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ENERGY REVOLUTION: A SUSTAINABLE PATHWAY TO A CLEAN ENERGY FUTURE FOR THE NETHERLANDS

GREENPEACE

ENERGY REVOLUTION: A SUSTAINABLE PATHWAY TO A CLEAN ENERGY FUTURE FOR THE NETHERLANDS

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Introduction

The climate challenge: Climate change is real and is happening now. Climate change – the result of the greenhouse gases we are pumping into the atmosphere – already impacts our lives and is expected to severely affect us in the coming years. We have already experienced a global mean temperature rise of 0.6°C during the last century and, due to the greenhouse gases we have pumped into the atmosphere, the temperature will rise by 1.2° or 1.3°C, even if all emissions were to be stopped tomorrow.

As highlighted by the International Panel on Climate Change (IPCC) in its Third Assessment Report[1], an increase in mean temperature above 2°C compared to pre-industrial levels would dramatically increase damages to ecosystems and profoundly disturb the climate cycles. An average global warming of 2°C would:

* Threaten many people with increased risk of hunger, malaria, flooding and water shortages, mainly among the poor populations and in developing countries (particularly in sub-Saharan Africa, South Asia, and parts of South-East Asia and Latin America).
* Risk melting the main ice sheets, particularly the Greenland ice sheet and the West Antarctic ice sheet, with the probability of sea levels rising by many metres over several centuries. This would threaten large populations everywhere, particularly in low-lying areas in developing countries (such as Bangladesh, South China or Egypt) and low-lying island states everywhere. Not to mention 'low countries' like the Netherlands which is already for a quarter below sea level. And two thirds would be flooded on a regular basis if there were no dykes and dunes[2]. In the 'Erasmus' lecture of 2003, prof. dr. ir. Pier Vellinga states that in the period 2005-2025, 20 to 40 billion euro is required to ensure adequate safety to the Dutch population due to the impact of climate change.
* Provoke damage to major ecosystems, with loss of forests and species affecting the lives of everyone on Earth, and economic costs that would fall disproportionately on the poor and developing countries.

The goal of responsible climate policy should therefore be to keep the increase in global mean temperature below 2°C above pre-industrial levels, and then to bring it down as quickly as possible. This 2 degree limit is endorsed by the European Union and the Dutch government. This requires reducing greenhouse gases emissions from industrialised countries by 30 % below 1990 levels by 2020 and by 80 % by mid-century, while global emissions must be reduced by about 50 % by mid-century.

An 'energy revolution' is needed: To keep global mean temperature below the 2°C level, we have a very short time window to act. Within no more than one to two decades, we have to change the no.1 culprit as far as anthropogenic carbon dioxide (CO_2) emissions are concerned: our energy system. In the Netherlands, energy consumption accounts for about 80 % of total greenhouse gases emissions.

As we face this challenge and short time period to act, the Dutch electricity sector in particular stands at a crossroads. This sector is still characterised by large, centralised power plants using fossil fuels and wasting its heat mostly into the sea. The average age of the operating Dutch power plants is eighteen years old and the nuclear plant in Borssele is over 30 years old. Over the next twenty years, the power sector is going to make large investments - and decide whether the new capacity will be powered by fossil fuels or the efficient use of renewable energy. It is crucial that the choice be made nów to make the transition to a cleaner and safer energy system.

What's more, the Netherlands currently relies on imports of almost all its oil and coal. Political and industry leaders should ensure that the decisions made in the next two decades help achieve the energy shift needed to contribute to the global fight against dangerous climate change. They should further ensure security of supply for the future, decrease our dependence on imported fuels, and end the nuclear threat.

A sustainable pathway to a clean energy future for The Netherlands: In order to clarify what political and industrial action needs to be taken in the Netherlands, Greenpeace has asked the Institute of Technical Thermodynamics, Department of Systems Analysis and Technology Assessment of the German Aerospace Center (DLR) to develop the energy blueprint outlined in this report. This blueprint shows a pathway from the unsustainable situation in the Dutch energy system today, towards a sustainable energy use.

This pathway demonstrates that a massive reduction of our CO_2 emissions and the rapid phase-out of nuclear power are indeed possible. The 'Energy Revolution' scenario developed by DLR foresees the closure of the Dutch nuclear reactor after 30 years of operation and, in the long run, the closure of all coal power plants. At the same time it achieves a 76 % reduction of CO_2 emissions by 2050 compared to 1990. Instead of increasing by almost 15 % between 2000 and 2050 under a Reference Scenario, per capita CO_2 emissions in the 'Energy Revolution' scenario drop by more than 80 % between 2000 and 2050.

The pathway in this scenario is achieved with existing technological options offered by renewable energy sources and energy-efficiency – i.e. without making use of the 'flexible mechanisms' of the Kyoto Protocol, end-of-pipe solutions such as carbon capture and sequestration or technological fixes like 'clean coal'.

The scenario shows that, in the long run, an efficient renewable energy system will be cheaper than conventional energy use. The rapid growth of renewable energy technologies will lead to large investments. This dynamic market growth will result in a shift of employment opportunities from conventional energy-related industries to new occupational fields in the renewable energy industry. In the mid-term, renewable energy sources are expected to provide 15,000 to 22,000 jobs in the field of electricity generation.

This scenario shows that renewable energy sources, combined with energy-efficiency, have the potential to enable the Netherlands to switch to clean energy, contribute to saving the climate, protect its economy from world market prices of imported fossil and nuclear fuels, and provides future generations with a secure access to energy.

No time to waste!

The Netherlands have little time left to kick start the renewable energy revolution. The Netherlands are not on track to meet their first Kyoto targets, while they have the third lowest renewable energy target of the former EU15 Member States. A delay of even a few years will make it extremely difficult for the Netherlands to get back on track to achieve the needed medium and long-term CO_2 reduction targets. Therefore, we have to make clear and precise choices today.

Greenpeace calls for Dutch policy-makers to invest in our future and take action now. The Netherlands can phase-out nuclear power and – in the medium to long term – coal power generation while drastically reducing its CO_2 emissions. The choice is clearly not beween new dangerous nuclear capacity, expensive technological fixes like clean coal and climate catastrophe. The choice is between a wholly unsustainable energy system and clean and safe energy accessible to all.

1 | See http://www.ipcc.ch.
2 | http://www.knmi.nl/kenniscentrum/zeespiegelstijging.html

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Technical summary

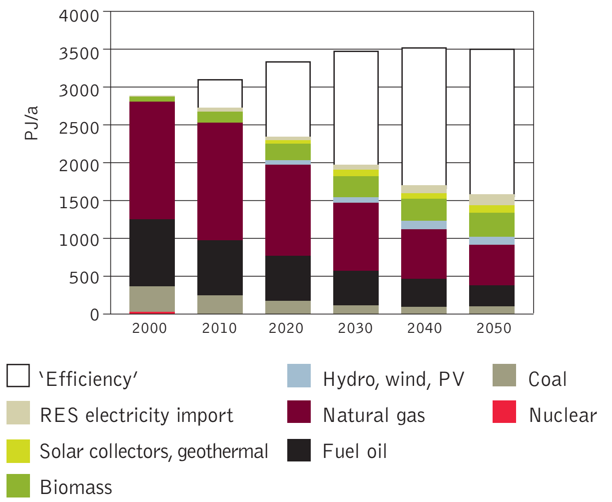
Today, about 97 % of the Netherlands' primary energy[3] comes from fossil fuels such as oil, gas and coal, and from nuclear power. The latter accounts for about 4 % of the Dutch electricity generation. Renewable energy sources (RES) only account for about 3 % of the domestic electricity generation. The most relevant sources for renewable electricity production in the Netherlands today are biomass and wind energy. Compared to the average of the other 25 EU countries, this is a rather low use of renewable energy sources.

The current Dutch energy system is both unsustainable and challenging. The energy consumption per inhabitant is above the EU average. The same goes for the CO_2 emission per capita: in 2005, every Dutch person produces an average emission of 11 tonnes of CO_2 per year (compared to an average of about 8 tonnes per capita and year in the 15 EU States). At the same time, the Netherlands are confronted with some limitations as far as some RES are concerned: it has comparatively limited resources of those renewable energy sources which are suited for combined heat and power (CHP) generation, which can deliver 'dispatchable' energy, namely biomass and geothermal energy. The Netherlands is also one of the European countries, which only has a relatively small potential of hydropower use. On the other hand, there is a largely untapped potential for domestic RES, such as offshore wind energy.

The Netherlands are characterised by high levels of energy demand and CO_2 emissions, which call for prompt and determined political action to transform the current Dutch energy system. The 'Energy Revolution' scenario developed in this report describes how this transformation can be reached, i.e. a pathway which turns the present situation into a sustainable energy supply for The Netherlands:

* Exploiting the existing large energy-efficiency potentials is crucial. This is a prerequisite for achieving a significant share of renewable energy sources in the overall energy supply system, for compensating the phasing-out of coal and nuclear energy, and for reducing the consumption of other fossil fuels. It is possible to reduce primary energy demand from about 2900 PJ/a in 2000 to about 1600 PJ/a in 2050.
* The electricity sector reaches the highest share of renewable energy sources in the Netherlands: by 2050, about 57 % of the electricity generated will come from renewable energies. Taking renewable electricity imports into account, almost 70 % of the electricity consumed in the Netherlands will be produced by renewables. A capacity of 18 GW will generate 48 TWh/a RES electricity in 2050. By then, the greatest contributors will be wind power, biomass and photovoltaic (PV) power.
* In the heat supply sector, the contribution of renewables will continue to grow substantially, reaching a share of 53 % in 2050. Solar collectors and biomass/waste in particular will substitute conventional systems for heating and cooling.
* In the long term, more than 30 % of the fossil fuels for combined heat and power are being substituted by biomass. At the same time, the decreasing demand for electricity and the relatively small biomass potential limit a further expansion of CHP with higher shares of renewable energy.
* Before biofuels are introduced on a large scale in the transport sector, the existing large efficiency potentials have to be exploited. Given that the use of biomass for CO_2 reduction in stationary applications is more cost-effective, its availability limits the use of biofuels. On the other hand, the substitution of fossil fuels by biofuels is an important measure for bringing down CO_2 emissions in the transport sector. As the relatively low domestic potential for generating biofuel would restrict an ambitious deployment in 2010 already, an import of biofuels from 2010 onwards is assumed.
* By 2050, more than 42 % of the primary energy demand can be covered by renewable energy sources (see figure 1).

FIGURE 1: DEVELOPMENT OF PRIMARY ENERGY CONSUMPTION UNDER THE 'ENERGY REVOLUTION' SCENARIO ('EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO)



3 | Primary Energy: Energy embodied in natural resources (e.g., coal, crude oil, sunlight, uranium) that has not undergone any anthropogenic conversion or transformation. After conversion it is referred to as final energy.

CO_2 emissions Under the Reference Scenario, per capita CO_2 emissions will increase by 13 % between 2000 and 2050, and are thus far removed from a sustainable development path. Under the 'Energy Revolution' Scenario, per capita CO_2 emissions drop by more than 80 % between 2000 and 2050 (from 9.8 t/capita to 1.9 t/capita).

Under the 'Energy Revolution' Scenario, CO_2 emissions will decrease to 34 million tons per year in 2050, a reduction of 78 % compared to 2000 and 76 % compared to 1990. Under the Reference Scenario the CO_2 emissions would have soared in these periods by almost 40% compared to 1990.

Other measures could be taken to reduce the overall Dutch emissions by targeting other greenhouse gases, methane, nitrous oxide and F-gases, which have a higher Global Warming Potential[4] (GWP) than CO_2. Such measures, however, are beyond the scope of this report.

Costs of electricity generation The massive introduction of renewable energy technologies for electricity generation under the 'Energy Revolution' Scenario leads to higher specific generation costs compared to the Reference Scenario in the mid-term. These higher costs are to a large extent compensated by the reduced demand for electricity. Thus the total costs for electricity generation, including costs for efficiency measures, are lower under the 'Energy Revolution Scenario' already from 2020 on.

Assumptions in fossil energy prices in the Reference and 'Energy Revolution' Scenarios are relatively conservative. In 2010, the assumed average price of oil is 32 dollar per barrel, while the long-term price of a barrel of oil rises up to 59 dollar per barrel.

Any further increase in fossil energy prices is a direct additional burden on fossil electricity production, and is thus an advantage for the 'Energy Revolution Scenario'.

The inclusion of the costs of CO_2 emissions would clearly put forward the long-term economic benefits of the 'Energy Revolution' Scenario. When these CO_2-related costs are taken into account, the costs of generating electricity in 2050 are actually 1.4 ct/kWh lower under the 'Energy Revolution' Scenario.

Additional costs should also be weighed against the increase of the risks, e.g. of flooding and heat waves, associated with climate change, which are potentially much higher.

Employment in the electricity sector The growing contribution of renewables is expected to provide 15,000 to 22,000 jobs (gross figures) in the field of electricity production from renewable energy sources in the mid-term.

Because of increasing labour productivity and growing import quotas, in the long term, the total number of jobs related to electricity generation is expected to shrink.

The number of jobs in the energy-efficiency sector is also expected to increase, but this remained beyond the scope of this report.

Energy efficiency - better with less

Energy efficiency often has multiple positive effects. For example, an efficient clothes washing machine or dishwasher uses less water. Efficiency also usually provides a higher level of comfort. For example, a well insulated house will feel warmer in the winter, cooler in the summer, and is healthier to live in. An efficient refrigerator will make less noise, have no frost inside, no condensation outside, and will probably last longer. Efficient lighting will offer you more light where you need it. Efficiency is thus really: 'better with less'. Efficiency has an enormous potential. There are very simple steps you can take, such as putting additional insulation in your roof, using super-insulating glazing or buying a high-efficiency washing machine when the old one wears out. All of these examples will save both money and energy. But the biggest savings will not be found in such incremental steps. The real gains come from rethinking the whole concept, e.g. 'the whole house', 'the whole car' or even 'the whole transport system'. When you do this, surprisingly often energy needs can be cut back by four to ten times what is needed today. Take the example of a house: by insulating the whole outer shell (from roof to basement) properly, which requires an additional investment, the demand for heat will be so low that you can install a smaller and cheaper heating system - offsetting the cost of the extra insulation. The result is a house that only needs one-third of the energy without being any more expensive to build. By insulating even further and installing a high-efficiency ventilation system, heating demand is reduced to one-tenth. It sounds amazing, but thousands of these super-efficient houses have been successfully built in Europe over the last ten years. This is no dream for the future, but part of everyday life for those thousands of families. Here is another example: imagine you are the manager of an office. Throughout the hot summer months, air-conditioning pumps cold air on your staff's shoulders to keep them productive. As this is fairly expensive, you could ask a clever engineer to improve the efficiency of the cooling pumps. But why not take a step back instead and look at the whole system. If we first improve the building to keep the sun from heating the office like an oven, then install more energy-efficient computers, copiers and lights (which save electricity and generate less heat), and then install passive cooling systems such as ventilation at night - you may well find that the air-conditioning system is no longer necessary. Then, of course, if the building had been properly planned and built, you would not have bought the air-conditioner.

4 | An index, that represents the extent to which a greenhouse gas contributes to global warming, relative to that of carbon dioxide. (www.ipcc.ch)

ENERGY REVOLUTION: A SUSTAINABLE PATHWAY TO A CLEAN ENERGY FUTURE FOR THE NETHERLANDS

'ENERGY REVOLUTION' SCENARIO: A SUSTAINABLE PATHWAY TO A CLEAN ENERGY FUTURE FOR THE NETHERLANDS

Scenarios are used to describe possible future development paths, to give decision-makers an overview of future perspectives and to indicate how far they can shape the future energy system. Two different scenarios are presented here to characterise the wide range of possible development paths for the future Dutch energy supply system: a Reference Scenario, reflecting a continuation of current trends and policies into the future (business-as-usual), and the 'Energy Revolution' Scenario, a normative scenario developed in a back-casting process. Both scenarios are based on the methodology and assumptions of the European (EU25) scenario developed by DLR for Greenpeace[5].

The scenarios do not claim to predict the future; they simply describe two potential development paths out of the broad range of possible 'futures'. The 'Energy Revolution' Scenario is designed to indicate the efforts and actions required to achieve ambitious climate mitigation objectives, and to illustrate the options Dutch policy-makers have at hand to cope with the challenge of changing our energy supply system into a sustainable one.

Data compilation To set up its scenarios, DLR used commonly accessible European databases and studies, as well as methods of extrapolation and reasoned estimation where no explicit data was available. The following main European data sources were used:

* The European Commission's 'European Energy and Transport – Trends to 2030'[6] and 'European Energy and Transport – Scenarios on key drivers'[7] publications.
* The EuroStat Online Database for base-year model calibration.

Data and scenarios from regional or national sources, whenever they were available, were used to refine and upgrade the database.

Reference scenario The Reference Scenario is based on the aforementioned European Commission publications. This Scenario takes existing policies into account. Baseline assumptions include, for example, the modernisation of the EU economy and the completion of the internal electricity and gas markets, certain policies to support renewable and energy-efficiency, as well as the nuclear phase-out decision in some Member States. The Reference Scenario does not include additional policies to reduce greenhouse gas emissions. As the European Commission's scenario only covers a time horizon up to 2030, it has been extended based on the extrapolation of key macroeconomic indicators. This Scenario provides a baseline reference for comparison with the 'Energy Revolution' Scenario.

'Energy revolution' scenario The 'Energy Revolution' Scenario is a normative scenario developed in a back-casting process. To prepare this scenario, DLR used the energy system simulation tool PlaNet, which allows for modelling the energy system structure of the region of consideration and preparing long-term energy supply scenarios in line with given targets.

These key targets were:

* A reduction of Dutch CO_2 emissions, which is consistent with an overall greenhouse gases emission reduction target of 80 % by 2050 for industrialised countries.
* The rapid phase-out of nuclear energy production.

Although general framing conditions referring to population development and GDP growth remain unchanged compared to the Reference Scenario, the 'Energy Revolution' Scenario is therefore characterised by:

* Significant efforts towards fully exploiting the large energy-efficiency potentials.
* As far as possible, all cost-effective renewable energy potentials are made accessible for heat and electricity generation, as well as for the production of biofuels.
* The closure of the nuclear power station after a lifetime of 30 years, which means the immediate shut-down of the existing power plant in Borssele.
* Fossil fuels power plants will be employed to fill the gap between renewable energy production and electricity demand. Natural gas as primary energy carrier is preferred as a transition fuel to replace fuel oil and coal.
* Renewable electricity technologies are expanded to the limits of their estimated economic potential where necessary while ensuring still realistic growth rates of capacity expansion. Even with a substantial share of fluctuating renewables the secured capacity is higher than the expected peak load demand at any time.
* Due to limited potential and nature conservation concerns, hydropower does not significantly increase from its 2000 level.
* Power plants burning biomass will be phased-out as biomass is increasingly used in CHP plants at a higher overall efficiency rate.
* The domestic biomass potential does not cover the demand from the power, heat and transportation sectors. Despite this, a share of biofuels for cars which equals the EU25 average level is assumed. Therefore, biofuel imports might be necessary, which cannot be made explicit in the model used here. Obviously, all biomass needs to meet strict sustainabililty criteria.

The following chapters outline the main results of the 'Energy Revolution' Scenario, with special emphasis on the electricity sector.

The complete PlaNet results worksheets are available by contacting Greenpeace.

5 | Energy revolution, a sustainable pathway to a clean energy future for Europe. Available at: http://www.greenpeace.nl/reports
6 | European Energy and Transport – Trends to 2030, European Commission, Directorate-General for Energy and Transport, 2003. ISBN 92-894-4444-4
7 | European Energy and Transport – Scenarios on key drivers, European Commission, Directorate-General for Energy and Transport, 2004. ISBN 92-894-6684-7

1. Development of energy demand

The development of the future energy demand is basically determined by three key factors:

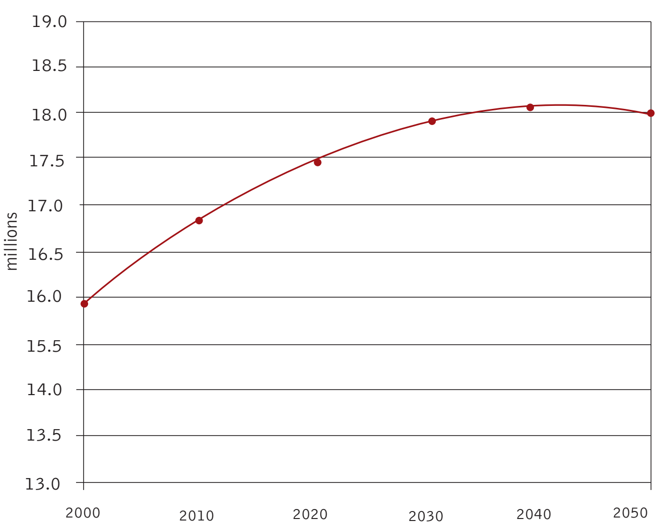
* Population development, i.e. the number of people consuming energy or using energy services.
* The development of economic activities, for which the Gross Domestic Product (GDP) is a commonly used indicator. In general, an increase in GDP goes along with an increase in energy demand.
* Energy intensity, which is a measure of how much energy is required to produce, for example, a unit of GDP. Energy intensities can be reduced by exploiting the still large energy-efficiency potentials.

Both the Reference and the 'Energy Revolution' Scenarios are based on the same projections of population development and of the development of economic activities. The future development of energy intensities, however, differs between the two, taking into account the efforts for increasing energy-efficiency under the 'Energy Revolution' Scenario.

2. Population development

The population in the Netherlands is expected to grow from 15.9 million people in 2000 to more than 18 million people around 2040 (see figure 2). Then the population growth is expected to almost stall at that level until 2050. The considerable growth in the next decades means a further challenge for reducing the energy demand and thus the pressure on environment and energy resources.

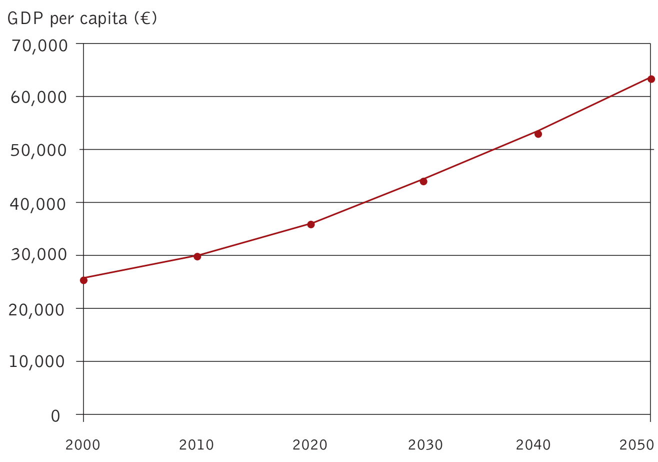
FIGURE 2: POPULATION DEVELOPMENT PROJECTION FOR THE NETHERLANDS



3. GDP development

While we anticipate that the Dutch population will grow, people will continue to enjoy a further rise in living standards. The per capita Gross Domestic Product (GDP), which is often considered as an aggregated welfare indicator, is today above the European average. The Netherlands, as an advanced economy, is expected to have a GDP growth of 2.1 % per year in average until 2050, which is below the European average. Thus, in 2050, the per capita GDP in The Netherlands is 63,000 €/capita (see figure 3).

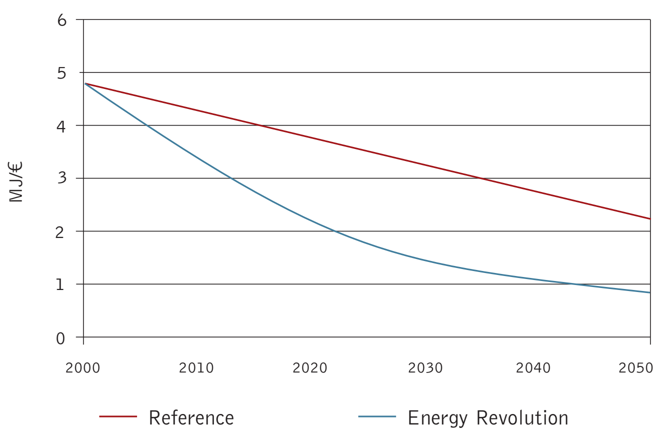
FIGURE 3: PROJECTION OF AVERAGE GDP PER CAPITA DEVELOPMENT IN THE NETHERLANDS



4. Projection of energy intensities

Growing economic activity and economic welfare does not necessarily result in an equivalent increase in energy demand. The energy demand per unit GDP in the Netherlands today is only slightly higher than the European average. As the Netherlands have a high share of energy intensive industry and production this means that energy efficiency potentials in this sector have already been exploited to some extent. Nevertheless, overall there is still a large potential for exploiting energy-efficiency measures. Even under the Reference Scenario, it is assumed that the total energy intensity will be reduced by about 1.6 % per year, leading to a reduction of final energy demand per unit GDP by 55 % between 2000 and 2050. Under the 'Energy Revolution' Scenario, it is assumed that due to active policy support, the technical potential for efficiency measures is largely exploited. This results in an average reduction of energy intensity of 3.4 % per year between 2000 and 2050 and an overall reduction of the intensity by more than 80 % (see figure 4).

FIGURE 4: PROJECTION OF ENERGY INTENSITIES UNDER THE REFERENCE AND 'ENERGY REVOLUTION' SCENARIOS IN THE NETHERLANDS



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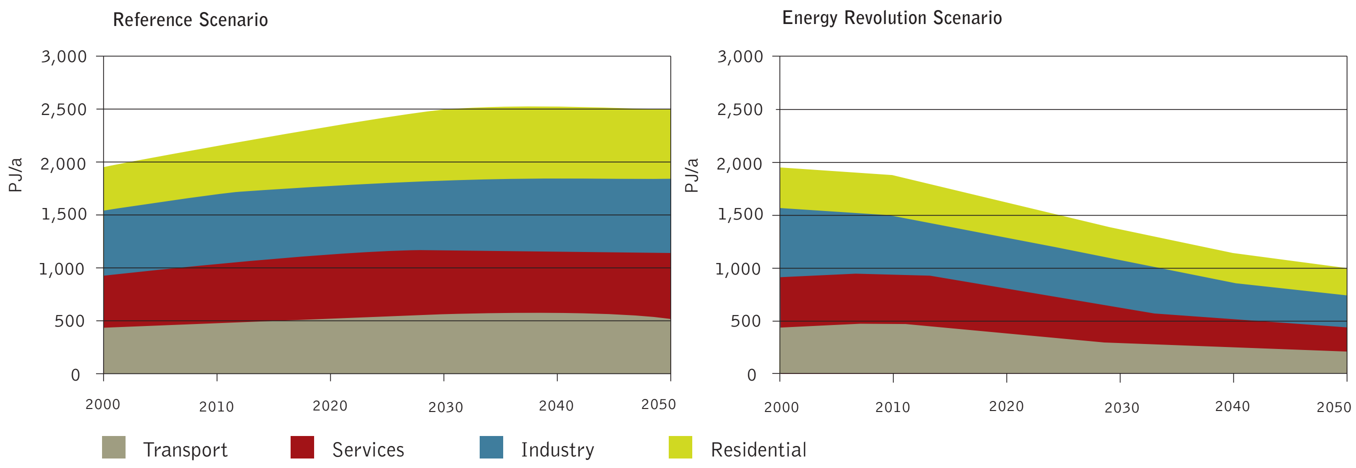
5. Final energy demand

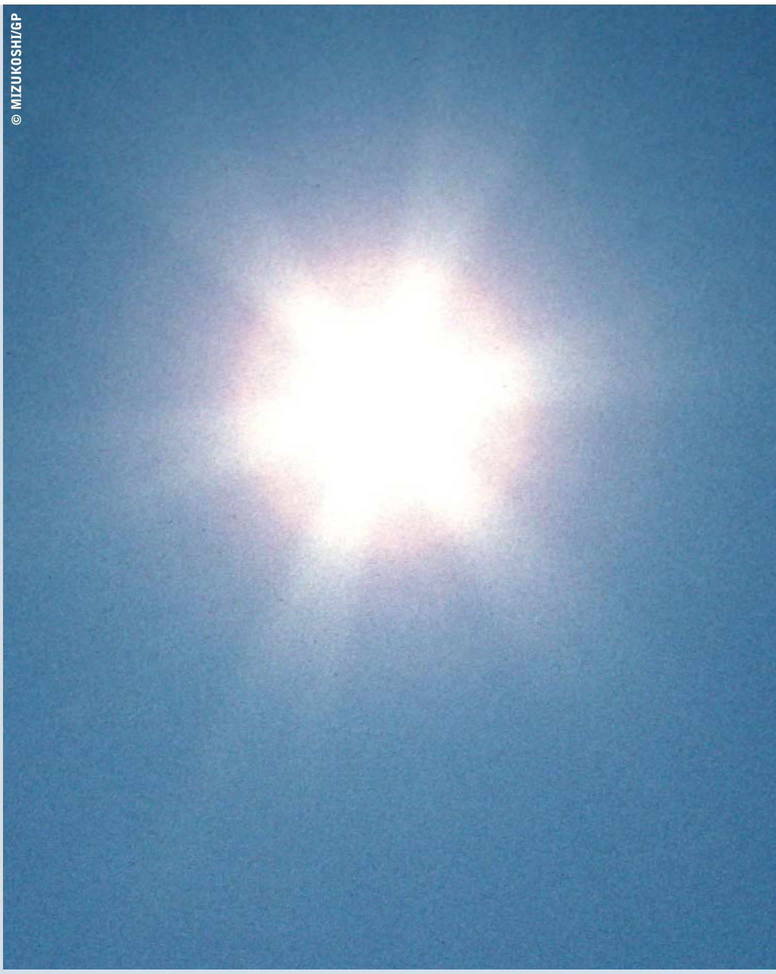
Combining the projections on population development, GDP growth and energy intensities results in future development pathways for final energy demand in the Netherlands, which are shown in figure 5 for both the Reference and the 'Energy Revolution' Scenarios. Under the Reference Scenario, the total final energy demand increases by 20 % from 2000 PJ/a in 2000 to 2500 PJ/a in 2050. In the 'Energy Revolution' Scenario, energy demand steadily declines to about 1000 PJ/a in 2050, which is the half of the final energy demand in 2000.

The accelerated increase in energy-efficiency is a crucial prerequisite for achieving a sufficiently large share of renewable energy sources in the Dutch energy supply. Moreover, energy-efficiency is not only beneficial for the environment, but often also from an economic point of view. Taking into account the full service life, in most cases the implementation of energy-efficiency measures saves costs compared to the additional energy supply. The mobilisation of cost-effective energy saving potentials leads directly to the reduction of costs. A dedicated energy-efficiency strategy thus also helps to compensate in part for the additional costs required during the market introduction phase of renewable energy sources.

Under the 'Energy Revolution' Scenario, the final electricity demand is expected to peak around 2020. Despite continuous economic growth, after 2030 the overall electricity consumption is anticipated to drop, leading to an electricity demand of about 100 TWh/a, which is slightly higher than in the year 2000. From 2000 on, the Dutch service sector is the sector that is expected to push up electricity demand the most (figure 6). Due to the exploitation of efficiency measures, electricity consumption will start to decrease in the service sector after 2030. This reversal of the trend cannot be observed in the residential sector. Although the energy efficiency of e.g. domestic appliances and illumination gets improved substantially under the 'Energy Revolution Scenario', the increased purchase of domestic applications will over-compensate the efficiency gains. In the industry sector, there will be a similar peak of electricity demand in 2020 as in the service sector with demand for electricity declining afterwards. Altogether, compared to the Reference Scenario efficiency measures avoid the generation of about 80 TWh/a in 2050.

FIGURE 5: PROJECTION OF TOTAL FINAL ENERGY DEMAND BY SECTOR FOR BOTH THE REFERENCE AND 'ENERGY REVOLUTION' SCENARIOS





Efficiency gains in the heat supply sector are even larger. The consideration of solar architecture in both residential and commercial buildings helps to curb the growing demand for active air-conditioning. Under the 'Energy Revolution' Scenario, the final energy demand for heat supply will be reduced by more than 55 % by 2050 (figure 7). Compared to the Reference Scenario, which is characterised by putting less efforts into the implementation of energy-efficiency measures, in 2050 the consumption of more than 750 PJ/a can be avoided through efficiency gains. Space heating is by far the largest contribution to this reduction. As the result of the energy-related renovation of the existing stock of residential buildings, as well as the introduction of low-energy standards and 'passive houses'[8] or new buildings, enjoying both the same comfort and energy services will accompany a much lower energy demand in the future.

The reduction of energy demand in industry, the residential, and the tertiary sectors is complemented by significant efficiency gains in the transport sector, which is not analysed in detail in the present study. Under the 'Energy Revolution' Scenario, it is assumed that the final energy demand for transportation will be reduced from 440 PJ/a in 2000 to 180 PJ/a in 2050. This reduction in energy demand can be achieved by the introduction of highly efficient vehicles, by shifting the transport of goods from road to rail (running on renewable energy), and by changes in mobility-related behaviour patterns.

FIGURE 6: DEVELOPMENT OF FINAL ELECTRICITY DEMAND BY SECTORS ('EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO)

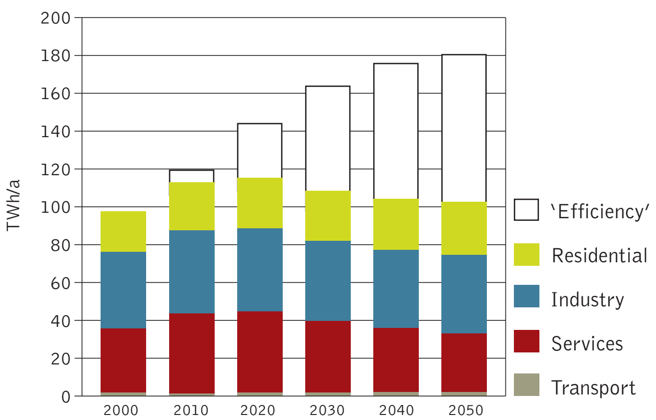
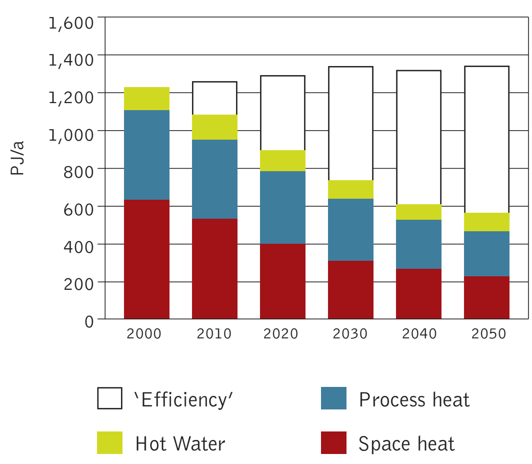


FIGURE 7: DEVELOPMENT OF FINAL ENERGY DEMAND FOR HEAT SUPPLY



8 | The term passive house refers to a specific construction standard for residential buildings with good comfort conditions during winter and summer, without traditional heating systems and without active cooling by combining a high level of insulation with minimal thermal bridges, low infiltration and utililizes passive solar gains and heat recovery.

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6. Electricity generation

In the 'Energy Revolution' Scenario, the development of the electricity supply sector is characterised by a dynamically growing RES market and a continuously increasing share of renewable energy sources. Fossil fuels power plants are used to fill the remaining gap between renewable power generation and electricity demand only. Secured capacity is always exceeding the estimated peak load demand by at least 20 %.

The following strategy paves the way for a future renewable energy supply:

* Phasing-out nuclear electricity generation by shutting down plants after a lifetime of 30 years. For the Netherlands this means an immediate shut-down of its one nuclear power plant which has started operation in 1973. The resulting, small gap of 4 TWh/a of nuclear electricity generation is mainly filled by highly efficient combined cycle gas power plants.
* At the same time, reducing the use of carbon-intensive solid fossil fuels for electricity generation shall be a priority target for the Dutch energy policy. Coal power plants can be substituted in a first step by bringing into operation new highly efficient gas-fired combined-cycle power plants, and again by increasing the capacity of wind turbines and biomass. The expansion of wind energy use (both onshore and offshore) is expected to reach a capacity of around 8,500 MW in 2050. Photovoltaic solar energy will contribute substantial shares of electricity from 2030 onwards. In the long term, wind, PV, biomass and natural gas will be the most important sources of electricity generation.
* Because of limited potential and nature conservation concerns, the use of hydropower will remain limited and will not grow compared to its 2000 level.
* The installed capacity of renewable energy technologies will increase from 715 MW in the year 2000 to 18,000 MW in 2050. This growth in RES capacity by a factor of 25 in 50 years requires policy support and well-designed policy instruments.
* By 2050, 57 % of the electricity produced in the Netherlands comes from renewable energy sources (see figure 9). In 2050, another 13% of Renewable Energy Sources (RES) will be imported. This consist of hydropower from Norway and Concentrated Solar Power from Southern Europe.
* Because of a still growing electricity demand and the age of the existing power plants, there will be a large demand for investment into new capacities during the next 20 years. As investment cycles in the power sector are long, decisions for restructuring the electricity supply system need to be taken now.

FIGURE 8: DEVELOPMENT OF THE ELECTRICITY SUPPLY STRUCTURE UNDER THE REFERENCE SCENARIO

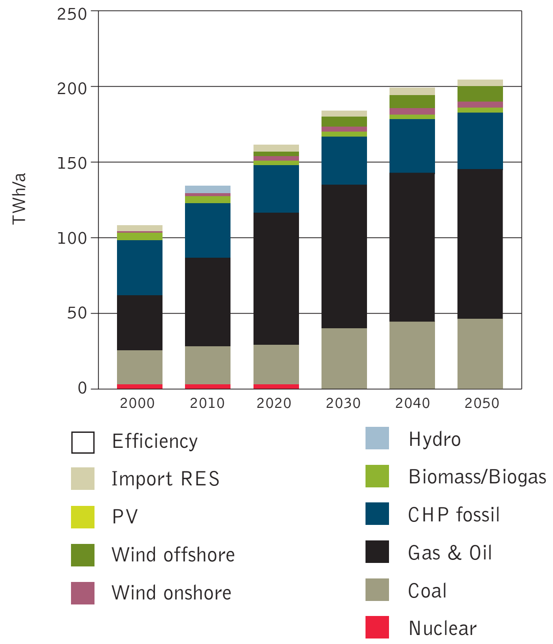
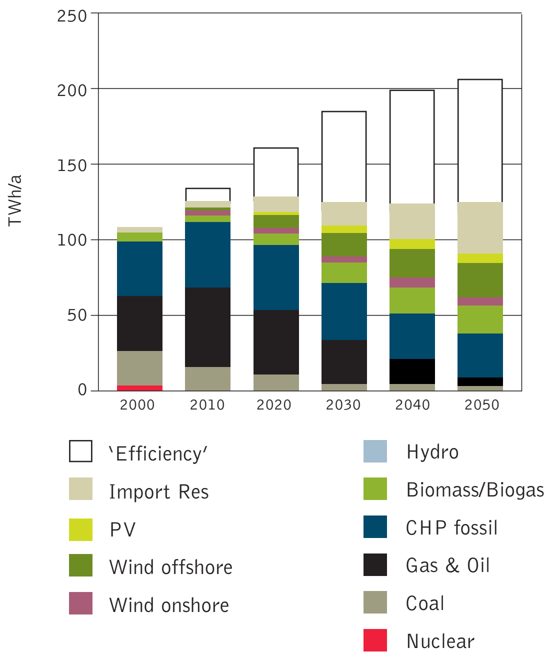


FIGURE 9: DEVELOPMENT OF THE ELECTRICITY SUPPLY STRUCTURE UNDER THE 'ENERGY REVOLUTION' SCENARIO ('EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO)



To achieve an economically attractive growth in renewable energy sources, a balanced and timely mobilisation of all available RES sources is of great importance. This mobilisation depends on technological potential, current costs, cost-reduction potentials, and technological maturity. Figure 10 and table 1 show the complementary evolution of the different RES technologies over time. Wind turbines and biomass power plants will mainly contribute to the growing market share of RES technologies, which will be complemented by an increasing contribution from PV power.

FIGURE 10: GROWTH OF RES ELECTRICITY GENERATION UNDER THE 'ENERGY REVOLUTION' SCENARIO, BY INDIVIDUAL SOURCES

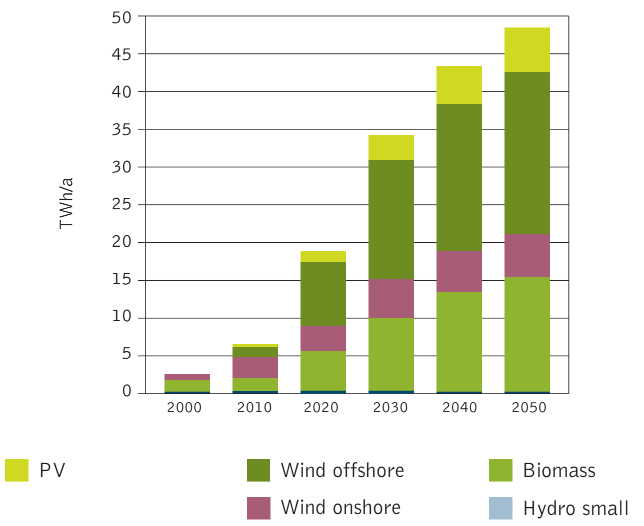


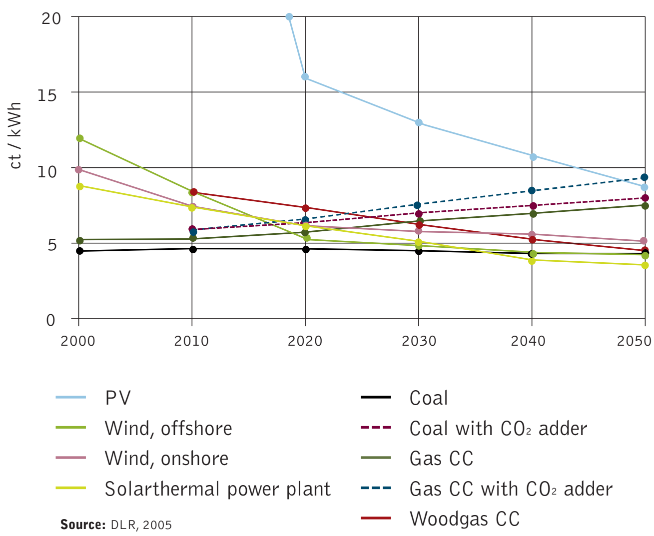
TABLE 1: PROJECTION OF RES CAPACITY FOR ELECTRICITY GENERATION UNDER THE 'ENERGY REVOLUTION' SCENARIO, IN MW

YEAR	2000	2010	2020	2030	2050
Hydro	37	37	37	37	37
Wind	446	2020	4571	6879	8492
- onshore	446	1620	2074	2407	2537
- offshore	0	400	2497	4472	5955
Solar PV	13	243	1503	3900	6508
Biomass	219	419	1263	2001	2927
Total	**715**	**2719**	**7374**	**12817**	**17964**

The expected cost reduction is of course basically not a function of time but of cumulated capacity, thus a dynamic market development is required to facilitate the exploitation of the cost reduction potentials. Most of the renewable energy technologies will be able to reduce their specific investment costs to a level of between 30 and 60% of current costs by 2020 and to between 20 and less than 50% in a more or less fully developed state (after 2040). Reduced investment costs for renewable energy technologies lead directly to reduced electricity costs. Electricity generation costs today are around 9 to 20 ct/kWh for the most important RES technologies, with the exemption of photovoltaics, which is still characterised by higher generation costs. In the long term, the specific generation costs of the different technologies are expected to converge at around 4 to 6 ct/kWh, and PV electricity will be available at costs around 10 ct/kWh.

In conventional technologies, in spite of growing fuel efficiency and reduced investments costs, the expected increase in the development of fossil fuel prices, electricity generation costs are at least in the same order of magnitude as those from renewable energy technologies, as is shown in figure 11. Any increase beyond the conservative assumptions the scenario is working on, e.g. in 2010 the assumed average price of oil is 32 dollar per barrel, while the long-term price of a barrel of oil rises up to 59 dollar per barrel, will further increase the competitiveness of renewable energy technologies. Adding in the economic burden resulting from CO_2 emissions, the electricity generation costs from fossil fuels becomes higher, which is also indicated in figure 11.

FIGURE 11: EXPECTED DEVELOPMENT OF SPECIFIC ELECTRICITY GENERATION COSTS FROM FOSSIL AND RENEWABLE OPTIONS



Source: DLR, 2005

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7. Heat supply

In 2000, renewables provided about 2.5 % of the Dutch energy demand for heat supply, the main contribution being biomass. Past experience in several countries, however, has shown that it is easier to implement effective support instruments in the grid-bound electricity sector than in the heat market, with its multitude of different actors. Dedicated support instruments are required to ensure a continuously dynamic development of renewables in the heat market:

* Energy-efficiency measures like e.g. improved insulation of buildings can reduce the current energy demand for heat supply by about 55 %.
* Solar collectors, biomass/biogas and, to a much lesser extent, geothermal energy are increasingly substituting conventional fossil-fired heating systems.
* A shift from coal and oil to natural gas in the remaining conventional applications leads to a further reduction of CO_2 emissions.

Figure 13 shows the crucial strategic importance of heat consumption savings for gaining substantial contributions of renewable energy sources.

FIGURE 12: DEVELOPMENT OF THE HEAT SUPPLY STRUCTURE UNDER THE REFERENCE SCENARIO

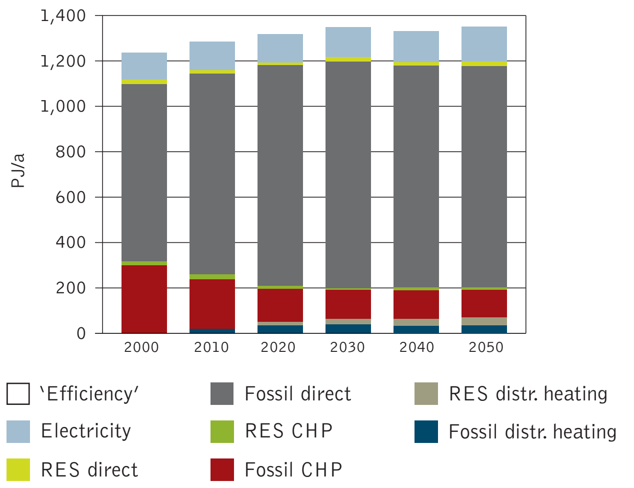
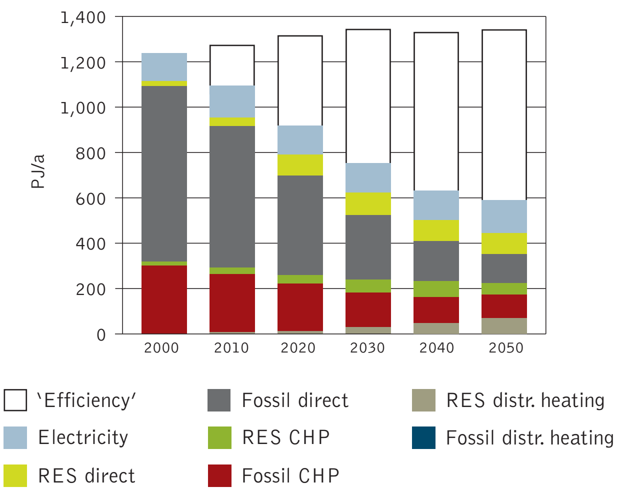


FIGURE 13: DEVELOPMENT OF THE HEAT SUPPLY STRUCTURE UNDER THE 'ENERGY REVOLUTION' SCENARIO ('EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO)



8. Primary energy consumption

Taking into account the assumptions outlined above, the resulting primary energy consumption in the Netherlands under the 'Energy Revolution' Scenario is shown in figure 15. Compared to the Reference Scenario (figure 14), the primary energy demand will be reduced by almost 50 % in 2050. More than 40 % of the remaining primary energy demand can be covered by renewable energy sources.

Because of the method generally used for the calculation of primary energy consumption, the share of renewables seems to be lower than their actual importance for providing energy carriers. Following this method, the amount of electricity generation from hydro, wind, solar, and geothermal energy equals exactly the primary energy consumption from these sources. For nuclear and fossil fuels, only a fraction (typically 40-50 %) of the primary energy gets transformed into electricity in conventional power plants, the remainder is wasted as heat.

FIGURE 14: DEVELOPMENT OF PRIMARY ENERGY CONSUMPTION UNDER THE REFERENCE SCENARIO

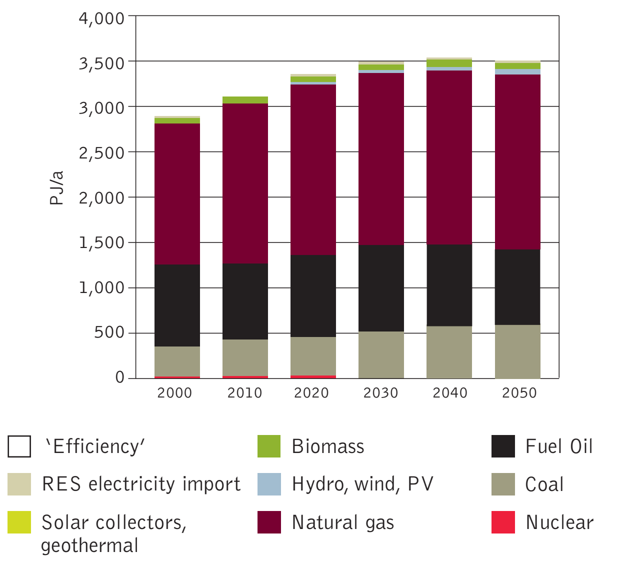
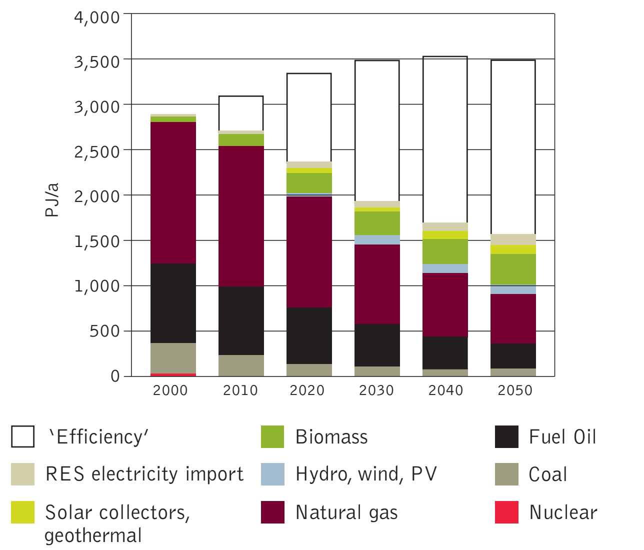


FIGURE 15: DEVELOPMENT OF PRIMARY ENERGY CONSUMPTION UNDER THE 'ENERGY REVOLUTION' SCENARIO ('EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO)



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9. CO_2 emissions

Despite the national target of reducing greenhouse gases emissions (-6 % by 2008-2012 compared to 1990), Dutch CO2 emissions increased by about 9 % between 1990 and 2000, reaching that year a level of about 168 million tons per year (see figure 16).[9]

Annual per capita emissions will drop from 9.8 t/capita in 2000 to 1.9 t/capita in 2050, a drop of more than 80 %. Substituting coal-fired power plants with highly efficient natural gas-fired power plants and electricity from renewable energy sources provides the main contribution for bringing down the CO_2 intensity of electricity sector.

Additional measures could be taken to reduce the overall Dutch emissions by targeting other greenhouse gases, methane, nitrous oxide and F-gases, which have a higher Global Warming Potential* (GWP) than CO_2. Such measures, however, are beyond the scope of this report.

FIGURE 16: DEVELOPMENT OF CO_2 EMISSIONS BY SECTOR UNDER THE 'ENERGY REVOLUTION' SCENARIO ('REDUCTION' = REDUCTION COMPARED TO THE REFERENCE SCENARIO)

9 | The scenario is taking 155 million tons as baseline in 2000, because air tranport emissions are not taken into account.

10. Costs of electricity generation

The long term provision of energy at affordable cost is one aspect of a sustainable development. It means securing the supply from an economic point of view.

As figure 17 shows, the massive introduction of renewable energy technologies for electricity generation under the 'Energy Revolution' Scenario leads to higher specific generation costs from 2010 until 2040 compared to the Reference Scenario. But with escalating fossil fuel prices and technological learning in the field of renewables, costs approach a similar level around 2040. Thenceforward, under the 'Energy Revolution Scenario' electricity is cheaper than under the Reference Scenario. The difference between the specific costs under the two scenarios does not exceed 0.4 ct/kWh. That the gap is not higher is a positive effect of the already now high share of combined heat and power in the Netherlands. Revenues for the sold heat make the electricity from CHP a cheaper option.

Table 2 gives an overview of the price development assumed for fossil fuels. Any increase in fossil energy prices beyond the relatively conservative price projection given in table 2 would, however, be an additional direct burden on fossil electricity generation, and thus reduce the cost-gap between the two scenarios.

When taking the costs of CO_2 emissions into account, because of the high CO_2 intensity of electricity generation under the Reference Scenario, there is a break-even between the two scenarios before 2030. From that time on, electricity in the 'Energy Revolution Scenario' gets increasingly cheaper than in the business-as-usual scenario. In 2050, the specific electricity generation costs are actually 1.4 ct/kWh lower under the 'Energy Revolution Scenario'.

Figure 18 shows that the higher specific electricity generation costs under the 'Energy Revolution' Scenario are to a large extent compensated by the reduced demand for electricity. Assuming average costs of 4.5 ct/kWh for implementing energy-efficiency measures, the additional cost for electricity supply under the 'Energy Revolution' Scenario – again, excluding the costs of CO_2 emissions – is only slightly higher than in the Reference Scenario in 2010. These additional costs of about 200 Mill Euros per year can be understood as the Dutch society's investment into a future climate-friendly, safe, and economic energy supply. From 2020 on electricity supply under the 'Energy Revolution Scenario' will become cheaper than in the Reference Scenario. Already in 2030 the annual saving under the 'Energy Revolution Scenario' amounts to about 900 Mill Euros. The inclusion of the costs of CO_2 emissions would provide further evidence of the long-term economic benefits of the 'Energy Revolution Scenario'.

Additional costs should also be weighed against the increase of the risks, e.g. of flooding and heat waves, associated with climate change, which are potentially much higher.

TABLE 2: ASSUMED EVOLUTION OF PRIMARY ENERGY CARRIER PRICES IN € 2000/GJ

	2000	2010	2020	2030	2050
Crude oil	5.3	4.8	5.6	6.7	8.9
Crude oil (dollar / barrel)		32			59
Natural gas	2.8	4.1	5.0	6.3	8.6
Hard coal	1.4	1.9	2.1	2.3	2.8

Source: DLR, 2005

FIGURE 17: DEVELOPMENT OF SPECIFIC ELECTRICITY GENERATION COSTS UNDER THE TWO SCENARIOS (THE COST OF CO_2 INCREASES FROM 15€/T_{CO_2} IN 2010 TO 50€/T_{CO_2} IN 2050, HEAT CREDITS RANGE FROM 1.1 TO 2.1 CT/KWH_{EL})

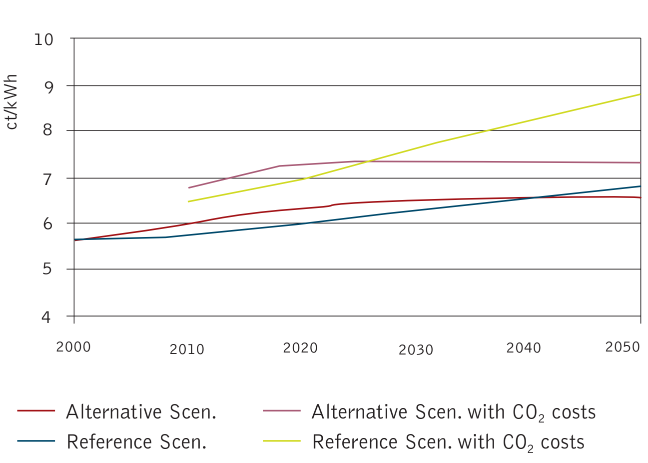
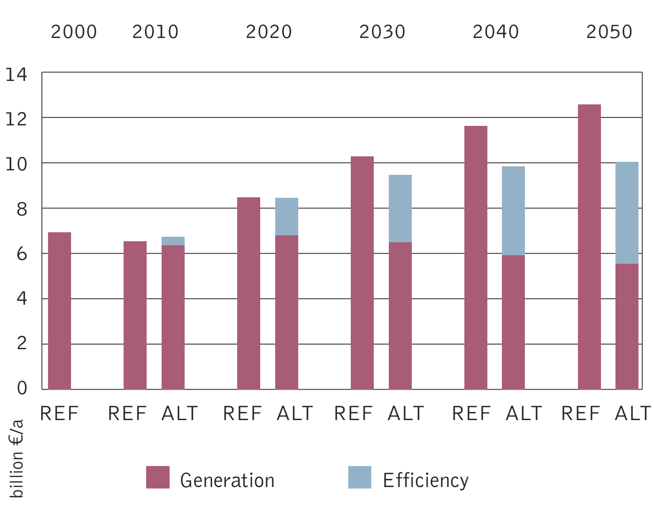


FIGURE 18: DEVELOPMENT OF TOTAL ELECTRICITY SUPPLY COSTS (WITHOUT TAKING THE COST OF CO_2 INTO ACCOUNT); REF = REFERENCE SCENARIO, ALT = 'ENERGY REVOLUTION' SCENARIO



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11.Employment in the electricity sector

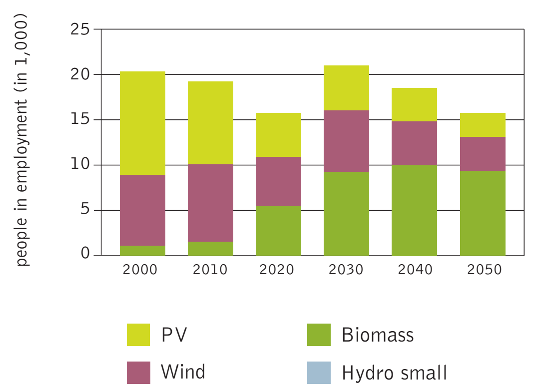
The rapid growth of renewable energy technologies described under the 'Energy Revolution' Scenario will lead to large investment in new technologies. This dynamic market growth results in a shift of employment opportunities from conventional energy-related industries to new occupational fields in, for example, the wind and solar industry.

The growing contribution of renewables is expected to provide between 15,000 to 21,000 jobs in the field of electricity generation from renewable energy sources in the mid to long term (figure 19)[10]. This includes both 'direct' effects related to electricity generation and the production of investment goods, as well as 'indirect' effects covering the upstream production chain.

The employment effects are estimated by using assumptions on import shares, labour productivity, and their growth rates until 2050. Because of increasing labour productivity and growing import quotas, in the long term the total number of jobs related to electricity generation is expected to shrink.

The number of jobs in the energy-efficiency related industries is also expected to increase substantially, but this remained beyond the scope of this report.

FIGURE 19: PEOPLE IN EMPLOYMENT IN THE NETHERLANDS RESULTING FROM ELECTRICITY GENERATION FROM RENEWABLE ENERGY SOURCES IN THE 'ENERGY REVOLUTION' SCENARIO



10 | Gross employment figures are given here. They relate to the total number of people employed in the renewable energy sectors. Net employment figures, which consider that other jobs might get lost by an expansion of renewable energy technologies, are not taken into account here.

Greenpeace demands

Greenpeace calls for Dutch policy-makers and the electricity sector to invest in our future and take action now by:

* Urgently adopting a binding long-term greenhouse gases emission reductions target consistent with limiting the temperature rise to below 2°C. For industrialised countries, like the Netherlands, this translates to 30% below 1990 levels by 2020 and 80 % below 1990 levels by 2050.
* Adopting concrete and ambitious actions to promote energy-efficiency. Existing best practices, should be the standard after five years. Authorities should strengthen and check existing energy-efficiency standards, adopt further fiscal measures to stimulate energy-efficiency and run information and awareness campaigns targeting all consumers and the industry. Last but not least, they should 'govern by example' by reducing energy consumption in the public sector (for example large-scale relighting).
* Adopting concrete and ambitious actions to promote renewable energy sources by supporting, at the European level, the adoption of a legally binding target of 25 % renewable energy from primary energy in the 25 EU by 2020, coupled with strong efficiency measures. Within this overall target, sectoral targets need to be adopted. Renewable electricity should have a share of 17% in 2020 in the Netherlands, and for heat a share of 19% should be attained. In 2050 the share of renewable electricity should be increased to 55%.
* Strengthening and expanding the support for renewable electricity with a stable and effective feed-in system and implement comprehensive support instruments for heating and cooling from renewable sources of energy. At the same time, authorisation procedures have to be simplified and renewable electricity should be guaranteed priority access to the grid at fair and transparent prices.
* Taking political action to overcome distortions in the Dutch electricity market created by decades of massive financial, political, and structural support towards conventional polluting and dangerous technologies, in order to create a level-playing field for renewable energy sources. Adoption of polluter-pays taxation and internalisation of external costs over the whole chain, is important to achieve fairer competition on the electricity market.
* Integrate the application of district heating networks and CHP in spatial planning procedures to ensure optimal opportunities for use of heat.
* A rapid phase-out of the use of carbon-intensive solid fossil fuels (coal) for electricity generation.
* The immediate closure of the nuclear power plant at Borssele, as it is over 30 years old. Leaving it in operation is an unsustainable and irresponsible act towards current and future generations. New nuclear capacity can be avoided and will only increase the amount of poisonous waste, threat of proliferation, and nuclear terrorism.

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Energy Revolution

A sustainable pathway to a clean energy future for the Netherlands

INSTALLED CAPACITY (EXCEPT FOR ENERGY-EFFICIENCY)

Note: all data are rounded to the lower 500MW (for efficiency, to the lower TWh)
1 symbol = 500 MW (for efficiency, 1 symbol = 2 TWh)

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