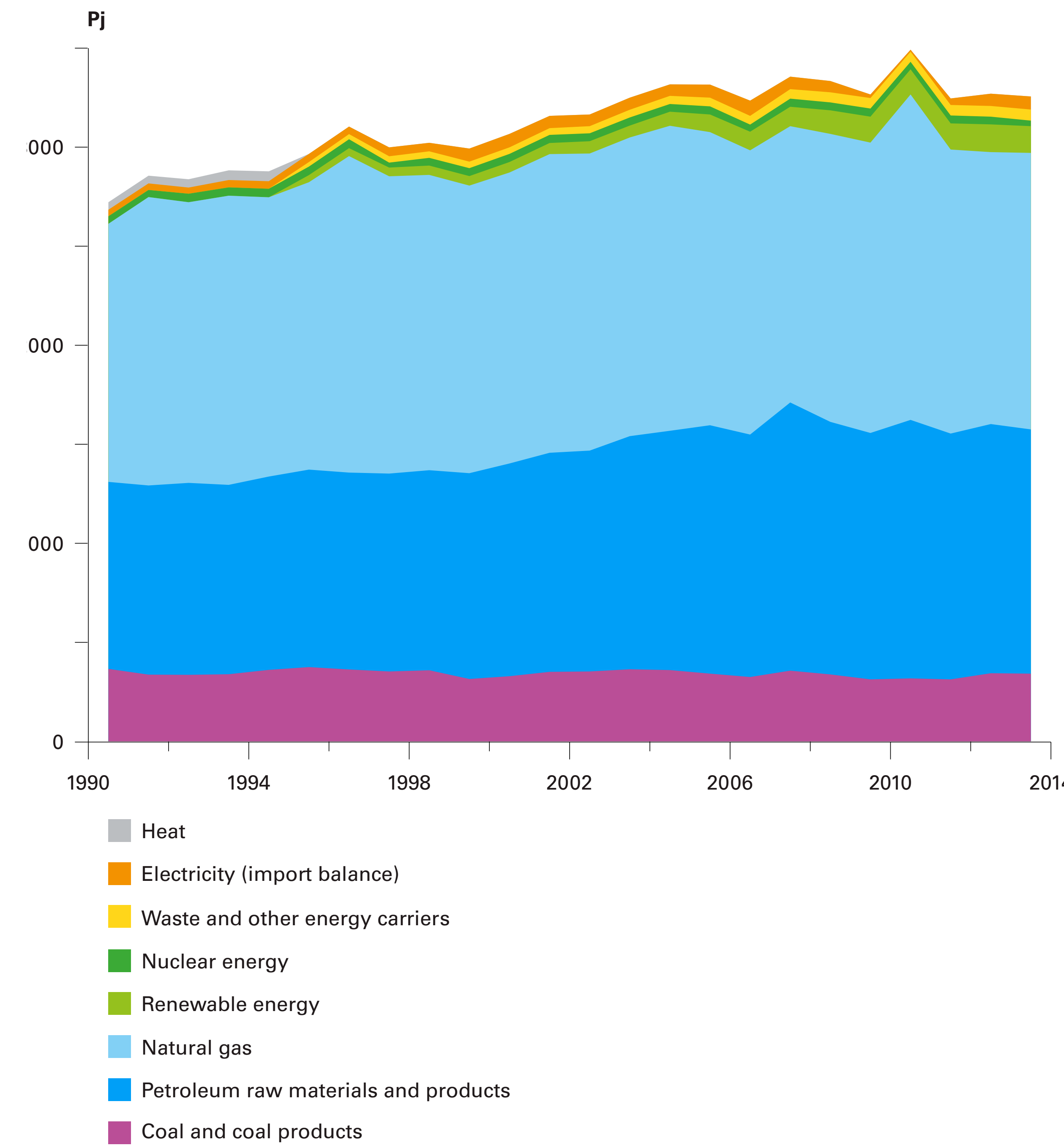
27 Source: http://www.compendiumvoordeleefomgeving.nl/indicatoren/nl0201-Energiebalans-Nederland-%28stroomdiagram%29.html?i=6-40

The Netherlands: an important petroleum product staging and production centre

Final energy consumption in the Netherlands, including non-energetic use.[28] Final energy consumption is the demand for energy from final-consumer sectors (industry, services, households, transport and agriculture). Electricity generation by the final-consumer sectors themselves is ‘transferred’ to the energy sector. The gross final consumption includes the energy sector’s own consumption of electricity and heat in the production of electricity and heat, including electricity and heat losses during distribution and transport. The flows in 2013, when final energy consumption was 3,255 PJ, are illustrated in Figure 2-1. A breakdown of the data for the period 1990-2013 by source is presented in Figure 2-2.

Much of the energy imported to and extracted in the Netherlands is exported. The Dutch havens are important staging ports for crude oil and petroleum products, and coal is also imported for subsequent export to other countries. The Netherlands is also an important hub for natural gas. The country’s natural gas exports (2,007 PJ) far exceed domestic consumption of natural gas, which is 1,376 PJ (including natural gas used for electricity generation). The main energy carriers imported to the Netherlands are crude oil and petroleum products and, to a lesser extent, natural gas, coal and electricity. Some of the imported crude oil is refined in the Netherlands to make petrol, diesel and chemicals.

Figure 2-2: Renewable energy’s share of total energy consumption in 2013, broken down by source



Source: Statistics Netherlands

28 The consumption of transport fuels for international aviation and shipping is not included in the energy balance. The aviation and shipping industries bunker a lot of fuel (676 PJ) in the Netherlands.

Much of the energy imported to and extracted in the Netherlands is exported. The Dutch havens are important staging ports for crude oil and petroleum products, and coal is also imported for subsequent export to other countries. The Netherlands is also an important hub for natural gas. The country's natural gas exports (2,007 PJ) far exceed domestic consumption of natural gas, which is 1,376 PJ (including natural gas used for electricity generation). The main energy carriers imported to the Netherlands are crude oil and petroleum products and, to a lesser extent, natural gas, coal and electricity. Some of the imported crude oil is refined in the Netherlands to make petrol, diesel and chemicals.

The Dutch economy has a relatively large petrochemicals cluster: the turnover of the chemicals sector in 2013 was nearly € 51 billion. Roughly 3 per cent of the Netherlands' gross domestic product was generated within the cluster (Statistics Netherlands). The Netherlands is consequently Europe's third largest chemicals producer, after Germany and France (Cefic Chemdata International). Roughly 80 per cent of the chemicals produced in the Netherlands are exported.

Natural gas extraction is important for the Netherlands

Energy carrier extraction in the Netherlands (2,871 PJ) is accounted for mainly by natural gas. The amount of petroleum, renewable energy and other energy carriers extracted is considerably smaller.

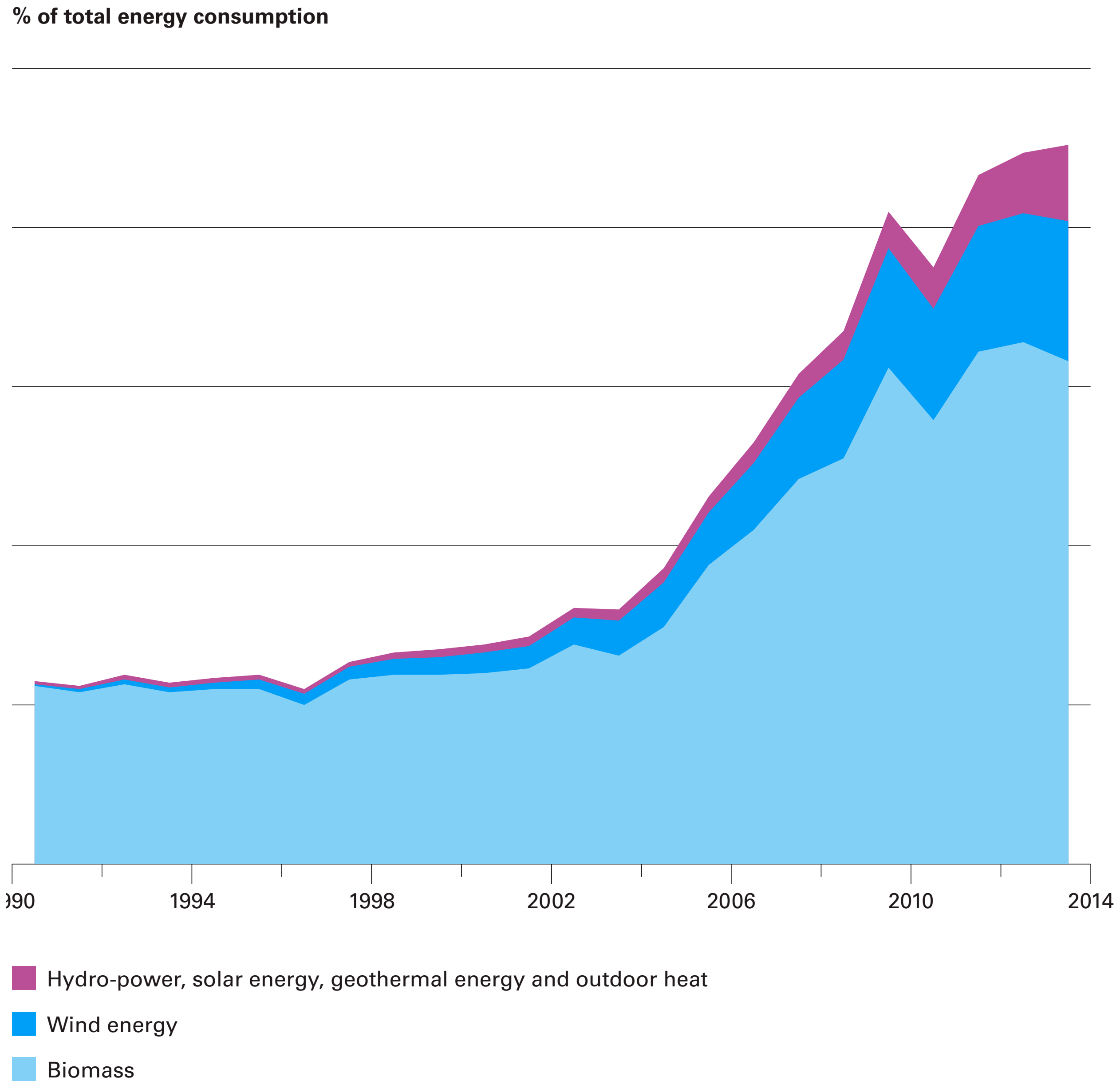
Fossil fuels are the main energy carriers

Fossil fuels – natural gas, petroleum and coal – are the Netherlands' main primary energy carriers. Roughly 90 per cent of the energy consumed comes from those sources. Coal is both converted into electricity and used in industry (mainly steelmaking). A number of large refineries convert crude oil into various petroleum products for use in transport and into raw materials for the petrochemicals industry (e.g. plastics). Natural gas is used for the production of heat and electricity and as a raw material for certain products (e.g. artificial fertiliser).

Renewable energy's contribution to the energy supply is modest and consists mainly of bio-energy

In 2013, renewable energy accounted for 4.5 per cent of final consumption (see Figure 2-3). The main renewable energy source was biomass (used e.g. to produce electricity and heat in waste incineration plants, as a secondary fuel in power plants and as biofuel for transport). Renewable energy's contribution has to be increased to 14 per cent by 2020 in order to comply with the EU's Renewable Energy Directive, and to 16 per cent by 2023 in order to comply with the Energy Agreement.

Figure 2-3: Renewable energy's share of total energy consumption in 2013, broken down by source



Source: Statistics Netherlands

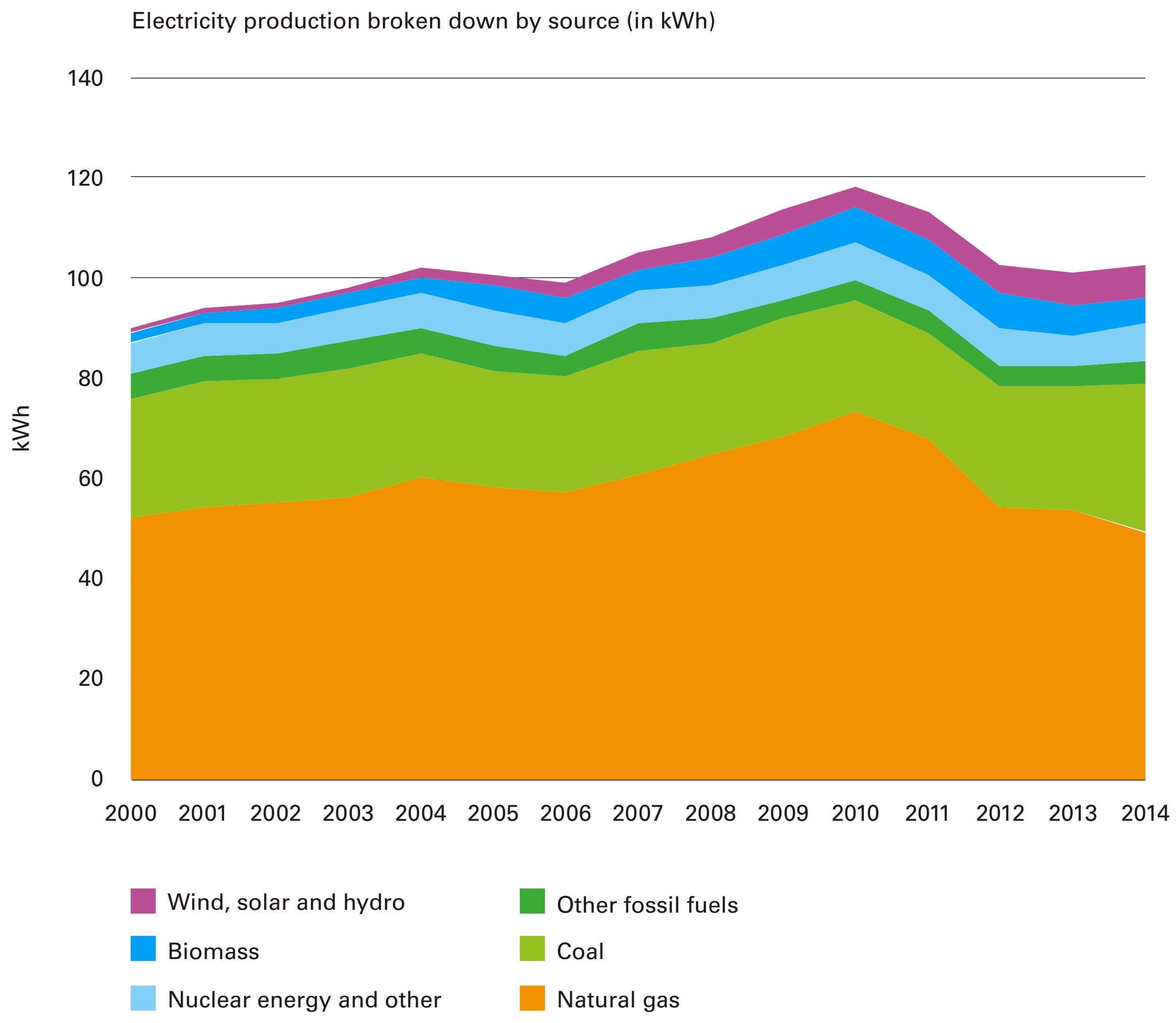
Conversion losses count

Final consumption of electricity in 2013 was roughly 115 billion kWh (roughly 410 PJ), or 12.6 per cent of total energy consumption in the Netherlands. The generation of electricity from conventional sources involves substantial conversion losses: 386 PJ in 2013 (see Figure 2-1). By contrast, electricity generation from solar energy and wind energy involves no conversion losses. Furthermore, the conversion losses involved in electricity production are far greater than those involved in the production of, for example, transport fuels and heat. When comparing electricity (from conventional or renewable sources) with other forms of energy, much therefore depends on whether one compares primary demand or final consumption.

The origin of electricity

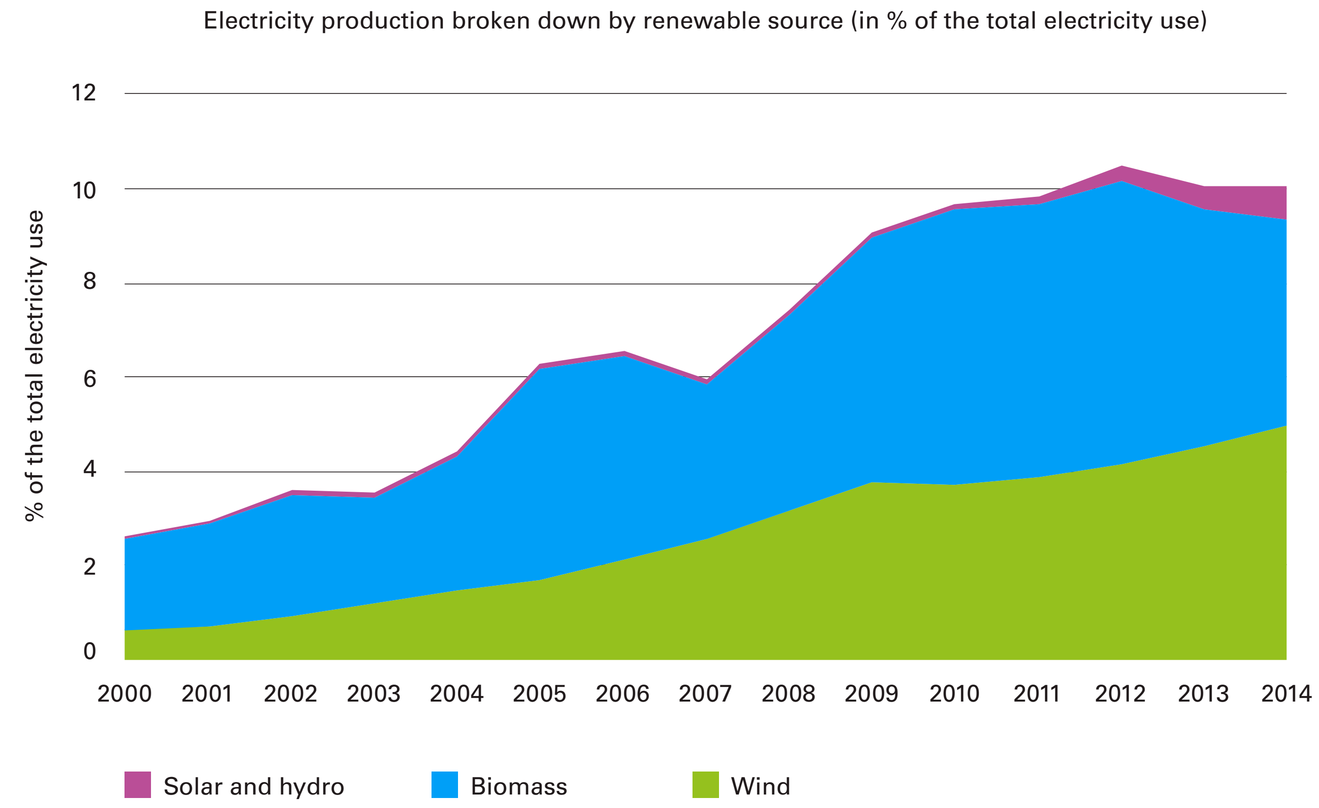
In the Netherlands, most electricity is produced by firing fossil fuels. In 2012, roughly 81 per cent of electricity was generated from fossil sources and 12 per cent from renewable sources (solar energy, wind energy, hydro energy and biomass). The breakdown is illustrated in Figure 2-4. Figure 2-5 shows the breakdown of renewably generated electricity by renewable source, as a percentage of electricity use.

Figure 2-4: Electricity production by source in kWh



Source: Statistics Netherlands

Figure 2-5: Production of electricity from renewable sources, in percentages of total electricity use



Source: Statistics Netherlands

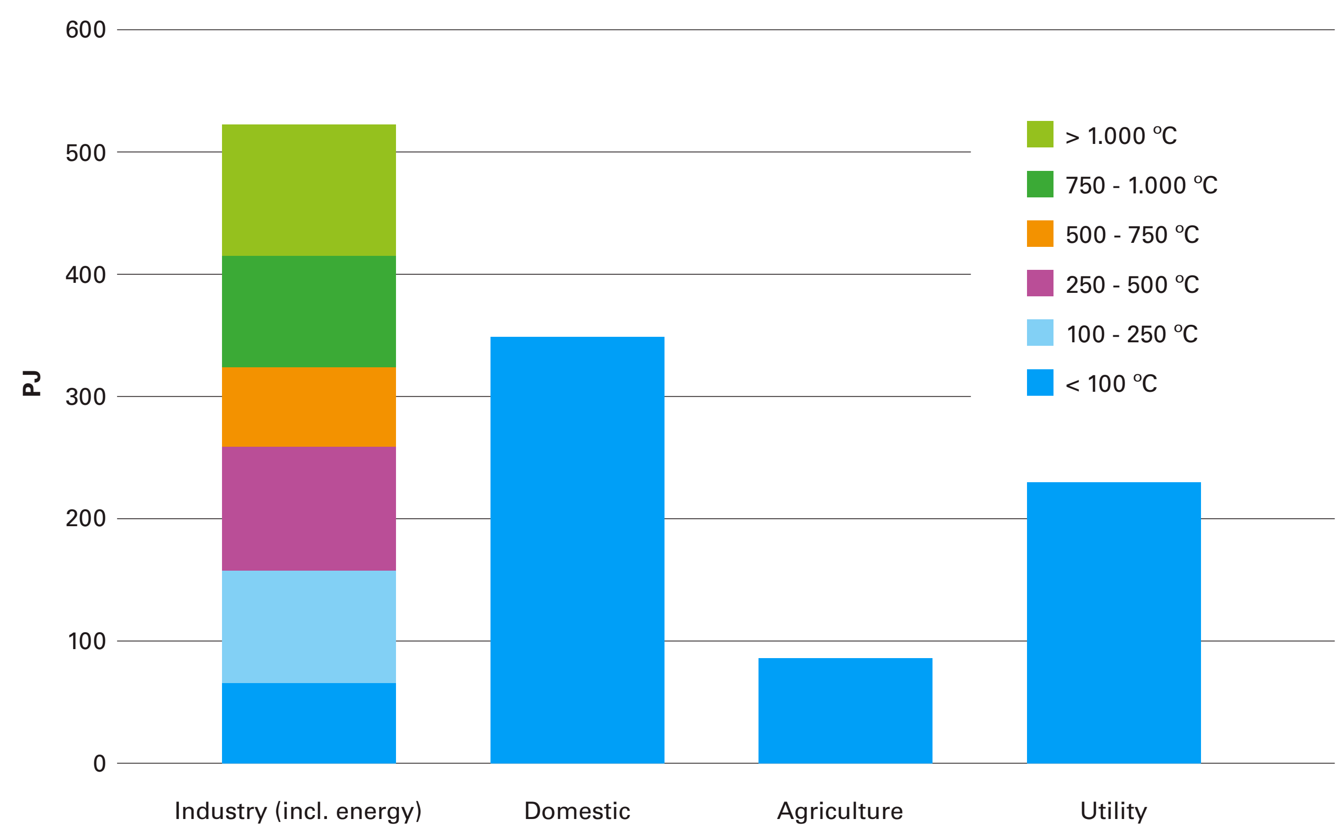
3. THE CURRENT ENERGY SUPPLY IN FUNCTIONALITIES

This appendix describes and defines first the energy functionalities on the basis of the report *Primaire energievraag en CO_2-emissies tot 2050 (Primary energy demand and CO_2 emissions in the period to 2050*), which was produced to inform the preparation of this advisory report, and second the distribution of the primary energy demand and emissions across the four functionalities.[29] The figures have been calculated on the basis of the energy balance for 2012 published by Statistics Netherlands.

The Council distinguishes four functionalities of energy and the Council's analyses assume that in 2050 the total demand for energy will derive from four fundamental social requirements. In order to fulfil those requirements, energy performs four functions:

1. Energy is required to fulfil low-temperature heating functions, such as the heating of buildings and the provision of hot water (e.g. for bathing and food preparation). This is referred to as energy's low-temperature heat functionality.
2. Energy is required to fulfil high-temperature heating functions, such as manufacturing and high-temperature industrial processing. This is referred to as energy's high-temperature heat functionality.
3. Energy is required to fulfil transport and mobility functions, enabling the movement of people and goods. This is referred to as energy's transport and mobility functionality.
4. Energy is required to fulfil lighting and appliance functions, such as powering lights, electrical and other appliances and ICT equipment. This is referred to as energy's lighting and appliances functionality.

Figure 3-0: Breakdown of demand for heat in the Netherlands on the basis of temperature category and economic sector in 2012 (CE Delft, 2014)



29 Warringa, G.E.A. & Rooijers, F.J. (2015). Verkenning functionele energievraag en CO_2-emissies tot 2050 (Survey of functional demand for energy and CO_2 emissions in the period to 2050). Delft: CE Delft..

Figure 3-0 shows the types of heat (temperature categories) used in various sectors of the Dutch economy. High temperatures (higher than 100-120°C) are used only in industry. In 2012, the primary energy demand in the Netherlands was 2,660 PJ and the energy-related CO_2 emissions were 166 Mt.

In tables 3-1 and 3-2, the total figures are translated to the four functionalities (calculations by CE Delft 2015). The four functionalities are considered in more detail in the following subsections.

1. Low-temperature heat

The demand for low-temperature heat comes mainly from the urban environment, for spatial heating and to provide hot water for bathing and food preparation.[30] Roughly 20 per cent of the total heat use by households is for hot water and 80 per cent for spatial heating.[31]

A small proportion (about 10 per cent) of the heat demand comes from agriculture, primarily for heating greenhouses. In industry too, low-temperature heat is used to provide hot tap water and heat production areas, offices, etc. In the food and drinks industry low-temperature heat is also used for processes such as cooking, drying, evaporation and baking. The greatest demand for low-temperature heat comes from households, followed by utility buildings, agriculture and industry (see Figure 3-1). In 2012, the primary demand for low-temperature heat was roughly 790 PJ. In the same year, the CO_2 emissions associated with the functionality were 45 Mt (tables 3-1 and 3-2).

Table 3-1: Primary energy demand in 2012,* broken down by function and sector (PJ)

	Transport	Industry	Urban environ-ment and agriculture	Total (rounded off)
Light and appliances	0	260	440	700
Transport and mobility	500	0	0	500
HT	0	670	0	670
LT	0	40	750	790
Total (rounded off)	500	970	1190	2660

* At the time of writing, the most recent year for which all data are available.

Table 3-2: CO_2 emissions in 2012, broken down by to function and sector (Mt)

	Transport	Industry	Urban environ-ment and agriculture	Total (rounded off)
Light and appliances	0	16	26	42
Transport and mobility	37	0	0	37
HT	0	43	0	43
LT	0	2	43	45
Total (rounded off)	37	61	69	166

30 Increasing use is being made of air conditioning systems; in the context of this analysis, such use is included under ‘lighting and appliances’.
31 Energietrends (2014) is published by ECN, the Energy Research Centre of the Netherlands.

In the Netherlands, low-temperature heat used in the urban environment is produced mainly using natural gas. About 85 per cent of households have gas-fired central heating.[32] In addition, residual heat from industry is used to provide heat via heat grids (district heating). Less than 1 per cent of homes are heated by heat pumps.

2. High-temperature heat

In the context of this advisory report, the demand for high-temperature heat is defined as the demand for temperatures in excess of 100-120°C. That demand comes entirely from industry, where heat is used mainly for thermal processes. The Netherlands' manufacturing and process industries are internationally significant and make important contributions to economic prosperity, welfare and employment. The temperature range of the heat required is very considerable, from a little above 100°C (e.g. in the food industry), to more than 1,500°C for the production of metals. More than half of the heat required by industry is more than 500°C. The biggest contributor to demand is the chemicals industry, followed by refinery and the base metals industry. The refinery industry, (petro-) chemicals and metallurgical industries, food industry and paper industry all require high-grade process heat in order to operate. The chemicals industry is the largest single heat consumer (accounting for 60 per cent of consumption), followed by the refinery industry.[33]

Examples of processes for which high-temperature heat is used:

- Production of methanol, ammonia and hydrogen in steam crackers and furnaces (chemicals industry)
- Production and processing of crude steel (base metals industry); in the non-ferrous metals industry, the demand for high-temperature heat is linked to the smelting and casting of metals
- Production of glass, glass wool, mineral wool, ceramic products and cement clinker (building materials industry) in furnaces
- Cooking, drying, evaporating and baking in the food and drinks industries (roughly 50 per cent of the heat used for such processes is more than 100°C)
- Drying paper and pulp in the paper and cardboard industry
- Refinery processes such as distillation and desulphurisation

In 2012, the primary demand for high-temperature heat was roughly 670 PJ (see also Table 3-1) and came exclusively from industry. The associated CO_2 emissions were 43 Mt (Table 3-2).

The demand for high temperature heat is met by industrial production units and by combined-heat-and-power (CHP) plants and coal and gas-fired power plants. The energy carriers associated with this functionality are therefore both gaseous and liquid, nearly all of them fossil fuels. The main source used in the production of high-temperature heat is currently natural gas,[34] except in steelmaking, where coal is used. Refineries use their own oil to meet their heat demand.

32 Energietrends (2014) is published by ECN, the Energy Research Centre of the Netherlands.
33 National Heat Expertise Centre (2013), *Warmte en koude in Nederland (Heating and Cooling in the Netherlands).*
34 Davidse Consultancy (2012). *Warmte-energie, de motor van de industrie (Thermal energy, the engine of industry).*

3. Transport and mobility

The transport and mobility functionality covers the propulsion of various means of transport for people and/or goods. Where road transport is concerned, only transport via the public road network is considered. The energy carriers used for that purpose include petrol, diesel, kerosene, natural gas, electricity, fuel oil, biodiesel and hydrogen. Transport on business premises and consumption by mobile machinery, such as tractors and construction vehicles that do not operate on the public road network are outside the scope of this functionality.

The primary energy demand for transport and mobility was roughly 500 PJ in 2012 (Table 3-1). The consumption of transport fuels within this functionality covers various transport modalities. Road transport accounted for the lion's share (85 per cent) of total transport-related energy consumption. Of that 85 per cent, 45 per cent was attributable to passenger transport.

Mobility is an important driver of greenhouse gas emissions in the Netherlands, accounting for about 37 Mt of CO_2 in 2012. Transport and mobility-related emissions in the Netherlands have fallen slightly in recent years, but not enough for the transport and mobility system to be regarded as sustainable or efficient.

The energy carriers used for the transport and mobility functionality are predominantly liquid fuels, mainly of a fossil origin. Relatively little use is made of gaseous energy carriers. Automotive gas (liquefied petroleum gas, LPG) accounts for a small proportion of the energy used in passenger transport and compressed natural gas (CNG)[35] is also sometimes used in passenger vehicles and buses. Liquefied natural gas (LNG) has recently started to be used for inland water transport. Electricity accounts for an even smaller portion of total energy consumption for transport and mobility, but its contribution has been growing rapidly in recent years. Roughly 35,000 (semi-) electric passenger vehicles are now in use in the Netherlands[36] (NEV, 2014).

4. Lighting and appliances

The lighting and appliances functionality covers all the energy functions which rely on electricity as the carrier, and which are covered by the other three functionalities. The most significant functions are lighting and powering electric appliances and processes. Also included is energy for air-conditioning in homes, in the service sector (supermarkets, data centres) and in industry (chemicals, dairy, cold storage). Electricity is produced both from fossil fuels (thermal power plants and diesel/non-diesel generators) and from renewable sources (solar energy, wind energy, biomass).

In 2012, the primary demand for energy for lighting and appliances was 700 PJ (Table 3-1). The expectation is that the demand for energy for lighting and appliances will increase in the years ahead. The associated CO_2 emissions were 42 Mt (Table 3-2).

35 CNG is natural gas that has been compressed under high pressure (200 bar). LNG is natural gas that has been liquefied by cooling to a very low temperature (-162°C).
36 NEV (2014). *Nationale Energieverkenning 2014 (National Energy Survey 2014).*

Figure 3-1: Breakdown of electricity use for lighting and appliances

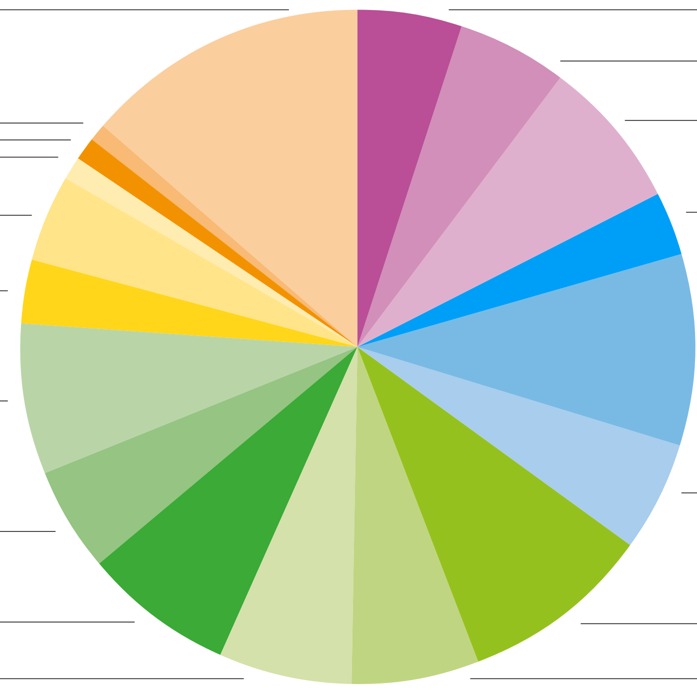


Figure 3-1 shows the breakdown of electricity consumption for domestic lighting and appliances. Electric appliances are increasingly energy-efficient, but additional types of appliance are constantly entering use. In the context of the European Eco-design Directive, it has been agreed that electric appliances should be made even more energy-efficient.

Demand for cooling

The demand for electricity to cool offices, hospitals, hotels and restaurants and shops, for chilling in the chemicals and food processing industries (dairy and meat industries) and for refrigerated transport and storage (cold stores) is smaller than the demand for electricity for heating. The associated primary energy demand is 84 PJ, which represents 2.4 per cent of the primary energy use associated with the lighting and appliances functionality. More than a third of the total demand for cooling in the Netherlands comes from domestic refrigerators.

4. SCOPE FOR ENERGY-RELATED EMISSIONS IN THE NETHERLANDS

This appendix describes how the scope for energy-related CO_2 emissions in the Netherlands in 2050 has been calculated. The calculation is based largely on a study by PBL and ECN (PBL, 2011, pp. 27-28).

A national objective of an 80 to 95 per cent reduction in the emission of CO_2 equivalents represents a major challenge for the Netherlands and the various sectors of the Dutch economy. Greenhouse gas emissions may be divided into energy-related and non-energy-related emissions. In 1990,[37] greenhouse gas emissions in the Netherlands were about 220 Mt of CO_2 equivalents.[38] [39] That total includes CO_2 and various other greenhouse gases, the main ones being methane (CH_4), nitrous oxide (N_2O) and fluorinated gases. Agriculture is the main 'producer' of methane and nitrous oxide.

If by 2050 greenhouse gas emissions in the Netherlands must be at least 80 per cent lower than in 1990, that implies that a maximum of 44 Mt of CO_2 equivalents may be emitted by all sectors of the economy collectively.

How that emissions scope is actually divided across the various sectors in 2050, and therefore what the scope for energy-related emissions is, depends on the availability to the various sectors of cost-effective means of reducing emissions.

The current estimates are as follows:

- There is relatively little technical scope for cost-effectively reducing agricultural emissions. Improvements in milk production, livestock farming and fertiliser use, coupled with the fermentation of animal manure, can reduce agricultural emissions to an estimated 12 Mt of CO_2 equivalents by 2050.
  Further reduction of agricultural emissions will require a change in the structure of agricultural production. From a global perspective, there is nothing to be gained from the displacement of production. However, reduced consumption of animal products and changes in the patterns of consumption may offer a way forward (PBL, 2011, p. 27).

37 For the Kyoto Protocol reference year, the figure is 221 Mt. The figure given for greenhouse gas emissions in CO_2 equivalents is a sum of the (CO_2-equivalent) emissions of carbon dioxide, nitrous oxide (N_2O) and methane (CH_4) in 1990 and of fluorinated gases in 1995. Source: *Compendium voor de Leefomgeving (2015) (Environmental Compendium (2015))*. Consulted on 14 August 2015 at http://www.compendiumvoordeleefomgeving.nl/overhetclo/.

38 In order to aggregate the influence of the various greenhouse gases, the emission figures are converted into 'CO_2 equivalents'. One CO_2 equivalent is the amount of the gas in question whose emission has the same effect as the emission of 1 kg of CO_2. The emission of 1 kg nitrous oxide (N_2O) is 296 CO_2 equivalents and the emission of 1 kg of methane (CH_4) is 23 CO_2 equivalents. Each of the fluorinated (chlorine) gases has its own high CO_2 equivalent, but because the quantities emitted are relatively small, their contribution to the national total is modest. Source: Statistics Netherlands, www.cbs.nl, under 'Methods'.

39 Source: website of the *Compendium voor de Leefomgeving (2015) (Environmental Compendium (2015))*, greenhouse gas emissions in the Netherlands.

- The other non-CO_2-greenhouse gas emissions from industry and waste processing can be reduced considerably, to a residual level not exceeding 2 Mt of CO_2 equivalents.
- Major industrial sources of N_2O are expected to have been almost entirely eliminated by 2050.[40]
- The use of fluorine compounds for applications such as cooling can be eliminated by substitution. Methane emissions from landfill sites will gradually decline to almost zero, while those from waste water purification can be considerably reduced (PBL 2011, p. 28).

Together, agricultural emissions and the residual industrial emissions will take up an estimated 14 Mt of the scope for greenhouse gas emissions in 2050. Hence, the residual scope for energy-related emissions is 30 Mt. That represents an 82 per cent reduction, when expressed as a percentage of energy-related emissions in 1990. A substantially higher reduction percentage would therefore necessitate negative energy-related emissions. That is possible if the sequestration of CO_2 emissions is combined with the production of bio-energy (a so-called ‘carbon sink’). The calculation described above is presented in table 4-1 and visualised in figure 4-1.

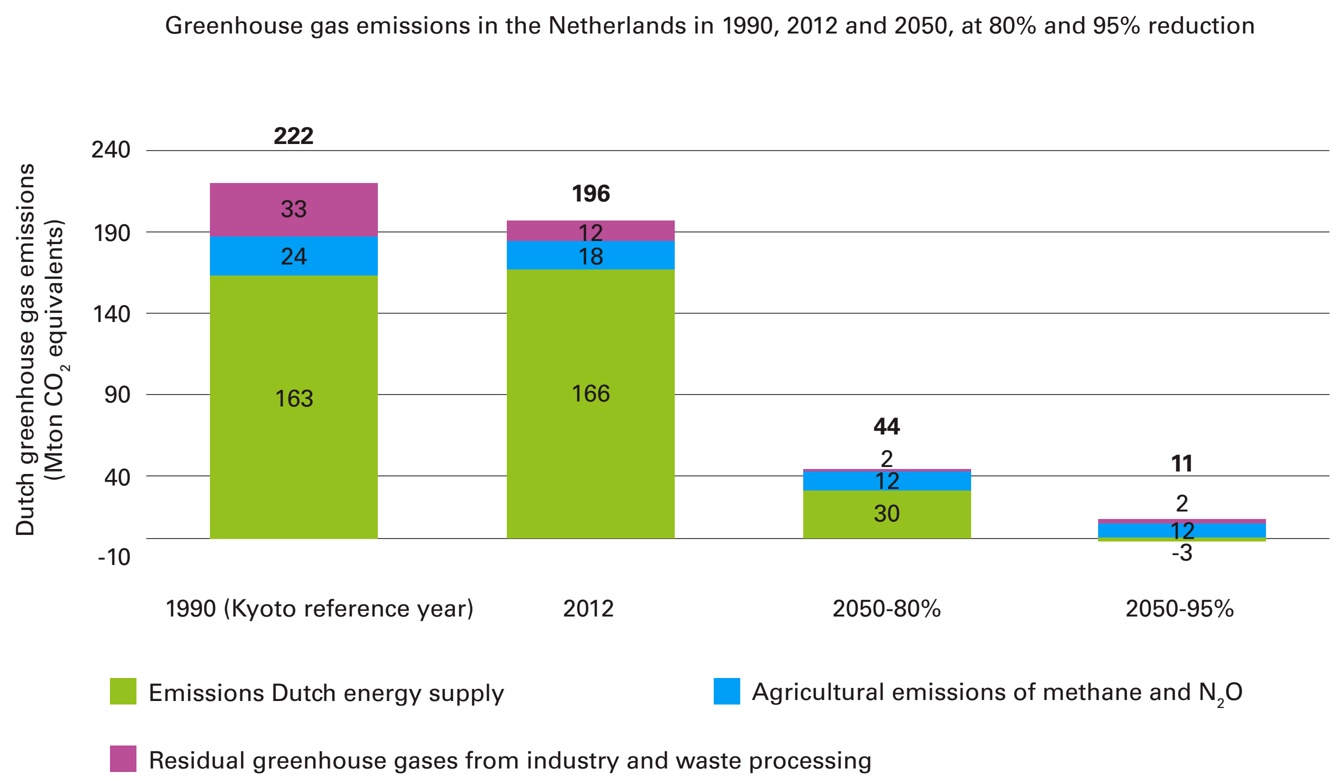
Table 4-1: Energy-related greenhouse gas emissions (Mt of CO_2 equivalents) in 2050, with various national greenhouse gas reduction

	National reduction objective	Total national scope for emissions	Of which, agricultural methane and N_2O*	Residual green-house gases from industry and waste proces-sing**	Scope for energy-related emissions	% reduction in energy-related emission (% of total energy-related emissions in 1990)
1990*		220	24	33	163	
2050	-80%	44	12	2	30	82
	-95%	11	12	2	-3	102
	-100%	0	12	2	-14	108

* reference year is 1990[41]
** for 2050 source: PBL/ ECN 2011, p28[42]

40 There is considerable uncertainty regarding the stated estimate, particularly concerning the extent to which CH_4 and N_2O emissions can be reduced. If the reduction actually realisable is a few megatonnes higher or lower than the estimate, that will influence the scope remaining for supply-related emissions.
41 *Compendium voor de Leefomgeving (2015) (Environmental Compendium (2015))*. Consulted on 14 August 2015 at http://www.compendiumvoordeleefomgeving.nl/overhetclo/. Corrected in line with revised CO_2 equivalent factors for CH_4 and N_2O.
42 Netherlands Environmental Assessment Agency and Energy Research Centre of the Netherlands (2011). *Naar een schone economie in 2050: routes verkend. Hoe Nederland klimaatneutraal kan worden (Towards a clean economy in 2050: an exploration of possible routes. How the Netherlands can become climate-neutral).* The Hague: PBL. Corrected in line with revised CO_2 equivalent factors for CH_4 and N_2O.

Figure 4-1: Energy-related greenhouse gas emissions (Mt of CO_2 equivalents) in 1990 and 2050



GLOSSARY

Base load The amount of electrical power that is in permanent demand on an electricity network; the level below which demand (and network load) never falls.

Biomass cascading Cascading involves the conversion of biomass into a range of marketable products and energy to replace fossil raw materials. The most efficient possible use of the biomass is sought: all components are put to optimal use and the creation of residual materials is minimised. In other words, all components of biomass are put to the best possible use that yields the highest added value.

Capacity mechanism A term relating to the structure of the electricity market. Where a capacity mechanism operates, producers are paid to keep production capacity available, in addition to receiving income from the sale of the power that they actually produce (the existing 'energy-only' market model). A capacity mechanism means that energy companies get paid not only for the energy that they supply, but also for the production capacity that they maintain in the interests of security of supply.

Carbon Capture and Storage (CCS) Collecting CO_2 that would otherwise have been emitted and storing it.

Circular economy The circular economy is an economic and industrial system based upon the reusability of products and raw materials and the restorative capacity of natural resources, which seeks to minimise value loss in the system as a whole and to promote value creation in each stage of the cycle.

CO_2 equivalent In order to aggregate the influence that the various greenhouse gases have on global warming, emission figures are converted to 'CO_2 equivalents'. One CO_2 equivalent is the amount of a greenhouse gas whose emission has the same effect as the emission of 1 kg of CO_2.

Compressed natural gas (CNG) Pressurised natural gas for use as vehicle fuel.

Dispersed energy generation The local generation of electricity and/or heat by consumers, for their own use or for feeding into the network. Dispersed energy generation involves combined production and use in a heat grid of up to about 3 km, a low-pressure gas network, or a low/medium-voltage electricity network, as distinct from centralised production and supply.

Electrification Use of electricity for new applications, as with electric cars, electric-powered industrial production, hydrogen production, power-to-heat, power-to-gas and heat pumps in buildings.

Energy Agreement The (SER) Energy Agreement – full title Energieakkoord voor duurzame groei (Energy Agreement for Sustainable Growth) – signed by more than forty organisations, including the government, employers' organisations, unions and nature/environmental lobby groups. The agreement covers matters such as energy conservation, clean technology and climate policy.

Energy source Raw material that serves as a source of energy, e.g. the fossil energy sources petroleum, natural gas and coal, and the sustainable energy sources wind energy and solar energy.

Energy carrier The medium (e.g. electricity) by which energy is conveyed from its source (e.g. coal) to the point of consumption. A given carrier (e.g. electricity) can serve multiple energy functions (e.g. both lighting and transport). A given carrier can also be produced from various energy sources: electricity can be produced from coal, natural gas or wind energy, for example.

Energy transition Energy transition is the comprehensive process of change from the current energy system to a sustainable energy system. An energy system (including mobility-related energy use) is sustainable only if the energy sources used are currently readily available and will remain so, if the effects of the energy use are currently unharmful to humans and the environment and will remain so, if the supply is reliable and safe and if everyone has access to energy at a reasonable price (Fourth National Environmental Policy Plan).

European Union Emissions Trading System (EU ETS) A European Union system for trading greenhouse gas allowances. Participating companies have to surrender an emission allowance for each CO_2-equivalent tonne emitted.

Final demand for energy The final demand for energy is the amount of energy required by final users. For example, a household's final demand for electricity is the amount of electricity consumption registered by the supply meter.

Flexibility The ability to respond to fluctuations in the supply of and/or demand for energy. Flexibility is increasingly important, because the availability of energy from sustainable energy sources (solar energy, wind energy) is inherently variable. Demand, e.g. from consumers, can also be made flexible. For example, appliances can be designed to automatically respond to changes in the supply of electricity, such as smart washing machines that come on when there is an electricity surplus.

High-temperature heat functionality Energy is required to fulfil high-temperature heating functions, such as manufacturing and high-temperature industrial processing. This is referred to as energy's high-temperature heat functionality.

Low-temperature heat functionality Energy is required to fulfil low-temperature heating functions, such as the heating of buildings and the provision of hot water (e.g. for bathing and food preparation). This is referred to as energy's low-temperature heat functionality.

Lighting and appliances functionality Energy is required to fulfil lighting and appliance functions, such as powering lights, electrical and other appliances and ICT equipment. This is referred to as energy's lighting and appliances functionality.

Transport and mobility functionality Energy is required to fulfil transport and mobility functions, enabling the movement of people and goods. This is referred to as energy's transport and mobility functionality.

Greenpeace Energy (R)evolution Scenario Scenario developed by Greenpeace International and the European Renewable Energy Council (EREC), and its translation to the Dutch situation. Key assumptions: global warming by 2050 not to exceed 2°C, major reduction in CO_2 emissions and phasing out of nuclear energy (Greenpeace, 2013; Warringa and Rooijers, 2015).

Group of seven (G7) The G7 is an intergovernmental forum of seven leading industrial countries (Canada, France, Germany, Italy, Japan, UK, USA).

IEA ETP Two-degree Celsius scenario A scenario published by the International Energy Agency. Key assumption: global warming by 2050 not to exceed 2°C (International Energy Agency, 2015; Warringa and Rooijers, 2015).

Innovation waves A theory of innovation developed by Lester and Hart (2012), which postulates three successive waves of innovation, which may be partially concurrent and overlapping: energy conservation, rollout of existing technologies, and implementation of radical new technology.

Intermittent Intermittent energy sources (solar energy and wind energy) are sources that are not continuously available for the production of electricity, because they are weather-dependent.

Security of supply In its narrow sense: a network's ability to supply electricity to consumers (Section 1, subsection 1, of the Electricity Act 1998). In this report, the phrase is used more broadly to mean the degree of certainty that the supply of any energy carrier is currently assured and will remain so. Hence, security of supply here covers all relevant aspects of the energy supply chain, including production, conversion, transportation and delivery.

Liquefied natural gas (LNG) Natural gas that has been turned into liquid for use as a transport fuel. The volume reduction achieved by the liquefaction of natural gas is considerably greater than that achievable by compression (to form CNG). Liquefaction is therefore often used for the transportation of natural gas by ocean-going tanker.

Social arrangements Collaborative agreements amongst the parties involved in a supply chain, an energy functionality or an area/location, under which goals are defined, progress towards those goals is monitored and (legal) commitments are made. Social arrangements are an important feature of the management system proposed in this advisory report, which assumes that transition management can no longer be provided exclusively by the central government.

Marginal cost The rise in the total cost associated with the production of one extra unit at a given location.

Market model The model or (legal) structure of the market: the agreements that apply; who is responsible for what.

Megaton (Mt) A million tonnes. Standard unit used for the quantitative expression of CO_2 emissions.

Merit order Production units are deployed in order of marginal cost. The unit with the lowest marginal cost is deployed first; when its capacity is fully utilised, the unit with the next lowest marginal cost is deployed, and so on.

Non-CO_2 greenhouse gases Gases other than CO_2 that contribute to the greenhouse effect and thus to global warming. The main gases in question are: methane (CH_4), nitrous oxide (N_2O), HFCs, PFCs, SF6.

Parts per million (ppm) Unit for the expression of a substance's concentration within something else. A concentration of 1 ppm means that the substance in question accounts for one millionth of the substance or medium containing it.

Petajoule (PJ) Unit of energy, equalling 1015 joules.

Peak load The amount of electricity required to meet peak demand.

Power-to-gas (P2G) Technology for the conversion of electricity into hydrogen by means of electrolysis, which enables electrical energy to be stored in gaseous form.

Power-to-heat (P2H) Technology for the conversion of electricity into heat.

Primary energy demand The amount of energy that is required to meet the final demand and cover the conversion losses.

Prosumer Energy user that is also an energy producer.

Smart grid Gas or electricity network that not only provides a supply of an energy carrier, but also enables information to be exchanged.

Management In this report: making the administrative, technical and social provisions needed ensure that the energy transition progresses towards its stated goal.

System integration System innovations that lead to the new knowledge, services and products required to ensure that the energy supply of the future is organised in a way that maximises use of the potential for energy sustainability, remains reliable and affordable and optimally facilitates the transition to a sustainable energy supply.

Thorium reactor technology A thorium reactor is a nuclear reactor in which the fission of thorium atoms serves as a source of energy. Compared with other technologies, thorium fission produces less (radioactive) waste and results in waste that remains radioactive for a much shorter period.

Demand response and management Demand response (or demand-side response) is a phenomenon which involves electricity users increasing or reducing their use in response to current market conditions. See also flexibility.

Thermal energy storage A sustainable method of storing energy underground in thermal form.

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Social consultation

To support the compilation of this advisory report *A prosperous nation without CO_2: towards a Sustainable Energy Supply by 2050*, the Council for the Environment and Infrastructure (Rli) undertook a social consultation, in the context of which interested parties were invited to express their views. The consultation involved two meetings and the opportunity to submit responses via Rli's website. Details of the consultation are available from Rli's website (www.rli.nl) in the Dutch-language publication *Opbrengst van* *de open consultatie ten behoeve van het advies Rijk zonder CO_2, naar een duurzame energievoorziening in 2050 (Input from the open consultation organised to support preparation of the advisory report A prosperous nation without CO_2: towards a sustainable energy supply by 2050).*

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OVERVIEW OF PUBLICATIONS

2015

Room for the regions in European policy ['Ruimte voor de regio In Europees beleid']. September 2015 (Rli 2015/05].

Changing trends in housing: flexiblity and regionalisation within housing policy ['Wonen in verandering, over flexibilisering en regionalisering in het woonbeleid]. June 2015 (Rli 2015/04)

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Fundamental Reform of Environmental and Planning Legislation ['Stelselherziening omgevingsrecht']. May 2015 (Rli 2015/02)

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Room for Sustainable Agriculture ['Ruimte voor duurzame landbouw']. March 2013 (Rli 2013/01)

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