The Role of Natural Gas in the Dutch Energy Transition:

Towards low-carbon electricity supply

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List of Abbreviations

ETS	European Trading System
CCS	Carbon Capture and Storage
CHP	Combined Heat and Power
BCM	Billion Cubic Meters
TTF	Title Transfer Facility
NBP	National Balancing Point
CCGT	Combined Cycle Gas Turbine
IGCC	Integrated Gasification Combined Cycle

PREFACE

From the start of its work the Natural Gas Programme at OIES had the intention of publishing a study on the potential contribution of gas to the transition to a low carbon economy. But it proved surprisingly difficult to find an author interested enough to devote time to this subject, and an approach which would not be dismissed as special pleading by a gas-focussed research group. The gas industry has been amazingly complacent in its assumption that, since the fuel emits less carbon dioxide than other fossil fuels, gas will automatically be the "fuel of transition" to, if not the "fuel of destination" for, the low carbon economy. Any such claims need to be backed up by research rather than stated as self-evident.

I was therefore very happy when Floris van Foreest agreed to take on this very difficult subject. The Netherlands provides a concrete example where specific low carbon scenarios can be constructed for a country where gas already plays a very large role in the energy balance. The aim was not to select a specific low carbon future but to examine, in as neutral a way as possible, the role of gas depending on which of the major options – renewable, nuclear and coal with CCS – is selected. I am very grateful to Floris for undertaking this very difficult analysis and bringing it to a successful conclusion. The Programme will continue to seek research opportunities on the role of gas in decarbonising energy balances.

Jonathan Stern, Oxford February 2010

1. Introduction

The issue of climate change and its consequences is increasingly acknowledged on a global level and the idea of moving towards a low-carbon economy is increasingly becoming conventional wisdom. However, the actual implementation of emission reduction measures is a complicated process that is subject to many uncertainties and conflicting political and economic interests. Meanwhile, global CO2 emissions further increased in 2008. According to the IPCC, without serious measures, CO2 emissions will increase by 60% in the coming 25 years, which could lead to a global temperature rise of 2-4°C.[2] A significant and structural reduction of CO2 emissions will require a fundamental shift from the current fossil fuel-based energy supply towards a sustainable and efficient energy system. This shift is also referred to as "energy transition".

The policy of the Dutch government regarding this transition is largely driven by cascading political processes around climate change. The issue of climate change has been addressed on different political levels in previous years. In 1997, the Kyoto Protocol was adopted and it entered into force in February 2005. This Protocol sets binding targets for 37 industrialized countries and the European Union for reducing greenhouse gas (GHG) emissions over the period to 2020.[3] In December 2009, a climate conference was held in Copenhagen to discuss and agree on objectives and mechanisms beyond Kyoto. Besides intentions and national ambitions, this conference did not result in a new climate treaty with binding targets on CO2 reduction. This will have to wait until at least the next summit that is planned for December 2010 in Mexico City.

On a regional level, the European Union embarked on establishing a common energy policy to achieve sustainable, competitive and secure energy supplies in the EU, and meet the commitments made under the Kyoto Protocol. In March 2006, the European Commission issued a Green Paper in which the famous 20-20-20 targets were put forward.[4] The common policy to meet the climate objectives further evolved towards a EU climate and energy package, which came into force in August 2009 and included a new renewable energy directive, the EU Emissions Trading System (EU-ETS) after 2012[5], effort sharing among EU countries to achieve 20% reduction of CO2 emissions by 2020 and subsidies and legislation for carbon capture and storage (CCS). Balancing national interests and European ambitions remains a major obstacle to the development of a European climate and energy policy.

This brings us to the level of national energy policies. As a Member State, the Netherlands has set an even higher target of 30% CO2 reduction by 2020.[6] This ambition forms the main driver for policies and transition programs such as stimulating the development of wind power and energy saving in the built environment. However, reality provides a less optimistic

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[2] IPCC, Climate Change 2007:*The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, New York 2007.*

[3] These amount to an average of five per cent against 1990 levels over the five-year period 2008-2012. Source: http://unfccc.int/kyoto_protocol/items/2830.php

[4] European Commission, *Green paper. A European Strategy for Sustainable, Competitive and Secure Energy*, March 8 2006. The targets include a 20% reduction of CO2 emission, 20% energy supply by renewable sources and 20% energy efficiency by 2020.

[5] This refers to a review of the EU Emissions Trading Scheme as of 2013, which includes that a majority of allowances would be auctioned, while the power sector will face full auctioning as soon as 2013, and other sectors will be gradually subjected to full auctioning also. http://www.europarl.europa.eu.

[6] Ministry of Environmental Affairs, *Government Program Clean and Efficient*: *New Energy for the Climate,* September 2007.

picture in the sense that it will be extremely difficult, if not infeasible, to realize this 30% reduction without buying tens of millions of CO2 certificates. The share of renewable energy in 2008 was only 3% and CO2 emissions in the industrial and energy sector stabilized at around 100Mton CO2.[7] Together, these sectors account for almost 50% of total emissions.[8]

Electricity production has been specifically targeted by the government to reduce CO2 emissions in the coming decade. The development of large scale low-carbon generation capacity will be pivotal to meet these ambitions.

Since the discovery of gas fields in the late 1950s and early 1960s, Dutch energy policy is inextricably connected with natural gas. For many decades, gas has been the main artery of its energy system and is an important source of income for the State.[9] In power generation, gas dominates the Dutch electricity mix with a share of 60%.[10] A distant second is coal with 23%. Looking at the plans for new capacity, which consists of 4GW gas and 5GW coal-fired generation, continuation of fossil fuel dominance is a realistic scenario.[11] However, public and political opposition against construction of conventional coal plants is rising and has become a serious obstacle to new coal capacity. The nuclear option has gained more support among politicians in the light of alarming climate reports, slow development of renewable energy sources and the gas crisis between Russia and Ukraine in January 2009. A breakthrough in Carbon Capture and Storage (CCS) linked to coal-fired generation could improve the case for coal from an environmental point of view. Thirdly, the government has put forward clear ambitions regarding the development of large scale wind, especially offshore (6GW). This will also have impact on the future configuration of base load generation in the Netherlands and the role of fossil fuels in this respect. Large investments are required in the coming years to make a significant step in bringing down CO2 emissions and to accommodate increasing electricity demand and decommissioning of old generation capacity. The next two to five years will be critical as large scale generation capacity projects have long lead times. The timeframe of realising nuclear or coal with CCS capacity will most likely reach beyond the 2020 horizon. Postponing decisions will only drift us further away from the carbon objectives.

The role of gas

This paper looks at the potential role of natural gas in the energy transition of one of Europe's leading natural gas markets. The main question that is addressed in this paper is: In what way could the nature and magnitude of the role of gas in the energy transition be affected by the development of a low-carbon power generation mix? This will largely depend on the political and commercial choices regarding this mix. What factors determine these choices? What are the implications for the role of gas? This paper discusses three scenarios that assume the dominance of a specific low-carbon generation technology. The decision in favour of one specific technology can have an impact on the future role of gas in the Dutch energy system. For example, an increasing integration of intermittent wind capacity increases the need for flexibility to maintain grid stability. The main provider for this flexibility in the Netherlands is gas-fired generation. In this paper the following generation scenarios are developed:

[7] Energy Research Centre of the Netherlands (ECN), *Monitor Clean and Efficient Program*, April 2009, p. 18 - 20.
[8] Ibid, p.17. Oil refinery and steel production are large contributors in the industry.
[9] In 2008, revenues for the government from gas exports increased by €2 billion to more than €10 billion. Financieel Dagblad, *Export of gas to a record*, 18 February 2009.
[10] Ministry of Economic Affairs, *Energy White Paper 2008*, June 2008, p.62.
[11] Energy Council, *Fuel mix in motion: looking for the right balance*, January 2008, p.52.

- Wind scenario: realization of large scale wind capacity (10 GW) by 2020
- Nuclear scenario: realization of large scale nuclear capacity (3-4 GW) by 2025
- Coal with CCS scenario: realization of large scale coal/CCS capacity (3-4 GW) by 2025

Chapters 2 and 3 elaborate on the current policies around energy transition and the characteristics of the Netherlands as a gas country. They provide the background for the scenarios and subsequent analysis. The scenarios are elaborated in chapter 4 and in chapter 5, the underlying fundamental issues of future development of low-carbon generation capacity in the Netherlands and the implications for the role of gas are discussed. The final chapter highlights the economic dimension of decisions regarding large scale generation capacity development.

2. Energy Transition in the Netherlands

Energy transition is a broad concept and refers to a certain timeframe in which the current energy system is transformed into a decarbonised system. There seems to be some consensus in the energy sector that this transition should be largely completed by 2050. What this energy system will actually look like and which energy carriers or transition fuels will facilitate this process are subject to intense debates. Moreover, ideas about “winners” in terms of sustainable sources such as wind and bio-fuels are surrounded by many uncertainties.

In general, transitions are long term change processes that are characterized by a high level of uncertainty and complexity. These changes are not only directly energy- related, but also have to take place at behavioural and geopolitical levels.[12] Consequently, the Dutch energy transition cannot be viewed in isolation from developments on the international level. The gas crisis in January 2009 between Russia and Ukraine and the economic recession of 2008-09 are both events which could affect decision making and investments in the field of new energy sources. For example, an increasing emphasis on security of supply and decreasing commercial viability put earlier choices for generation technologies in a different perspective. Furthermore, EU policy and directives on reducing the environmental impact of energy are important determinants of Dutch policy making. International agreements on climate change could result in adoption or amendment of policies at European and national levels. This chapter provides an overview of policies, initiatives and developments in (mainly) the electricity sector that can be attributed to energy transition in the Netherlands.

As mentioned in the introduction, the main milestone in the first phase of energy transition in the Netherlands is the realization of a 30% CO2 reduction by 2020. Meeting this target demands large investments in new technologies and fundamental changes in the way energy is used. The government has allocated € 7.5 billion for energy supply between 2007-2011.[13] Despite the plans and financial resources, overall CO2 emissions were 210 Mt in 2007 only 2.3% lower than in 1990, the reference year.[14] In terms of actual reduction, emissions have to be brought down from 215 Mton CO2 (equivalents) in 1990 to 150Mton CO2 in 2020. The industry and electricity sectors accounts for almost 50% of emissions (Table 2.1). Hence,

[12] Council for housing, Spatial planning and the Environment, Energy Council, *Energy Transition: climate for new opportunities,* December 2004, p.23
[13] Ministry of Economic Affairs, *Energy White Paper 2008,* p.23.
[14] ECN, *Monitor Clean and Efficient Program,* p.17

massive challenges lie ahead of us to bridge the gap between 2.3% reduction in 2007 and 30% in 2020.

Table 2.1 CO_2 emissions per sector

Mton/year	1990	2007	2010	2020	2020
Sector	Base year		No policy change	No policy change	Government program
Building environment	30	29	27	26	15-20
Industry / Electricty sector	93	101	105	131	70-75
Transport	30	39	40	47	30-34
Agriculture	9	7	9	7	5-6
Other	54	35	35	35	25-27
Total	**215**	**210[1]**	**215**	**246**	**150**

[1] Rounding

Source: Government program 'Clean and Efficient', Assessment ECN 2008

Focusing on the electricity sector, emissions have to be reduced by more than 30% in order to compensate for a lower level of reduction in other sectors and to meet the 2020 target.

The realization of around 30% power production from renewable sources and improved energy efficiency have been selected as main paths to achieve this reduction. Acceleration of coal with CCS technology implementation is also included as a reduction option. The cold facts are that the generation sector emitted more than 50 Mton CO2-eq in 2007 and in a *business as usual scenario* this would increase towards 85 Mton in 2020 because of increasing demand and lower imports.[15] Furthermore, emissions of electricity producers increased by 4.8% in 2007 due to higher production and lower imports.[16] The current generation mix is dominated by gas and coal. Especially coal-fired generation is a large emitter with 800-860 kg CO2/MWh.[17] Going forward, before the economic recession, electricity demand was estimated to increase from 116 TWh in 2007 to 143 TWh in 2020, assuming a yearly growth of 1.5%.[18] The recession caused a dip in electricity demand in 2009. Although the longer term effect is not clear, there is so far no reason to assume that future power demand will be significantly lower than the pre-crisis estimate.[19] In their 2009 World Energy Outlook, the International Energy Agency estimates an average annual growth in the EU of 0.9% between 2007-2030.[20] The results of energy efficiency measures will probably become increasingly material and have larger effects between 2020-2030. In other words, the sector faces a huge challenge to meet the targets, which calls for drastic measures and large investment in low-carbon and renewable generation capacity.

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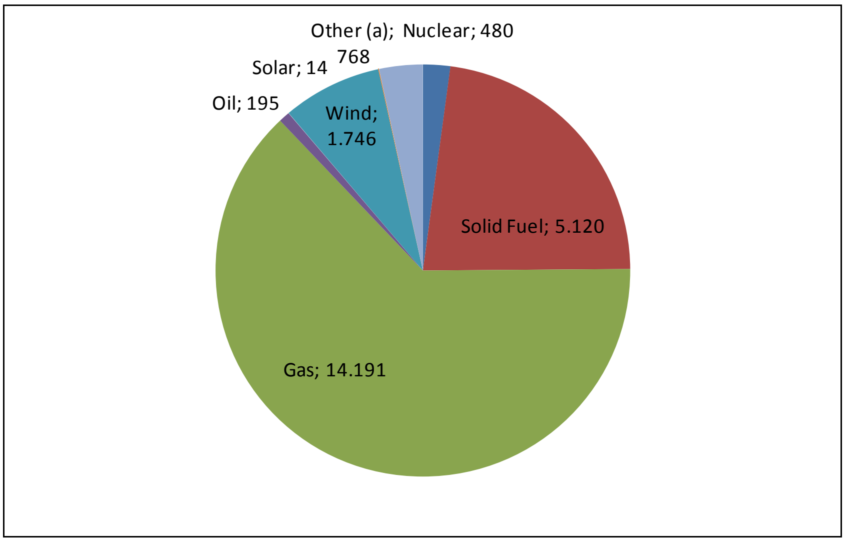
[15] Energiened, *Energy 2007-2020*, May 2007, p. 6. The term *business as usual scenario* is used in the Energiened report and should not be confused with the scenarios of this paper.
[16] Central Bureau for Statistics (CBS), *Environment Calculations 2007*, The Hague 2008, p.77
[17] See Table 5.1
[18] ECN, *Future electricity prices*, June 2008, p. 20
[19] The 143 TWh that was estimated by ECN includes effects of energy efficiency measures. Assuming economic recovery from 2010 onwards and taking into account that implementation of instruments to realize reduction in power demand is moving slowly, it is probable that demand will not be below 140 TWh by 2020.
[20] IEA, *World Energy Outlook 2009- Global Energy Trends to 2030*, Paris 2009, p. 98

Figure 2.1 Power generating capacity (MW) 2007



Source: Global Insight (2008)

One of the main pillars in the government plans is the realization of 10GW wind energy, 6GW offshore and 4GW onshore. Potentially, in the case of onshore wind, this could contribute to a yearly reduction of 7.1 Mton CO2 if it replaces conventional coal and 3.6 Mton CO2 if it would replace CCGT capacity. For offshore wind, the potential annual reductions are 14.5 Mton and 7.3 Mton CO2 respectively.[21]

In April 2009, the total installed wind capacity was 2.2 GW.[22] A structurally low CO2 price, relatively high integral cost-based prices and problems of grid integration, are factors that can hamper large capacity growth. This will be further discussed in the fourth and fifth chapters.

An increase of other renewable generation types such as biomass and solar PV is anticipated, but due to economic, technological and regulatory constraints, their share is expected to be relatively small in 2020; 800MW and 100MW respectively.[23]

A second prominent pillar concerns the increase of decentralized Combined Heat and Power units (CHP) in the industry and agriculture sector. These units run on gas and can produce heat and electricity at high efficiency levels. Operation is mainly heat or steam driven, with electricity as by-product. Larger units are also used for district heating. Through the use of heat buffers and boilers, electricity can be used more efficiently and delivered back to the grid during peak hours at attractive market prices. However, the majority of these units are "must-run" [24], which has implications for the development of base load in the Netherlands. In 2006, 45% of electricity demand was produced by decentralized units and this share is expected to

[21] See Appendix.
[22] Wind service Holland, Statistics NL, installed capacity April 2009, on and offshore.
[23] Ministry of Economic Affairs, *Energy White Paper*, ECN, MNP scenario, p.79
[24] "Must-run" refers to units that have a constant production profile due to underlying heat and steam supply obligations or technical limitations with respect to up- and downscaling of production.

increase.[25]As they primarily run on gas, this also has to be taken into account in the assessment of the role of gas in energy transition.

Thirdly, the government and the EU have embraced coal with CCS as low-carbon technology. With an extensive gas infrastructure, substantial potential storage capacity[26], almost depleted gas fields and the presence of attractive production locations in coastal areas, the Netherlands is theoretically well-positioned for large scale coal-fired generation with CCS. Despite its environmental controversies, coal is still recognized as a transition fuel in the Dutch generation mix. The geographically spread reserves and cost advantages over gas make it an attractive source from the security and economic points of view. Application of CCS would significantly reduce its carbon footprint. [27]

In January 2009, the European Commission has granted €250 million to the Netherlands as part of a larger CCS program.[28] In addition, the Dutch Ministry of Environmental Affairs allocated €60 million for two pilot projects. [29]

Different studies argue that large scale commercialization will not occur before 2020.[30] Issues around CO2 storage, allocation of high investment costs between market parties and the government and uncertainty about the level of CO2 prices, are factors that influence this timeline.

Realization of large scale wind and coal with CCS will definitely contribute to a significant CO2 reduction. However, uncertainties (mentioned above) that undermine their commercial viability may cause delays in development and consequently put the 2020 objectives under pressure.

At the same time, new capacity is needed to accommodate increasing demand and decommissioning of old power plants. Peak load is expected to increase by 3GW to 24GW in 2020 and around 2 GW will be phased out.[31] The current plans include 5GW of conventional coal-fired generation, but it becomes increasingly unlikely that all of this will be built. So far, only one project has entered the construction phase.[32] Consequently, gas-fired generation could become the preferred option to meet the medium term requirement in electricity supply.

The problems with wind and coal could open the way for new nuclear capacity in the Netherlands.

The nuclear debate among politicians, which began in 2008 after publications by leading advisory bodies, has put this option back on the table.[33] In Finland and France, construction of

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[25] Ibid., p.71

[26] The Dutch subsurface could technically store approximately 35-40 Mt/year of CO2 for a period of 40 years. Clingendael International Energy Programme, *Carbon Capture and Storage: A reality check for the Netherlands,* May 2008, p.5

[27]Ministry of housing, Spatial planning and the Environment, http://www.vrom.nl/pagina.html?id=38051, 27 November 2008.

[28] The Commission proposes € 5 billion new investment in energy and Internet broadband infrastructure in 2009-2010, in support of the EU recovery plan. http://europa.eu/rapid/pressReleases.

[29] The Ministry of Environmental Affairs has allocated €60 million for two CO2 storage projects, 27 November 2008, http://www.vrom.nl/pagina.html?id=38051

[30] International Energy Agency (2008), *Energy Technology Perspectives,* p.279 ; Mckinsey & Co (2008), *Carbon Storage competitive by 2030,* Datamonitor, *Wind and CCS stakeholders go head to head following funding years*, April 2009

[31] The information about decommissioning is based on IEA electricity information. It concerns the 4 oldest coal plants (Gelderland-13, Amer-81, Maasvlakte 1+2). ECN (2008), Future Electricity Prices, p.21

[32] EON coal plant (1080 MW) Maasvlakte

[33] Among others the Energy Council and Social Economic Council

a new generation of nuclear plants has already started. Today, the Netherlands has one 450MW nuclear plant in Borssele which will be phased-out in 2033. Nuclear energy scores reasonably well in terms of CO2 emissions. For European plants, emissions are calculated at 8-32 g CO2/kWh; a little higher than wind at 6-23 g CO2/kWh.[34] Uranium reserves are geographically spread and are estimated to cover current demand levels for the coming 70 years.[35] Investment costs are high, but marginal costs are very competitive. The main problems are indefinite storage of spent fuel, perceptions of safety and exposure to terrorist attacks. The current Dutch government stated that it will not decide on a nuclear option in this cabinet period (2007-2011). Considering the lengthy lead times, a decision in favor of nuclear will not materialize in new capacity before 2020. However, such a decision and subsequent realization beyond 2020 could have a significant impact on transitional configuration of the fuel mix and the role of gas.

To organize the energy sector and other relevant actors around the ambitious targets, an umbrella program, *clean and efficient*[36], has been drafted that provides a roadmap to make the Netherlands one of the most efficient and clean energy suppliers of Europe. It contains high level measures for different sectors and functions as an umbrella for other large initiatives that aim to bring down CO2 emissions.
One main example of such an initiative is the '*more with less*' agreement between the government and market parties in the building sector to make 2.4 million residential and office buildings energy economic.[37] The ultimate objective is to reduce emissions by 30-50% (6-11 Mt CO2/yr) in 2020.

Obviously, the energy sector, as the main CO2 emitter, is also included in this overall transition program. General directions are defined about stimulating the development of renewable energy and clean generation technologies. A more detailed vision and plan for the energy sector is described in the Energy White Paper issued by the Ministry of Economic Affairs in June 2008.[38] This paper articulates the government's view on challenges and developments in this sector. Furthermore, it provides a snapshot of the current energy supply and elaborates on the way forward with respect to management of national resources, securing energy supply and making electricity production cleaner. Although this paper provides a good overview of the issues and possible routes towards realizing the 2020 objectives, it lacks a clear direction for the transitional design of the generation mix. All options such as large scale wind, coal with CCS and even nuclear are on the table, but a roadmap with straightforward choices and a robust regulatory framework is missing.

This can be partly explained by the fact that the government has to deal with many uncertainties about for example technological developments, demand/supply balances of oil and gas and energy prices. Regulatory uncertainty also affects the investment climate and forms a constraint for energy companies that have to make large investments in low-carbon generation capacity. They are dependent on market conditions that are partly driven by legislative measures and support mechanisms. This interdependence holds the risk of possible

[34] ECN, Scheepers, M.J.J., Seebregts, A.J., Lako, P., Blom, F.J., Gemert, F. van, *Fact-finding nuclear energy*, October 2007, p.13
[35] ECN (2007), *Fact-finding nuclear energy,* p.28. Main reserves in Kazakhstan, Australia and Canada.
[36] Ministry of Environmental Affairs, *Government Program Clean and Efficient*: *New Energy for the Climate,* September 2007
[37] Ministry of Environmental Affairs, *More with Less: National Energy Savings Plan,* June 2007
[38] Ministry of Economic Affairs, *Energy White Paper 2008,* June 2008.

deadlocks in the development of low-carbon technologies. The relation between government and the market will be discussed in chapter 5.

Energy transition, and more specifically the configuration of the future generation mix, is surrounded by many uncertainties and challenges, which can also affect the position of gas. To bridge the gap between 2.3% and 30% CO2 reduction seems very challenging in a timeframe of a little more than ten years. Clear and maybe controversial choices have to be made to make a step forward in the transition. In order to gain insight into the implications for gas as a fuel for power generation and in the gradations in the importance of its role in this sector, this paper discusses three scenarios that assume dominance of a specific generation type. First of all, the next chapter elaborates on the position of gas in the Dutch energy system and the gas market.

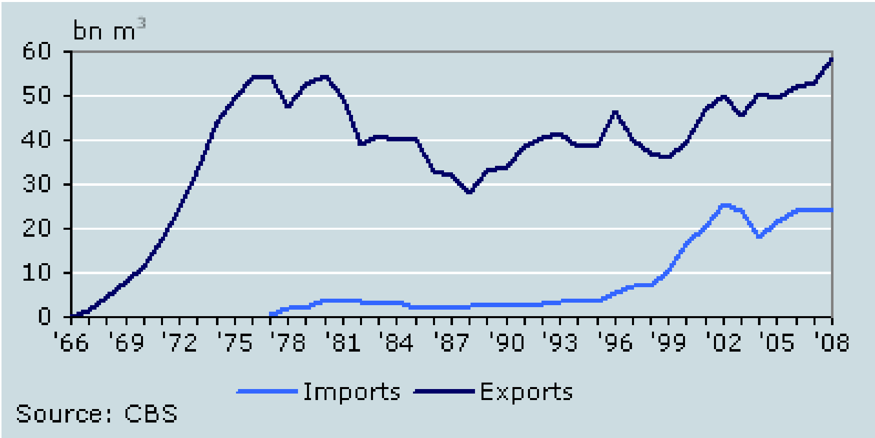
3. The Netherlands as a gas country

In order to put the current position of gas and its possible role(s) in the energy transition in the correct perspective, this chapter provides an overview of the Dutch gas landscape. The Netherlands became a gas country in the early 1960s. In 1959, the Dutch Petroleum Company (Shell) drilled for gas in the province of Groningen and exposed one of the largest onshore gas fields in the world. At the beginning, gas manifested itself as the energy source for heating buildings, cooking and the production of steam for industry. From the 1970s onwards, gas was increasingly used in the electricity sector and replaced coal as the main fuel for power generation. As mentioned before, gas now accounts for 60% of power generation. It is fair to say that gas forms a cornerstone in Dutch energy policy and also is an important income source for the government, which is 50% shareholder of the gas field assets. The other shareholders are Shell (25%) and ExxonMobil (25%). In 1974, the government adopted the small-fields policy that aims to maximize production from the small fields and use the large Groningen field, which has around 1,000 Bcm remaining reserves, as the swing supply. In addition, a production cap has been put on this field of 42.5 Bcm/yr for the period 2006-2015.[39]

Next to the United Kingdom, the Netherlands holds a unique position in the EU in terms of gas resources. In 2007, it accounted for 35% of total EU gas production.[40] On 1 January 2008, reserves were estimated at 1,400 Bcm and considering the current exploration rate of more than 70 Bcm/year, they will be depleted in less than 20 years.[41] The increase of imports from the mid-nineties is mainly driven by trading opportunities. In 2007, the main imports originated from Norway (38%), Germany (24%) and Russia (17%)[42]. In the light of the January 2009 gas crisis between Russia and Ukraine and the concentration of reserves in politically unstable regions, increasing exports could become subject to a more intense debate about the allocation of national resources.

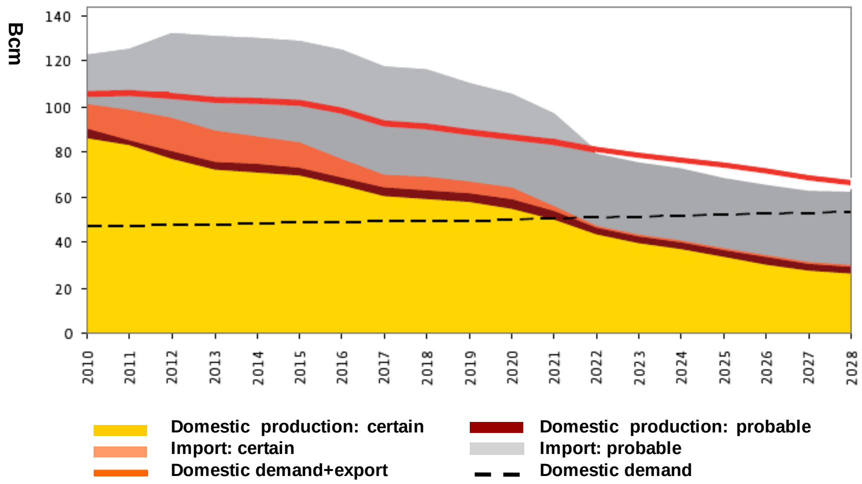
[39] Ministry Economic Affairs, *Oil and Gas in the Netherlands*, p.16
[40] Eurogas, *Natural gas consumption in EU-27 in 2007,* 13/3/2008. 71.8 Bcm production in the Netherlands and 198 Bcm in the whole EU.
[41] BP, Statistical Review of World Energy 2009, natural gas proved reserves.
[42] Datamonitor knowledge center, *Gas Market Profile: Netherlands*, February 2008

Figure 3.1 Gas imports and exports



Discussions around the role of gas in the context of energy transition such as presented in this paper, can further stir up this debate. Furthermore, exports reached a record level of 58.5 Bcm in 2008, which was largely driven by high gas prices. Domestic consumption has declined in the past years due to improved insulation and warmer winters. Total production in 2008 was 80 Bcm and 24 Bcm was imported.[43]

Figure 3.2 Natural gas balance of the Netherlands 2010-2028



Source: Gas Transport Services (2009)

According to calculations of Gas Transport Services, continuation of these levels will result in the Netherlands eventually becoming a net importer.[44] Figure 3.2 shows that this could be the case by 2021. This development has to be taken into account in assessing the role of gas in the transition to low-carbon electricity supply.

[43] CBS Web magazine, *Natural gas exports reach record level in 2008*, 19 February 2009

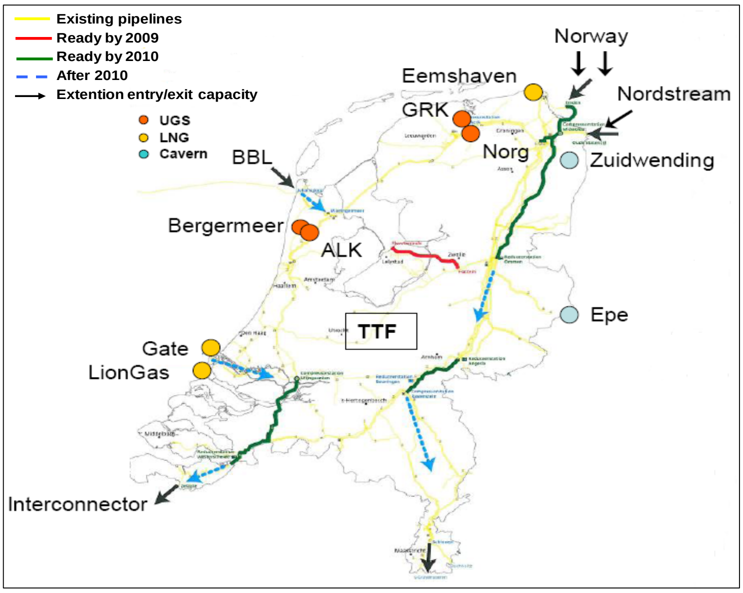
[44] Gas Transport Services, *Report Security of Gas Supply 2009*, p.12

The Dutch gas roundabout

A recurring theme in reports about the Netherlands in relation to its gas resources is the establishment of the Netherlands as the gas hub of Northwest Europe. Conceptually, it will form a “roundabout” that is connected to different European markets and supported by extensive infrastructure and storage facilities to manage the incoming and outgoing gas flows (Figure 3.3). Next to improved interconnection and domestic pipeline capacity, the role of peak storage, which allows for withdrawal of significant capacity in a short timeframe, is expected to become more prominent, following the increasing demand for flexible sourcing.

The increase of intermittent wind power capacity is one of the drivers behind this. The Netherlands has significant storage potential in the form of depleted gas fields and salt caverns. In addition, storage can also contribute to security of supply in the event of short term supply disruptions, which will have more impact as the share of imports increases. The construction of LNG terminals is also part of the gas roundabout concept. Two projects have been started since 2005. Gasunie and Vopak are the main investors in a 9 Bcm/year terminal in Rotterdam, which is expected to be operational in 2011. A second terminal is planned to be build in Eemshaven by ConocoPhillips and Essent.[45]

Figure 3.3 Dutch gas roundabout



Source: EBN 2009

The foundation for the roundabout has already been laid in previous years in terms of interconnection, local infrastructure, storage capacity and spot market development. However, large investments have to be made to make an additional step to a more sizeable operation. As is the case for many projects in the energy sector, the pace and success are influenced by a combination of regulatory and market factors.

The gas market structure

The development of the Dutch gas market is an important factor to consider in the analysis of the role of gas in the energy transition in relation to electricity production. Structural elements

[45] Datamonitor (2008), Gas Market Profile: Netherlands, p.18

such as flexibility, liquidity and interconnection with other markets partly determine the attractiveness of gas as a transition fuel, especially if sourcing requirements are increasingly focused on short term availability. For many years, the European Commission has attempted to reduce the dominance of large, incumbent, vertically integrated energy companies and ensure a subsequent break-up of concentration of market power by enforcing third party access, and unbundling of production and transportation assets.[46] This did not prevent the formation of mega-utilities such as E.ON and GDF-Suez that have established significant market power in different liberalized markets. In June 2009, the EU Council of Ministers adopted the third package of legislative measures concerning the internal energy market that was intended to provide the framework to realize this.[47]

In Continental Europe, the Netherlands has been a frontrunner in unbundling energy companies. Already in 2005, the incumbent monopolistic gas company, Gasunie, was separated into transportation and trade&supply companies. The trade and supply company, GasTerra, dominates the gas market although its market share has decreased from 100% to 60% in 2008 due to improved interconnection, entry of new suppliers and increased market liquidity.[48] Gas is traded at the Title Transfer Facility (TTF), a notional location for spot trading where gas can be transferred between shippers. The traded volume more than doubled from 29.7 Bcm in 2007 to 65.4 Bcm in 2008. Furthermore, interconnection with Belgium and the UK allows for sourcing at the Zeebrugge and National Balancing Point (NBP) trading hubs.[49]Finally, the presence of two types of gas quality in the Netherlands, high and low calorific gas, is no longer a market impediment.

As of 1 July 2009, at the front-end of the market, companies only have to deal with one type of gas quality and are no longer obliged to book gas quality conversion capacity.[50]

Gas Demand

Domestic gas consumption has been stable in the past 10 years, showing a small gradual decline since 2004, but an increase of 4% again in 2008 compared to the 43.5 Bcm in 2007 because of lower temperatures.[51] The position of gas has been anchored in the Dutch energy system since the early 1960s. This is reflected in the fact that many industries, office buildings and households rely on gas as primary energy source for heat and power generation. Moreover, gas has been one of the engines for economic development in the Netherlands. In 2007, industry accounted for 25% of total gas demand, of which 75% was used for generating heat and power, and 25% as raw material.[52] Households consumed 21% and power stations used almost 9 Bcm, which corresponded with 20% of total demand in 2007.[53] The latter does not include decentralized generation by industrial CHPs. Furthermore, the share of gas in power generation is around 60%. These figures illustrate the strong relationship between the gas and electricity sectors in the Netherlands.

[46] www.euractiv.com, EU unveils plan to dismantle big energy firms, 20/09/2007
[47] http://www.consilium.europa.eu/Newsroom, 25 June 2009
[48] Dutch Parliament, Letter from Minister of Economic Affairs, *Security of energy supply,* 19/01/2009
[49] Connection with the UK through the Balgzand Bacton Line (BBL)
[50] Dutch Competition Authority, the Energy Chamber, *decision implementation quality conversion gas,* 22 June 2009.
[51] CBS, Natural Gas Balance, February 2009
[52] CBS, 2008, Statline
[53] Energiened, *energy in the Netherlands,* August 2008, p. 47

In the light of intensifying efforts by the government to stimulate energy saving in, for example, the built environment through decentralized heat and cold technology, improved insulation and more efficient condensing boilers, it is anticipated that residential gas demand will gradually decrease. However, this could be partly offset by an increase of demand in the power sector.

A less highlighted segment for gas demand is the transportation sector. The role of gas as transportation fuel is still limited, especially as we only focus on natural gas and exclude LPG. Recently, initiatives have been set up to expand its role. For example, city buses have been equipped with natural gas engines. As part of the energy transition program, a platform called sustainable mobility is promoting the establishment of a nationwide network of natural gas stations. Although it is cleaner and more efficient than gasoline, the role of gas in this sector is expected to be very modest. The gain in terms of CO2 reduction and efficiency improvement compared to the conventional fuels is not big enough to significantly offset the investment in infrastructure (e.g. equipment filling stations).[54]

Gas-fired generation

The leading technology in gas-fired power generation is the Combined Cycle Gas Turbine (CCGT). Plants with this technology are equipped with a gas and steam turbine. The latter is generated by the steam that is produced by the gas turbine. This contributes to a higher level of efficiency. Today, new build plants can run with an efficiency of nearly 60%.[55] Consequently, they contribute to a significant energy saving if they replace older less efficient power stations. Moreover, they emit approximately 50% less CO2 than coal plants.[56]

Gas-fired plants mainly run during peak hours[57] and have the highest level of flexibility as they can be relatively easily switched on and off, depending on the demand profile. Only hydro installations hold a similar level of flexibility, but as the Netherlands does not have this technology in its generation mix, gas-fired generation has a unique and pivotal position in electricity supply. In addition to this flexibility, CCGT plants can be built relatively quickly at reasonable cost. The average construction time is two years and the investments ranges between 50-60 €/MWh.[58] Operating costs are also relatively low, €19-26/kW[59], but short term marginal costs are high because of the gas price, which is still significantly higher than for example coal and nuclear fuel.

Linkage between power generation and gas markets

We have seen that because of the significant share of gas-fired generation in total electricity production, there is a strong relationship between gas and electricity markets. This interrelatedness manifests itself (among other factors) in the price setting role of gas-fired plants in the electricity market during peak hours. Hence, the gas price is an important driver behind the profitability of large utility companies. Against this background, integration of gas and power assets is attractive for energy companies to optimize value and mitigate market risks.

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[54] CE Delft, *Gas4sure, Natural gas as transition fuel,* Delft, April 2008, p.62
[55] See table 5.2
[56] See table 5.1
[57] Peak is between 7 am and 11 pm during working days
[58] European Commission, Second Strategic Energy Review, *Energy Sources, Production Costs and Performance of Technologies for Power Generation, Heating and Transport,* Brussels, November 2008, p. 4
[59] Ibid., p.15

Vice versa, developments in the electricity sector influence the gas market. If for example the wind ambitions of the government materialize, the demand for flexible electricity production, to reflect fluctuating electricity demand, which today is mainly provided by gas-fired plants, will further increase to capture the fluctuations in supply. Consequently, demand for flexibility in the gas market will also increase. Subsequently, the economic attractiveness for this type of gas delivery (i.e. gas storage) will strongly increase.

However, it is not a given that supply will directly follow this demand through improved access to liquid markets and construction of assets such as storage facilities and infrastructure. It very much depends on the market structure in terms of liquidity, regulatory framework, transport capacity and number of market players.

The development towards a fully competitive market is currently hampered by the fact that parties other than the dominant player have limited access to import capacity and seasonal flexibility. Furthermore, there is no market mechanism that allows other players to meet their balancing obligations in a cost efficient way.[60] Investment in import capacity and better third party access are measures that could contribute to a better functioning of the market. In addition, increased availability of storage capacity will create a real market for flexibility services, seasonal and daily, which aligns with the expected increase of demand for flexible gas-based power generation.

4. Scenarios of low-carbon generation capacity

As mentioned in the introduction, the core of this paper consists of three scenarios that present a view on developments in the Dutch energy sector in the context of the political ambitions to significantly reduce CO2 emissions. The main objective of this exercise is to gain more insight into the different roles natural gas could play in this so called transition to a low-carbon economy. More specifically, this role is assessed in relation to the development of new generation capacity because the electricity sector is selected as a key reduction target by the government towards 2020. Political decisions and subsequent investments in the coming 10 years will largely shape the configuration of the Dutch generation mix towards 2050 and therefore also (partly) determine the long term position of natural gas. Moreover, the next 2-3 years will already be critical, as the lead times of many types of generation are considerable and the 2020 targets are closing in.

The scenarios are not built on “global visions” like those of Shell or the IPCC, but basically provide storylines for the dominance of a specific low-carbon technology in the context of the ambitious climate objectives.

They do not contain an in-depth quantitative analysis of different drivers, such as fuel and CO2 prices, but start from current political realities such as the EU and national regulation and plans (e.g. the EU green paper, the Dutch government’s energy white paper), existing technologies and technologies that hold a large probability of being deployed in the coming

[60] Dutch Competition Authority (NMA), Monitor energy markets, *Analysis developments in the Dutch gas and electricity wholesale market*, September 2008, p.5

years and assumptions from the European Commission about fuel and CO2 prices and costs.[61] Furthermore, the timeframe that is used reaches to 2020 for the first scenario and to 2025 for the latter two. The initial idea was to limit the scope to 2020, the year that very concrete reduction targets have to be met by Member States, but given the considerable timeline of building a nuclear plant and the status of CCS technology, it would not be realistic to apply the same timeframe to all three scenarios. The three scenarios are:

1) Large scale wind breakthrough: realizing 10 GW of wind capacity by 2020;
2) Nuclear renaissance: a significant expansion of nuclear capacity after 2020 to replace old base load plants and meet increasing demand;
3) Coal with CCS: coal fired plants with CCS dominating base load production after 2020.

Table 4.1 below presents an overview of the capacity configuration in the three scenarios. The capacity build-ups are indicative and based on different reports about capacity development in the Netherlands.[62] They aim to reflect the impact of the choice for dominance of a specific generation type on the overall generation park and, more specifically, on the position of gas in this respect. Furthermore, the table contains some basic assumptions that are applicable in every storyline in order to create internal consistency. First, the 30% CO2 reduction target, set by the current government, is the starting point of the scenarios. For the latter two this implies that the timeline has been adjusted towards 2025 against the background of failing policies and delay in technology development. Secondly, despite the increasing market for energy saving products and decentralized heat and power generation, demand will still increase by 1-1.5% every year. The economic crisis has caused a dip in electricity demand, but demand will pick up to the pre-crisis growth level as the economy recovers.

To meet this increase, additional capacity is required assuming that the Netherlands does not want increase its dependency on imported electricity. In previous years, imports ranged between 17-20%.[63] On the other hand, demand for gas in the built environment is expected to decline as a result of energy saving initiatives, regulations and the increased usage of small scale renewable power and heat generation, such as solar panels, solar thermal heating boilers and heat pumps.

Finally, with respect to renewable development and reducing the carbon footprint of fossil fuel-based generation, wind is the main renewable source and coal with CCS is only available for large scale operation after 2020. The assumption about CCS is based on statements and technology updates in different reports, which share the opinion that due to legal, financial, technological and public awareness constraints, CCS plants are not commercially viable before 2020.[64]

[61] European Commission, Second Strategic Energy Review, *Europe's current and future energy position Demand-resources-investments*, Brussels, 13 November 2008, p.59-61.
[62] The generation mix for the different scenarios is partly based on EURPROG 2007, Studies by ECN: 'Future electricity prices (2008)', 'Influence of innovative technology on future electricity infrastructure(2007)',' Assessment construction plans electricity plants in relation to WLO SE and GE-scenarios: a quick scan (2007)" ; Energy Council, 'Fuel mix in motion (2008)'; EC Delft, 'Transition strategy Electricity and Heat (2008)'.
[63] Energiened (2008), p.7
[64] See footnote 26 on page 8.

Table 4.1 Installed capacity per scenario

	Wind scenario (2020)	Nuclear scenario (2025)	Coal with CCS scenario (2025)
Demand	133-143 TWh	140-154 TWh	140-154 TWh
Peak load (MW)	24 GW	26 GW	26 GW
Installed Capacity (MW)			
Gas (CCGT)	9-11 GW	7-9 GW	7-9 GW
Coal	4 GW (no CCS)	3 GW (incl. CCS)	6-7 GW (incl. CCS)
Nuclear	0.5 GW	4 GW	0.5 GW
Decentralized[1]	10-12 GW	10-12 GW	10-12 GW
Wind	10 GW	5 GW	5 GW
Other[2]	1 GW	1-2 GW	1-2 GW
Total[3]	34.5-38.5 GW	30-35 GW	29.5-35.5 GW
General assumptions			
▪ CO2 reduction	In all three scenarios the objective is 30% reduction		
▪ Carbon Capture and Storage	The application of this technology is focused on coal-fired plants as coal has the highest relative net carbon emissions to electricity production		
▪ Energy efficiency	The economic recession has caused a significant reduction, but electricity demand will return to the pre-crisis growth level of 1-1.5% per annum. Gas demand of households and office buildings will decrease due to energy saving measures and non-fossil heat generation		
▪ Import	Interconnection will improve, but import level of electricity will remain between 15-20% of total demand		
▪ Clean electricity	Wind is the dominant renewable energy source and large scale commercial application of Coal with CCS is feasible after 2020		

[1]The majority (~ 90%) of decentralized capacity is gas-fired
[2]Mainly Biomass and some solar PV
[3]The higher total capacity in the wind scenario despite the shorter timeframe is a bit distorting in the sense that the 10 GW wind capacity produces less than coal with CCS and nuclear plants due to lower load factors. They range between 20% (onshore) and 40% (offshore)

Scenario I Large scale wind and gas-fired generation

Background
The underlying starting point of this roadmap is that the ambitions of the Dutch government to realize 10GW wind capacity in 2020 (of which 4,5GW is to be realized by 2012 will actually materialize. This scenario builds on the political and economic commitment of the government to wind as *the* renewable source that must bring the Netherlands towards compliance with its 2020 targets.

Going down the wind road
The prominent role for wind energy in this scenario follows from the lack of the development of viable renewable alternatives that can be applied on a large scale. Large scale co-firing of

biomass in coal gasification plants or construction of stand-alone biomass plants is obstructed by the continuing discussion about the availability and sustainability of different types of biomass such as pellets, palm oil and corn. Another often mentioned renewable source is solar PV.

Although it is widely recognized as a promising alternative form of generation and some countries such as Spain and Germany actually show significant progress in terms of installed capacity, its role will be limited in the Netherlands in the period until 2020. The absence of a consistent subsidy scheme that stimulates investments and the enormous financial pressure on the government budget to realize the wind ambitions, hamper a breakthrough.[65] Next to the development of renewable sources, another CO2 reducing technology, carbon capture and storage, will not be available for large scale power generation before 2020 due to technological, economic and regulatory barriers.

Against this background, the government agrees on providing the right conditions for the realization of 10GW wind capacity. Existing hurdles such as lengthy permitting procedures and inconsistent support schemes are removed. Other issues around large scale wind such as intermittency and subsequent demand for flexible capacity are mitigated through public-private partnerships and market incentives (e.g. increasing the value of flexible production). Furthermore, the competitiveness of wind power improves because of lower costs, higher fuel prices and introduction of the third phase of ETS, which leads to a gradual increase of CO2 prices towards 2020. Finally, to stimulate development, new legislation requires grid priority for wind power over other large scale production sources.

Going down the wind road has significant implications for the development of Dutch power generation capacity and the position of natural gas. On top of current imbalance drivers such as deviations between estimated and actual demand and unpredicted production outages, the need for flexible capacity increases due to the intermittent character of wind and subsequent fluctuations in wind power supply. The main driver of imbalance is the forecast error in wind speed predictions. It gives rise to very short notice (15-60 minutes ahead) for flexible production capacity, especially during peak hours. Under-estimation errors can lead to over-commitment of import and generation assets. Over-estimation will result in more expensive imports in pre-dispatch, or scheduling of more expensive real-time generation. Consequently, wind energy must be supported by flexible capacity that can easily, from a technical and economic point of view, be switched on and off in order to maintain balance in the electricity grid. The ambition to install 10GW wind capacity in 2020 requires a significant addition of operational reserve and regulating capacity to accommodate the fluctuations. Gas-fired generation offers the technical and economic flexibility to regulate these very short term variations.

In addition to these flexibility requirements, wind turbines have a low capacity factor[66]compared to conventional production assets. This factor differs between on- and offshore wind, but ranges between 20-40%.[67] 10GW of wind capacity will produce between 18-35 TWh in a year, which is between 13-24% of expected demand in 2020. On the other

[65] The cost price ranges between €c 20-40/kWh. EPIA, *Grid parity- definitions and scenarios,* September 2008.
[66] The amount of energy delivered during a year divided by the amount of energy that would have been generated if the generator were running at maximum power output throughout all the 8,760 hours of a year
[67] The guideline for the capacity factor in the Netherlands is 20% for onshore and 40% for offshore. Source: ECN, Factsheets Energy Technologies.www.ecn.nl/ps/onderzoeksprogramma/transitietechnologieen.

hand, 10GW is around 30% of the estimated total installed capacity. Consequently, additional capacity, especially base load, is required to compensate for this discrepancy.

In addition, the phase-out of old plants[68] forms another driver for investment in base load capacity.
This scenario assumes that a part of this investment will be met by gas-fired generation. Due to the growing pressure to reduce CO2 and intensifying opposition to new conventional coal plants, gas is considered as the most technically and economically viable alternative. Furthermore, gas will continue to be the main source for peak power production towards 2020.

The application of CCS technology is focused on coal-fired plants as they account for the largest emissions relative to energy output.

CCS can also be installed on gas-fired plants, but the costs per tonne of CO2 avoided is significantly higher compared to coal. The fuel costs that correspond with the energy loss of capturing CO2 form the main driver for this. In addition, gas already has a much lower CO2 footprint. Although not yet required by law, it will become very difficult to build new coal-fired generation capacity without CCS in the Netherlands. This scenario assumes that gas-fired generation can be built without this restriction towards 2020. Coal with CCS projects will have to compete with highly efficient CCGT's that are less capital intensive.

The prominent role of gas towards 2020 not only manifests itself in power generation, but also in the industrial segment. In comparison with other countries, the proportion of installed decentralized CHP capacity in the Netherlands is very high. The further penetration of CHP units in the industrial sector is an important pillar in the government's energy efficiency program.

In addition to the increasing demand for flexible generation, which will be primarily met by gas, another implication of large scale wind generation is the subsequent increasing volatility in gas demand. More wind capacity increases the need for daily balancing gas storage services, especially peak storage. The Netherlands is geologically well positioned in this respect considering the presence of depleted gas fields and salt caverns. The economic value of these facilities improves as the need for flexibility in the electricity market increases. Consequently, new peak storage capacity is built towards 2020, which also enhances the role of the Netherlands as a roundabout in an increasingly interconnected Northwest European gas market.

Summarising these developments and considering the lack of alternatives for flexible peak production and relatively clean base load electricity towards 2020, the role of gas in the power sector will become even more important in the coming 10 years.

Scenario II 'Nuclear Renaissance'

Background
Against the background of new alarming climate reports by the IPCC and other institutions, approaching EU targets and possible penalties for non-compliance with the CO2 reduction

[68] See chapter two.

targets, the government decides to pave the way for nuclear power as a low carbon base load provider. New capacity is built to achieve a significant reduction in the carbon footprint of base load capacity in the Netherlands.

Considering the timeline of more than 10 years to build a nuclear plant and the fact that a government decision cannot be taken before 2012 at the earliest, this scenario needs to be extended to 2025. Large scale commercialisation of coal with CCS will also only take place on a limited scale within this timeframe.

Nuclear power wins the battle for base load
This scenario builds on the assumption that the political and societal barriers for building new nuclear capacity in the Netherlands are removed. First of all, the sense of urgency for altering the energy system and dramatically reducing CO2 emissions gets stronger as the effect of climate change becomes more evident. Therefore, the EU sets a new, firmer target: by 2025, a reduction of 30% has to be achieved compared to the 1990 level. Furthermore, non-compliance will have serious financial implications such as penalties and large scale purchasing of CO2 certificates.

Secondly, financial, technological and regulatory hurdles obstruct a real breakthrough of wind energy. A relatively high cost-based price, grid balancing issues because of the intermittency of wind power and lengthy permit procedures are main examples of these hurdles.

Thirdly, other renewable sources such as solar PV and biomass do not really take off for the above-mentioned reasons.

Against this background, the Dutch government decides to adjust its wind ambitions downward and to make way for nuclear energy. The main arguments in favour of nuclear are concentrated around limiting emissions (see chapter 2), fuel diversification and the relatively low variable production costs which have a positive effect on electricity prices. In addition, the Netherlands is geographically well positioned for base load capacity such as (coal and) nuclear. The large coastal area and logistic facilities provide a good condition for the supply of fuels and the availability of sufficient cooling water.

Politicians, scientists, leading advisory and research bodies and other opinion makers, provide increasing support for the decision to concentrate on nuclear energy as a technical and economically feasible option for significantly bringing down CO2 emissions. Subsequently, all necessary legislation is prepared for creating the right conditions and investment climate for starting legal procedures, the design and construction of new capacity. A decision is taken by the new cabinet in 2012 to construct 3-4GW of nuclear capacity that is expected to be operational in 2023. The current 450MW plant in Borssele, which will be phased out in 2033, is to be replaced by another large unit. Consequently, by 2023, the installed nuclear capacity is around 4GW and before 2050 this will expand towards almost 5GW.

Following this scenario, nuclear obtains a prominent position in base load production and does not have to compete with coal with CCS. Although two demonstration plants are build in the period 2015-20, the introduction of large scale coal with CCS is hampered by high investment costs, uncertainty about the regulatory framework and future CO2 prices.

The technical and financial uncertainties around CCS are also part of the rationale which removes the obstacles for the two nuclear plants. Because the nuclear plants partly replace decommissioned coal-fired generation, they make a substantial contribution to CO_2 reduction.

The economic and regulatory obstacles to large scale wind energy($\geq$ 10GW) are considered to outweigh not only the benefits of wind energy, but also the disadvantages of nuclear generation, such as storage of nuclear waste. This does not imply that wind is completely marginalized. Despite the impediments, wind capacity will be expanded towards 2020 and beyond to comply with revised EU renewable targets and maintain an investment climate and knowledge base for future development. This scenario assumes that 4 GW (3GW onshore/1GW offshore) is realized in 2020 and 5GW (3GW onshore/2GW offshore) in 2025.

Compared with the wind scenario, the energy transition role of gas in the power sector is less significant in the nuclear scenario due to the moderate expansion of wind capacity and subsequent lower demand for flexibility. However, its role as transitional fuel is definitely not marginalized as a result of the construction of substantial nuclear capacity.

First, some additional gas-fired generation is required to facilitate the wind energy increase. 5GW of installed wind power capacity requires additional flexible capacity.

Secondly, nuclear is for base load generation. Consequently, peak demand, which is estimated to increase, still has to be met. The main peak power provider up to 2025, and probably beyond, continues to be gas. Improved interconnection with peak supplying countries such as Norway, which holds a lot of flexible hydro capacity, and/or the creation of large scale energy storage in the Netherlands could partly take over this function. However, dry seasons, wind development in Germany and high investment costs, attach a lot of uncertainties to these alternatives.

Thirdly, additional gas capacity is required to replace a proportion of the decommissioned base load plants until new capacity is built, assuming that the majority of conventional coal projects are cancelled towards 2025[69]and the share of electricity imports is maintained at 15-20%.

Finally, gas will continue to play an important role in the industrial sector because of an increased use of CHPs to improve energy efficiency. It is widely accepted that natural gas is the transition fuel for this sector until alternative gases or other sustainable technologies can replace natural gas as fuel for de-centralised, efficient and flexible generation of heat and electricity. This will also depend on the development of the industry in the Netherlands in general. A continued shift of large industries to lower-cost countries will change the heat and power demand profile and subsequently the need for gas.

Scenario 3 Coal with CCS dominates base load

Background
The third scenario is built on the assumption that coal-fired generation in combination with Carbon Capture and Storage (CCS) will dominate base load by 2025. This technology was not

[69] The original plans contain a 5000MW new-built of coal plants before 2015. Energy Council, *Fuel Mix in motion:looking for the right balance,* Jan. 2008, p.51. This scenario assumes that only the EON plant will be realized, which is 1080MW.

available on a large scale before 2020, but its development has been strongly promoted at EU and national level through large subsidies and creating the legal framework for implementation. Two large demonstration projects, including infrastructure and storage facilities, are started and successfully developed between 2010 and 2020.
The strong commitment to CCS follows from the decision of the European Council to achieve a 30% CO2 reduction by 2025 and the decision to exclude further expansion of nuclear capacity in the Netherlands.

Coal with CCS wins battle for base load
The fundamentals of the coal with CCS scenario are a favourable coal price, a broad geographical spread of resources, and the implementation of the third stage of the European Emission Trading System (EU ETS). This is expected to have an upward effect on CO2 prices as scarcity of CO2 certificates increases due to the shift to auctioning instead of free allocation of permits.[70] Furthermore, the Netherlands is well positioned for CCS considering the presence of gas infrastructure and CO2 storage facilities in the form of depleted gas and oil fields. These fields offer good opportunities for large scale CO2 storage. Furthermore, the possibility to build power plants in coastal areas provides logistical and operational advantages in terms of coal supply and the availability of cooling water. The Netherlands becomes front runner in CCS technology in Europe and has the ambition to become the “CO2 roundabout” of Northwest Europe as an extension of the gas roundabout concept (discussed above). As a result, 4-5GW of coal-fired capacity is built before 2025.

As in the nuclear scenario, the decision in favour of coal partly undermines the position of wind as competitor for base load. Only a substantial increase of export potential could ‘save’ the business case for 10 GW of wind, which forms the basis of the first scenario. The government acknowledges this conflict and decides to limit the expansion of wind energy to 5GW in 2025.

As in the nuclear scenario, the role of gas will remain strong in power generation. First of all, a capacity bridge has to be built between 2010 and 2025 to accommodate the decommissioning of old coal plants and an increase in electricity demand. The preferred technology for this is gas-fired generation (CCGT) because it can be built in a relatively short timeframe (18 months) and there are no real alternatives for realising large scale new capacity that are economically viable without subsidies.

Secondly, gas will remain the fuel for peak production as discussed in the previous scenario.

Regarding the role of gas as flexibility provider, after 2020 base load power generation is dominated by coal with CCS which consequently limits the extension of wind capacity. Consequently, less flexibility is required in the overall generation park to maintain balance in the system.

Finally, a constant factor in all three scenarios is the position of gas as a source for decentralized generation, which is enhanced towards 2025 in the light of energy efficiency improvements.

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[70] Estimates of the future carbon price varies between €30-€70. Clingendael International Energy Programme, *Carbon Capture and Storage: A reality check for the Netherlands*, September 2008, p.23

Also in this scenario, the position of gas continues to be very strong. Only events such as increasing uncertainty about Russian gas due to economic and/or political issues, which leads to long term disruptions of gas supply, could hamper investment in gas capacity given the depletion of national resources. This could significantly alter the importance of gas in power production towards 2025. However, this is not in line with current expectations. Moreover, energy saving measures in the built environment and industry, and the increase of decentralized renewable technologies, can reduce the power peak load and reduce gas demand.

5. Assessment of the scenarios

Three capacity scenarios in energy transition

As mentioned in the previous chapter, the three scenarios have been drafted to provide illustrations of the possible different roles of gas in the energy transition. More specifically, they deal with the transition in the electricity sector and corresponding choices regarding the future design of the generation mix, as this sector has been selected by the government as the main target sector for achieving its CO2 reduction ambitions. The actual penetration of each generation type is subject to many uncertainties such as shifting regulations, technological issues and financial risks. These uncertainties can give rise to potential conflicts between governmental institutions and market players.

Legislative efforts on EU and national levels form an important market driver. The legislation around CO2 reduction and subsequent policies and support mechanisms is a major example, and has a large impact on strategic priority setting and underlying investments by energy companies.

In this complex framework of political and economic interests, regulatory measures and technological developments, the transition towards a sustainable power generation mix has to take shape.

If we look at the three scenarios, the realization of large scale wind, in combination with additional gas-fired capacity, seems to be the most concrete and probable as it is already an integral part of government policy for meeting its 2020 targets. Installed wind capacity has gradually increased to more than 2GW in 2008. Wind has gained a prominent position in the renewable portfolio of leading energy companies and is considered as the most viable source for contributing to the target of producing 20% of electricity from renewable sources. Very limited emissions[71] and zero marginal costs make wind an attractive energy source in terms of affordability and sustainability.

Furthermore, technological progress has resulted in a higher turbine capacity and enhanced availability. Consequently, volumes produced from wind generation are increasing, and this is beneficial for its economic value. However, the technical and financial impacts on the electricity system[72] are impediments that hamper further large scale development. First of all, fluctuations in supply put an extra burden on balancing the grid. Short-term forecasting of

[71] The direct emission of wind is zero, but from a chain perspective, including construction and installation of turbines, there is limited emission. See table 5.1.

[72] Additional flexible capacity will be required to capture the intermittence of wind. In addition, conventional base load units will run for shorter periods, which has financial implications for energy companies and a possible upward effect on the market price. This will be further discussed in next section.

wind power is prone to errors depending on factors such as prediction horizon, complexity of the site and the level of predicted wind speeds.[73] The Technical University of Delft has calculated a forecast error of 25% day ahead for 8 GW installed capacity.[74] One hour before actual production the error is 10-12%. Consequently, an increase of wind capacity to 10GW would have to be supported by an additional 1-1.2 GW of flexible capacity.

In the current technological context and considering the absence of the main alternative flexibility source, hydro power, gas-fired generation is the technology selected to accommodate this increase. Secondly, new generation capacity that is built to regulate the fluctuations and/or to meet increasing demand will probably be less utilized if significantly more wind power is installed. This potential production and value loss has to be mitigated somehow to attract investors.
It could lead to higher electricity prices or, alternatively, wind turbines will be shut down, which is technically possible in the short term, and the value of wind will be destroyed.

In addition, the relatively high cost of (especially) offshore wind generation forms another hurdle. Further cost reduction, performance improvement and an increase of green value (i.e. significant revenue for CO2 abatement) will improve the competitiveness of wind.

However, the outlook of significant burdens on the government's budget for financing the difference between the average production costs and revenues of wind projects in order to stimulate investments, restrains the government from implementing a subsidy scheme that would provide the required economics for investors to build the envisaged 10GW. Nevertheless, the coming years will be crucial in the sense that a specific regulatory and financial framework somehow has to be created to ensure that 6GW of offshore wind is built by 2020.

These hurdles, in combination with an increasing sense of urgency to reduce CO2 emissions, could create the political and public support for the nuclear scenario. This path probably has the lowest probability as nuclear power is still a controversial topic in Dutch politics and society. The technology is proven and continuously improves, but the structural uncertainty within society about the safety of this type of generation, which is probably still partly linked to the Chernobyl accident in 1986, forms a large obstacle for politicians. Nevertheless, it could become an alternative way of reducing the current carbon footprint of base load generation in the Netherlands. It is a proven and continuously developing technology with limited emissions and low marginal costs.

Increasing environmental necessity and high fossil fuel prices can alter the sentiments in favour of nuclear. The establishment of an EU nuclear policy could further contribute to this by providing a common framework for safety and storage of waste. Developments in Finland, France and UK, which are partly the result of national energy policies, might also spur other member states to reconsider their nuclear policy.[75] In fact, national approaches cannot be

[73] Giebel, G., Sørensen, P., Holttinen, H., Trade wind, forecast error of aggregated wind power, Risø National Laboratory, April 2007, p.19
[74] Ummels, B.C., Hendriks, R.L., Kling, W.L., *Integration of large scale wind capacity offshore in the Dutch Electricity System*, Technical University of Delft, February 2007, p.16
[75] In Finland, a fifth 1600 MW plant was approved by the government in 2002. This is now under construction for 2012 start-up. In France, The construction of a new III generation 1600 MW nuclear plant started in 2007. The UK government has committed itself to a future of nuclear power. The acquisition of British Energy by EdF could be perceived as part of this policy. Source: www.world-nuclear.org, *Country briefings*.

viewed in isolation from general EU interests. Any serious accident will also affect neighbouring countries and an overall increase of nuclear capacity could improve the EU energy supply and security outlook. However, here we touch upon a recurring and fundamental issue - policy-making at EU level in areas that are also pivotal for national interests. Energy policy is one of them.

The main sensitivities around the application of nuclear power concern the issues of waste management and storage, allocation of risks and responsibilities between public and private parties, safety in relation to the possible destructive consequences of an accident and financial risks due to long lead times and high investments costs. A lead time which ranges between 10-13 years[76], makes the nuclear roadmap not a realistic option within the 2020 timeframe. A possible decision in favour of nuclear will probably be the result of a partial failure of the original renewables policy and reflect redefined CO2 objectives related to, for example, 2025.

Once in operation, a large nuclear plant would give a substantial impulse to CO2 reduction in a case where it replaces conventional coal-fired units. To illustrate, a 1,000MW plant with a load factor of 80% will lead to an annual reduction of 5.6 Mton CO2 if it replaces conventional coal.

Table 5.1 Emissions per technology

Technology	Emission (Lifecycle) kg CO2 (eq)/MWh
Wind	
Onshore	7-30
Offshore	9-22
Combined Cycle Gas Turbine	365-495
Combined Cycle Gas Turbine CCS	80-235
Pulverised Coal Combustion	800-860
Coal CCS	
Pulverised Coal Combustion	240-290
Integrated Gasification Combined Cycle	240-291
Nuclear	3-40

Source: European Commission, Second Strategic Energy Review (2008)

The issues around nuclear power are to some extent also applicable to CCS. Although it is not a proven large scale generation technology like nuclear, the estimated lead times for realizing a sizeable operation, including infrastructure and storage, are comparable since CCS is still in a testing phase on a small pilot scale.[77] The estimated investment costs for building a coal plant with a CO2 capture installation are substantial (see table 6.1). In addition, the costs for transportation and storage of CO2 have to be included to get the total cost overview of coal based generation with CCS. The viability very much depends on the development of CO2 prices (see table 6.2). Furthermore, the controversy around environmental consequences and

[76] The decision making and permitting process is estimated to be 5-7 years in the Netherlands. On top of this comes the construction time of 4.5-6 year. Source: ECN (2007), *Fact finding nuclear energy*, p.14,17

[77] McKinsey and Company estimated in their study on CCS that the lead time in a base case scenario ranges from 6-10 years, from deployment of a demo plant, which could be deployed between 2012-2015, to commercial a full-scale coal CCS plant. McKinsey and Company, *Carbon Capture & Storage: Assessing the Economics*, September 2008, p. 40

the safety (e.g. leakage) of storing large volumes CO2 in for example depleted gas fields could become a constraint to the realisation of large scale CCS deployment. However, this debate is not backed by any data, nor any practical experience with large scale storage and has still many uncertainties. Finally, as is the case for nuclear power, base load coal with CCS will not be operational on a commercial scale before 2020.

Aside from the similarities, there are also differences. First of all, the comparison with nuclear is not really fair in terms of safety, as the implications of an accident at a nuclear power plant are of an extraordinary level. Secondly, coal with CCS is more or less generally accepted by government and utilities as a possible transitional solution in power generation and has more positive associations in terms of technological progress. Nuclear on the other hand, is an incumbent technology that is more negatively explained as an option if other options fail or move forward too slowly.

Finally, one could argue that nuclear power is a proven technology that can be built today in a commercially viable way, depending also on the characteristics of a specific national energy market, while coal with CCS is heavily dependent on subsidies to reach the point of becoming an alternative for large scale power generation. However, in the case of nuclear power it should not be overlooked that although government may not subsidize the construction, they do provide guarantees that cover a part of the financial risk in case of an incident. In the Netherlands for example, the operator of a nuclear facility has a liability up to €340 million. The government will provide additional financial resources to compensate for the damage up to an amount of €2.3 billion.[78] Furthermore, the Dutch government is responsible for storage of nuclear waste.
In the UK, the government has clearly stated that nuclear power will play a role in future electricity supply and the issue of guarantees to incentivise investors such as EDF and E.ON to actually embark on construction, is being debated.

Besides the impediments, there are also arguments in favour of building coal with CCS in the Netherlands. First of all, the country is well-positioned to pursue this path. The (almost) depleted small gas fields offer sufficient CO2 storage opportunities for a considerable period of time.

Furthermore, coal reserves are, in contrast to gas, well spread across the globe in countries such as Australia, Indonesia and South Africa that participate in global trade and export large quantities to for example Europe.[79] This contributes to the security of coal supply and therefore also electricity supply. In addition, this security is also enhanced through a diversified fuel mix, including a significant coal share.

Finally, coal is well rooted in the Dutch energy system, which is reflected in its current share of 23% in the fuel mix and the intention of the government to maintain its role, but with a cleaner profile. If the choice is between nuclear and coal with CCS it is therefore more likely that the latter will be the preferred option as base load power producer.

Either way, the configuration of Dutch base load installed capacity will change in the long run. Although the three scenarios are only to some extent mutually exclusive, decisions in the

[78] Scheepers et al, Fact Finding Nuclear Energy, October 2007, p. 91
[79] The global market for Bulk Commodities – 2007, *Top 5 exporters of coking and thermal coal*. Source: ABARE; AME Mineral Economics; International Energy Agency.

coming 1-3 years, in favour of one, will impact the outlook for the others. Such decisions will also affect the role of gas in power generation. The dynamics in base load development will be discussed in the next section.

The battle for base load

Large scale development of low-carbon generation not only forms the basis for the scenarios, to show variations in the role of gas in energy transition, but also exposes a fundamental issue in the future development of generation capacity in the Netherlands. A decision in favour of one of the three technologies in our scenarios, not only affects the position of gas, but also has implications for the role of the other technologies. The so called lock-in effect is a concept that is used to make these implications more explicit. Arthur (1989) describes it as a situation where increasing returns to the adoption of one technology results in market dominance at expense of the other and therefore prevents the take up of potentially superior alternatives.[80] This lock-in theory can also be applied to the development of base load electricity generation technology.

Today, indigenous base load is dominated in the Netherlands by coal plants and 'must-run' decentralized installations that mainly use gas. Already with the current 2GW of installed wind capacity, minimal load problems can arise during off peak, high wind periods. Due to the limited flexibility of incumbent installations, production cannot always be scaled down to allow for the full intake of wind power by the grid at a specific hour.[81] As indicated earlier, this is caused by the fact that a large part of the generation capacity consists of decentralized units that are heat demand driven. In addition, coal-fired plants will not be shut down for a short period of time, for economic and technical reasons. The business case for these plants rests on maximisation of load hours to earn back the high investment costs. Furthermore, the shut down and start up time is relatively long. Consequently, wind turbines are occasionally shut down and clean energy and value is wasted. This indicates the potential conflicts in low-carbon base load generation capacity towards 2020 and beyond.

First of all, the stimulation of CHPs and district heating, as described in the second chapter, will create more inflexibility, which is detrimental to the wind case.[82] This example illustrates conflicts in base load development and contradictions in government policy to, on the one hand increase renewable production, and on the other hand improve efficiency in the industry by promoting the use of CHPs.

Another conflict in the development of base load generation capacity in the Netherlands concerns the limited room for co-existence of wind energy and coal and/or nuclear capacity in the fuel mix. During peak hours, there are no big hurdles to doubling wind capacity as a large proportion of electricity is generated by gas-fired units, which are able to balance the variations in wind power supply. The step from 5GW to 10GW wind capacity will require expansion of flexible gas-fired generation. However, this is only one side of the coin, which mainly refers to peak production. The other side is that wind competes with base load plants during off peak hours. If new coal with CCS or nuclear capacity is built to reduce CO2 emissions and maintain a diversified fuel mix, a potential conflict can arise because these

[80] Foxon, T.J., *Technological lock-in and the role of innovation,* Chapter 22 in 'Handbook of Sustainable Development', Cheltenham, UK, 2006.

[81] Ummels, B.C., Gibescu, M., Pelgrum, E., Kling, W.L., *System Integration of large scale Wind Power in the Netherlands,* October 2006, p.5

[82] This means an increase of gas-fired or other large CHP units with heat supply obligations that cannot be easily scaled up and down

plants are only economically viable with high load factors. To some extent, they will replace old decommissioned plants, but looking at the project pipeline for base load generation, it is reasonable to assume that the net total installed base load capacity will increase to meet increasing electricity demand.[83] Moreover, there will a transition phase where both new capacity and a share of the old capacity will be operated.

Consequently, situations of excess electricity supply will occur more frequently in cases where the share of wind gradually increases. Ummels et al. (2007) estimate that the increase of coal-fired generation will lead to a further increase. From an economic and technical point of view, the most logical response is to shut down the wind turbines because they are more flexible to operate and have a lower capital burden. It is estimated that up to 4GW installed wind capacity, the amount of wasted energy is limited. However, the amount of wasted wind power is estimated at 11% with 8GW wind capacity.[84] This will further undermine the economic rationale for building large scale wind energy. In addition, the cost for subsidizing additional capacity would rise dramatically. Against this background, the political and subsequent investment decision in favour of significant new nuclear or coal with CCS capacity will potentially obstruct or at least slow down the penetration of wind in the Netherlands. In other words, it creates a lock-in effect at the cost of wind. A substantial increase of export opportunities through improved interconnection and market coupling for trading purposes, could enlarge the room for coexistence, but this also largely depends on political decision making and capacity developments in other member states.

Alternatively, the government could introduce legislation that prioritises the feed-in of wind on the grid to push the share of wind in the fuel mix. In this case, we will see a contrary situation. A gradual increase of wind generation will undermine the profitability of nuclear and coal plants because their running hours will decline, with an upward effect on the cost price as the capital component increases. This scenario will restrain energy companies from heavily investing in new base load capacity and a mirror lock-in effect is established. Commercially attractive export opportunities, and/or a premium in the electricity price for compensating the loss of load hours, could still create a viable business case for this policy.

The third potential lock-in scenario that builds on the previous discussion, concerns the choice between coal with CCS and nuclear. Although both technologies can be part of the national fuel mix up to a certain level, a decision by the government in favour of one, in terms of financial support and creating the right legal framework, will affect the development of the other. For example, if there is a green light for two 1600MW nuclear plants that are completed in 2023, the case for coal with CCS weakens as a significant part of the low-carbon base load capacity required to meet the climate objectives and increasing demand is covered, in addition to the fact that nuclear stations will generate power at lower marginal cost. Considering the long timeline for building this capacity, the drive to accelerate CCS development is probably reduced. Again, this nuclear lock-in could be partly offset by attractive export opportunities, but this will depend on capacity and price development in respective export markets.

[83] A part of this base load pipeline, which today primarily consist of coal plants, will also include nuclear if we follow the nuclear roadmap.
[84] Ummels, B.C., Kling, W.L., Paap, G.C., *Optimization of the Generation Plant mix with the integration of large scale Wind Power*, May 2007, p.4

Vice versa, a clear choice for coal with CCS will probably block the way for nuclear to increase its footprint in the Dutch electricity sector beyond 2020.

Gas dominates peak generation

One of the main consistencies in all three scenarios is the unmistakable role of gas as *the* fuel for peak generation. The presence of a domestic gas sector with still significant indigenous reserves and the advantages of gas-fired generation, such as operational flexibility, which have been described in chapter 3, are the main reasons for the current dominant role of gas as a peak fuel. Given the underlying demand profile, then regardless of the base load discussion, the need for peak production will remain, and probably even increase, in the coming decades. So far, the Netherlands has no real alternative sources of flexible electricity production. From a technological point of view, coal and even nuclear power plants can also be ramped up and down relatively quickly and within a certain capacity range but, because of the high upfront investment, the commercial viability of these plants is based on maximum utilisation. Furthermore, gas generators are technically better equipped for daily starts and stops. The start-up time is much shorter compared to coal plants and ramping up and down of the capacity has less impact on the plant's lifetime.[85] The main alternative to the sources already mentioned, hydro power, is not an option. The viability of large scale energy storage is being investigated with technologies such as underground pumped storage or underground compressed air listed as possibilities. However, in addition to the high investment costs, there is much uncertainty about the economic value and technical necessity in terms of grid stability.

Expansion of interconnection capacity with Norway, which has large hydro installations, could be another flexibility provider.[86] However, this is subject to different uncertainties such as the wind capacity development in Germany and the subsequent need for flexible power.

Besides the lack of alternatives, there are other factors that make gas-fired generation a favourable option in the transition period towards a low-carbon energy system. First of all, Combined Cycle Gas Turbines (CCGT) are relatively easy to build at a competitive price compared to, for example, coal and nuclear plants. Today, a unit of 450MW takes approximately 3 years to build at an investment cost that ranges between € 480-730/kW.[87] Furthermore, compared with other fossil fuels, gas is a relatively clean energy source[88] and also contributes to the CO2 reduction targets in cases where new capacity replaces conventional coal-fired generation. Moreover, CCGT is an efficient generation technology because the additional steam turbine utilizes the residual heat to produce electricity.
Against this background, it would be fair to say that as long as access to gas resources is secure at commercially viable prices, gas-fired generation will be the main provider of peak electricity until at least 2025.

Only a structural change in the demand pattern through the implementation of drastic energy saving measures and penetration of small decentralized generation, which would lower and flatten the central generation demand curve, could decrease the dependency on gas-fired generation as peak supplier. Coal with CCS or nuclear plants with some level of flexibility

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[85] Dijkema, G., Lukszo, Z., Verkooijen, A., de Vries, L., Weijnen, M., *The regulating possibilities of power generation plants*, Technical University of Delft, 20 April 2009

[86] Today, there is a 700MW connection between the Netherlands and Norway, the Norned cable. Norway can supply power during peak hours and receive base load power during off peak from the Netherlands, for example during high wind periods.

[87] European Commission(2008), Second Strategic Energy Review, *Europe's current and future energy position*, p.53

[88] See table 5.1

could accommodate the less steep fluctuations. However, the increase of wind power discussed earlier still requires short term flexible back-up capacity. Gas-fired plants will increasingly operate at lower load factors. At times of high peak load, this will probably cause large spikes in spot electricity prices. The loss of value from running at these lower load factors will be compensated during periods when these stations are operating at maximum capacity for short periods at high prices.

The continuation of the role of gas as fuel for peak generation means an increasing emphasis on securing access to gas resources, especially because of the depletion of national reserves. Furthermore, if new gas-fired plants are built towards 2020 to meet increasing demand and/or the further penetration of wind power, this could lead to a lock-in of gas in the electricity sector beyond 2025. The average lifetime of a CCGT plant is 25 years[89], so construction between 2010 and 2020 will at least lock-in its role beyond 2030. The acquisition of gas-fired CHPs by large industries in the coming years will further enhance this effect.

Following this line of reasoning, the role of gas will be prominent in any of the energy transition scenarios. The actual increase of wind, changing demand patterns, and access to other flexible sources form the main factors that determine the degree of its prominence.

What if?

The three scenarios that have been presented in this paper assume that a significant capacity increase of the specific generation type will actually be realized. As indicated in previous chapters, the construction timelines, including permitting procedures, are considerable.

A nuclear plant for example takes more than 10 years to build and a large offshore wind park approximately 6-8 years, including permitting procedures. Large scale coal with CCS is not a proven technology yet, but the lead time will also be significant. In addition, extensive testing and modifications of new technologies hold the potential for significant delays. Against this background, political decisions in terms of creating the right regulatory framework and support schemes have to take shape in the coming years in order to meet the future power generation challenges.

Investment decisions in support of a low-carbon technology will be followed by a lengthy preparation process. Putting together all the necessary documentation, legal actions of opposing interest groups and negotiations with suppliers and construction companies, are key elements in this process. What are the implications of these long timeframes? One could argue that the longer this pre-construction phase, the more risk of a possible failure due to changing market and/or political conditions. At the same time, even without a single pile in the ground, the prospect of having a prominent position of a specific generation type in the medium term can hamper the development of others. This could be termed a “latent lock-in effect”. If large projects are actually implemented, the implications of integrating this new capacity in the electricity system need to be anticipated.

If for example advanced plans for the construction of new nuclear capacity are cancelled after a few years, it could lead to serious delay in the development of alternatives such as large scale offshore wind or coal with CCS as plans will have been postponed or scaled down in the light of the substantial new nuclear generation capacity. A large nuclear accident somewhere

[89] European Commission (2008), Second Strategic Energy review, *Europe’s current and future energy position*, p.41

in the world could be the circumstance for such a scenario where the public opinion and a majority of political parties turn against the nuclear option.

Secondly, if between 2010 and 2020 only a part of the wind plans materialize and the development of CCS to a commercially viable technology faces delays, the nuclear alternative can only be realized by the end the 2020s considering the long lead time. The background of such a scenario could be, as discussed earlier, the continuing non-competiveness of wind, which puts an enormous burden on the government's budget to subsidize all the projects. With respect to CCS, technological issues, strong opposition against CO2 (onshore) storage or low CO2 prices that undermine the economics, are circumstances that can give rise to delays. Consequently, the potential of other clean technologies is not fully utilized because of this "latent lock-in effect", and it will become even more challenging to meet the 2020 (and beyond) CO2 reduction targets. An increase of low-carbon electricity imports[90], purchasing CO2 certificates and additional funding of wind and CCS projects to accelerate development are possible measures to compensate for the back-log in CO2 reduction and catch up with building sufficient clean generation capacity. These measures will probably give rise to debates about financing and security of supply if imports further increase.

Government versus the market

The political dimension in the discussion on the development of clean generation capacity in the Netherlands is a constant in this paper. The often interwoven political and economic interests in the energy sector, which is characterized by the mutual dependency between policy makers and energy companies, makes the discussion about energy transition by definition complex and subject to many uncertainties. The scenarios developed in chapter 4, start from assumptions about political support for a specific generation technology.

Liberalisation caused a shift of activities and responsibilities from the public to the private sector. Most European utilities, some of which are still (partly) in state or municipal ownership by public shareholders, changed their business model to become commercially operated entities with value-creation objectives. Product and service portfolios are increasingly important and investments in production capacity are subject to value driven analyses.

On the European level we see, on the one hand, consolidation and increasing market integration and on the other hand a struggling European Commission that aims to establish a common electricity and gas market, an energy security policy and achieve the 20% CO2 reduction by 2020. In developing these policy areas, the Commission is confronted by national political and economic interests and an evolving private energy sector that follows commercial principles. The politicisation and commercialisation of energy are major constraints on the implementation of EU objectives.

Also on a national level, the government comes across different boundaries such as the interests of local stakeholders and conflicting company policies. On the other hand, energy companies are subject to changing government policies and regulations, which create investment uncertainty.

If we more specifically look at generation capacity development in the Netherlands in the context of energy transition, interdependencies between private and public parties can lead to

[90] For example, nuclear power from France or hydro from Norway.

fruitful cooperation agreements and shared financial burdens. Government support has proven to be a stimulus for investments. The development of the wind and solar market in Germany is a concrete example in this respect.

However, it can also result in a stalemate as both sides wait for the other to take the first step. The government appeals for socially and economically responsible behaviour; energy companies demand a more consistent policy to calculate returns on investments and gain certainty on the financial implications of implementation of 2020 objectives and measures such as the EU ETS.

This stalemate can lead to serious delays in building clean generation capacity and bringing the Netherlands towards a sustainable energy system. Moreover, meeting the CO2 reduction targets will become increasingly difficult.

A direction-setting plan by the government on the transitional design of electricity production and commitment from the private sector will be needed to prevent these potential deadlocks. Especially for projects with lengthy timelines such as coal with CCS and nuclear, political commitment is a prerequisite. The government depends on the private sector for realizing specific targets and successfully accomplish the energy transition at a national level.

Finally, the transitional design plan should also align with a consistent policy regarding the exploitation of indigenous gas resources. As stated earlier, at current production and export levels, the Netherlands will become a net importer within 20 years. Against this background, unfavourable import contracts and/or a dramatic deterioration of supply security, from for example Russia, could cause a gradual shift away from gas. However, following the discussion in this paper, the role of gas in the energy transition will remain as, or even more important than it is today. Hence, an evaluation of Dutch gas utilisation policy could be one of the consequences of this conclusion. The right balance has to be found between revenues from gas exports, and maintaining long term self sufficiency for national consumption. Gas exports are backed by several long term contracts between GasTerra and European energy companies such as E.ON Ruhrgas and Centrica. A more conservative nationally-oriented export policy would imply that some contracts will be phased out or renegotiated with lower volumes.[91]

6. Economics of generation capacity development

Decisions about new large scale generation capacity are politically and commercially driven. First of all, from a business perspective, large investments in new capacity are subject to many uncertainties and variables that determine the rates of return. These uncertainties originate from the political and market environment, which are very much interwoven. Political decision making about reducing CO2 emissions can create new investment opportunities, as new support mechanisms are introduced, or a stricter CO2 certificate regime results in structurally higher CO2 prices. Furthermore, geopolitical conflicts in oil and gas rich regions can influence the oil price, and indirectly the gas price, due to their linkage.

[91] The GasTerra contract portfolio would partly allow for such an approach. The Centrica contract for example ends in 2012, but the E.ON contract has been extended in 2008 up to 2028.

On the other hand, general economic and financial conditions also influence the economic viability of generation technologies. Economic growth or decline results in shifting demand and supply curves and subsequently affects fossil fuel and electricity prices. In addition, investment in new technologies is often financed by investment companies and banks, which therefore can influence the pace of development.

The current economic downturn underwrites the influence of market factors on the electricity sector. A lack of finance capacity and appetite among investors can cause delays or even cancellations of large renewable projects such as offshore wind farms.

The bankruptcy of Econcern, a Dutch-based energy company that invested heavily in sustainable energy, is illustrative in this respect. In May 2009, it filed for voluntary receivership after it failed in a bid to secure financing.[92] Events like this can cause a serious back-log in realising the ambitious renewable targets and consequently the 30% CO2 emissions reduction.

Another effect concerns decreasing power prices. Due to the fall of the oil price in the last quarter of 2008, gas and power prices also went down. This is beneficial for consumers, but it negatively affects the value of gas and generation assets. If lower prices continue for a couple of years, it could have a serious impact on the level of investment.

On the other hand, large investments are required in the coming years to secure electricity supply and meet climate objectives. In Europe, forecast capacity needs range between 360-390 GW, which corresponds with an investment of around €400-435 billion.[93] In the Netherlands, significant financial resources also have to be allocated to establish a low-carbon generation mix.

The limited availability of these resources, in combination with low price levels, can seriously hamper the development of renewable and clean conventional generation. This will put an increasing pressure on the 2020 objectives and more eyes will turn to the government to provide necessary incentives.

If we look at the different variables that determine the economic attractiveness of generation technologies, capital expenditures and the cost price are the main elements on the expenditure side. The former is an important factor as it requires huge investments that have to be financed and impact the risk profile of an energy company. Of the mainstream generation types (see table 6.1), nuclear requires the largest investment, but the plant has a long lifetime to earn it back. However, this also entails financial risks as it exposes a company to events such as volatile electricity prices, regulatory measures and disruptions that can negatively affect the value of the asset over a longer period of time.

In general, the business case for substantial investment in generation capacity builds on maximization of operating hours. This also applies to coal with CCS and (offshore) wind. The former has the advantage over nuclear of lower investment costs and a similar lifetime. It is probably less exposed to safety disruptions as the criticality of the process is lower. Offshore

[92] Reuters, 'Dutch energy firm Econcern files for receivership', 26 May
[93] European Commission, Second Strategic Energy Review, p.49

wind is less attractive in the sense that it has a much shorter lifetime and a significantly lower capacity factor.[94]

CCGT and onshore wind have the greatest advantages in terms of upfront investment. The lower capacity factor and lifetime however partly offset this advantage. The factor for onshore wind is even lower than for offshore and CCGT units are generally used for peak load. This means that CCGT has less running hours but, because it is the price setter during peak hours, it still has an attractive value outlook under current market conditions. Moreover, gas-fired generation has the highest efficiency.

Table 6.1 Parameters of the main generation technologies[95]

	Driver	Investment cost	Lifetime	Production cost 2007	Production cost 2020	Net Efficiency	Emission (Lifecycle)
	Unit	€2005/kW	Year	€2005/MWh	€2005/MWh		kg CO2 (eq)/MWh
Technology							
Wind							
Onshore		1000-1370	20	75-110	55-90	n/a	11
Offshore		1750-2750	20	85-140	65-115	n/a	14
Combined Cycle Gas Turbine		480-730	25	50-60	65-75	58%	420
Combined Cycle Gas Turbine CCS		1000-1300	25	n/a	85-95	49%	145
Pulverised Coal Combustion		1000-1440	40	40-50	65-80	47%	820
Coal CCS							
Pulverised Coal Combustion		1700-2700	40	n/a	80-105	35%[1]	270
Integrated Gasification Combined Cycle		1700-2400	40	n/a	75-90	35%	270
Nuclear		1970-3380	40	50-85	45-80	35%	15

[1] Reported efficiencies for carbon capture plans refer to first-of-a-kind demonstration installations that start operating in 2015

Source: author's calculations

This brings us to the production cost of power generation. During its lifetime, the production cost determines for a large part the profitability of a generation installation. Aside from the capital component discussed earlier[96], it mainly consists of fuel costs, operation &maintenance costs and, in the case of fossil fuel-based generation, CO2 costs. The latter will become more important when the plans for the third phase of EU ETS (2013-2020) materialize and an increasing share of CO2 certificates have to be purchased at a probably higher price. The development of CO2 prices is especially relevant for the viability of coal with CCS, as the additional costs for capture and storage have to be compensated. Table 6.2 shows the additional full cost per tonne of avoided CO2, including transport and permanent storage, of applying CCS on a new coal-fired plant. Cost estimates of CCS range between €25-60/tCO2. The estimated prices under EU ETS 3 (see table 6.3) could allow for commercial operation of a coal with CCS plant, however the wide range illustrates the uncertainty around future CO2 prices.

Simulations run by the European Commission show that for example the cost of electricity produced in IGCC power plants with CCS, with CO2 allowances priced at €40/tCO2 and

[94] The capacity factor of offshore wind ranges between 30-40%, against a factor of 70-90% for coal and nuclear.
[95] European Commission(2008), Second Strategic Energy Review, *Energy Technologies for Power Generation – Moderate Fuel Price Scenario*, p.4. State of the art technology in cost price calculation.
[96] This mainly concerns the depreciation costs of a plant.

relative prices of coal and gas as observed today, is calculated at €c 6.2/kWh in 2025 and €c 6.1/kWh in 2030 (in 2006 prices).[97]

Table 6.2 Cost estimates for Coal with CCS

	Cost estimate €/t
RCI ('08)	€ 25-57
European Commisson ('08)	€ 35
Pöyry ('07)	€ 45
World Coal Institute ('07)	$ 40-90

Source: Clingendael, CCS report (2008)

Table 6.3 CO2 price estimates

Price estimate €/t	ETS 2 2008-2012	ETS 3 2013-2020	2020
Deutsche Bank	€ 40	n/a	€ 65-70
Ecofys (2007)	€ 5-25	€ 15-35	€ 20-50
Point Carbon	€ 30	€ 30-70	n/a

Source: Clingendael, CCS report (2008)

Besides its importance for Coal with CCS, a stricter CO2 policy would also be beneficial for nuclear and wind power. The abatement and subsequent avoided costs, plus sales of CO2 certificates improve the value of both generation types.

For nuclear generation, the CO2 price is a less pivotal element in the valuation as it can already be profitable in a liberalised power market with relative high prices.[98] The wind case however, which still relies on government support of various types, would seriously improve and wind could become profitable as stand-alone energy source.

The development of the EU ETS and subsequent impact on CO2 prices is also important for the economic attractiveness of the conventional gas and coal- fired generation units. Rising CO2 prices are especially detrimental to the profitability of coal considering its large emissions. This could put gas before coal on the merit order, depending on the development of fuel prices. This especially relevant in the transition phase where the conventional units still produce are large share of the required electricity until CCS and large scale renewable or nuclear capacity is available.

Taking the estimates for 2020 from Table 6.1, costs of nuclear power remain constant and commercially attractive, taking also the earlier discussed risks and required government support into account. The cost of conventional coal increases compared to 2007 and the case for gas, with 50% lower emissions, improves relative to coal.

Onshore wind is estimated to be competitive with other forms of generation by 2020 by then, but along with coal with CCS, both PCC and IGCC, at the high end of the cost spectrum. Depending on the electricity and CO2 price, both generation types will probably have to be subsidized to stimulate investment.

The other main profitability driver is the electricity market price. This price is driven by marginal costs of the dominant generation source in any specific hour. The price in the Netherlands is relatively high, especially during peak hours, compared to other European countries, because of the large share of gas in the generation mix. In 2006, the wholesale prices for a 2007 contract was in the Netherlands on average 94.1 €/MWh for peak load and 65.9 €/MWh for base load.[99] The off peak price is mainly set by coal-fired generation.

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[97] European Commission working document, *Commission Communication on Sustainable Power Generation from Fossil Fuels: Aiming for Near-Zero Emissions from Coal after 2020,* SEC(2006) 1723, Brussels, 10/01/2007.
[98] From European perspective, this means higher prices compared to pre-liberalization period in a power market that is also connected to other markets in terms of infrastructure and trading.
[99] Özdemir, Ö., Scheepers, M., Seebregts, A., *Future electricity prices: Wholesale market prices in and exchanges between Northwest European electricity markets,* ECN, June 2008, p. 11

In general, base load production profits significantly from these high prices, especially during peak hours. Coal and nuclear units produce at very low marginal costs, which are mainly driven by fuel costs, and therefore an attractive spread is realized. Wind has zero marginal costs. The 2008-2009 economic recession exerted downward pressure on the market price, but the expectation is that it will recover along with European economies.

Moreover, as concluded in this chapter, the role of gas in peak generation will most likely remain in the coming decades, which secures attractive market prices to build new capacity. A serious breakthrough of wind will create downward pressure on prices. However, an increasing demand for flexible gas-fired power generation capacity with a lower capacity factor due to the increase of wind, can give rise to more price spikes at times significant capacity is required at very short term and consequently offsets an average reduction of power prices.

A decision in favour of a dominant role of wind or coal with CCS after 2020 in the current market context is not the most economically attractive and a substantial sum of public financial resources would have to be allocated, which have to be balanced against other government expenditures. In particular offshore wind is still far from profitable and billions have to be spent to realize the 6 GW. In November 2009, the Ministry of Economic Affairs announced to make €4.5 billion available for offshore wind projects. They expect to realise 700-1000 MW new capacity with this amount.[100] To realise another 5GW would require more than €20 billion.

The period 2010-13 will be crucial in terms of providing the right framework for establishing this low- carbon transition generation capacity. The economic dimension and all related drivers have to be taken into account in making decisions on investments. It is a given that any decision holds certain political, economic and environmental risks. However, continuous postponement may create much larger risks in relation to CO2 reduction targets.

7. Conclusion

The scenarios in this paper were developed to gain insight into how large a role gas will play in the transition to low-carbon electricity supply in the Netherlands. Although all three scenarios are possible, reality will probably be more nuanced. Following the almost sacred principle of fuel diversification in the energy sector, a balanced mix of generation technologies is most likely. Nuclear power has the lowest probability of expanding its share in the generation mix due to the political and public controversies which it raises. However, an increasing sense of urgency about climate change, could alter this outlook. In any case, the government and energy companies must be aware of the conflicts and possible lock-in effects in especially base load generation capacity development. This also includes the latent lock-in effect of pre-construction phases of large scale capacity.

The combination of large scale wind and nuclear or coal with CCS capacity will have detrimental effects on the value of one of those investments. The coming years will be pivotal for the transitional design of the Dutch generation mix and a 'keeping options open' approach will not help to establish this. Although base load technologies can co-exist to a certain extent, the conflicts between the different options, which also depend on the development of

[100] http://www.ez.nl/Actueel/Pers_en_nieuwsberichten/Persberichten_2009/November_2009/

export opportunities, require decision makers in the sector to commit to significant investments in a specific technology.

Looking at the role of gas in energy transition, a decision in favour of any alternative large scale base load generation technology will not reduce its current strong position in power generation. Although this conclusion is not earth shattering given the current strong footprint of gas in the Dutch energy system, all stakeholders must be aware that gas will stick around for many years to come. In fact, one of the main conclusions of this paper is that regardless of this decision, gas will probably become even more important as a transition fuel towards 2020. First of all, it will consolidate its function as the fuel for generation during peak hours because of the absence of alternative generation technologies that can be regulated in a similar way on a large scale. In absolute terms, more electricity will be produced by gas-fired units because of the expected increase of peak demand.

Secondly, following the assumption that the majority of conventional coal projects will be cancelled in the coming years, gas is probably the most technologically and commercially viable option for replacing a part of base load generation capacity. This means that the share of gas in power generation further increases, at least for an intermediate period until a cleaner alternative is available. Looking at the nuclear and coal with CCS scenarios, this alternative will not be there before 2020. Consequently, additional gas-fired capacity will be built between 2010-20 which, assuming that investments will have to be earned back, will create a lock-in of gas beyond 2025.

Thirdly, there is the role of gas-fired generation as regulating instrument to safeguard grid stability. Pursuing the wind scenario will put an additional call on gas-fired generation as the only indigenous flexibility provider to balance the intermittency of wind. If the ambition of 10 GW of wind capacity will be achieved, approximately 1 GW of flexible generation capacity is required to accommodate the integration of wind energy. This role will be less significant in the nuclear or coal with CCS scenarios, but additional balancing capacity will also be required in case 5GW wind capacity is installed.

Finally, the expected increase of CHP units in the industrial sector to improve energy efficiency further enhances the gas footprint in energy transition.

In my opinion, the only way to meet the 2020 targets, , is to replace decommissioned coal plants by gas-fired units, which also run partly base load, and build large scale offshore wind parks. Gas is a relatively clean and efficient energy source for power generation. Given the fact that a CCGT plant emits 50% less CO2 than a coal-fired plant and runs at higher efficiency levels, investment in the former faces much less opposition. The wind intermittency can be accommodated by the additional gas-fired capacity. However, this roadmap will have serious financial consequences for the government budget. If in the coming 2-3 years the government fails to implement a regulatory and financial framework which will allow the realization of the 6GW offshore wind and new coal-fired plants to be built, the 2020 targets will not be met.

Longer term, beyond 2020, to realize large scale decarbonization of base load power generation, large investments are also required in either coal with CCS or nuclear energy. Capital expenditures have to be balanced against estimates of production costs and revenues. These are based on assumptions about efficiency levels, capacity factors and fossil fuel and

CO_2 prices. Furthermore, government support will partly determine the investment climate. These investments should also be perceived in the light of the discussed conflicts in base load generation. Both generation types and wind can only co-exist to a certain extent to remain economically attractive.

Between coal with CCS and nuclear, the former is the preferred option of policy makers in the Netherlands today, but the latter should not be ruled out. I would suggest that the government should seriously investigate the nuclear option and prevent latent lock-in effects in case coal with CCS proves not to be a commercially viable option in the longer term.

The envisaged strong position of gas in energy transition requires the Dutch government to evaluate a longer term gas policy. An outlook which gives an increasingly important role to gas in power generation in the transition phase, in combination with depleting national reserves, puts current production and export policy in a different perspective. Although increasing power sector demand will be partly offset by a decrease in household and commercial demand, the importance of an energy transition which includes CO_2 reduction and energy security probably requires a different allocation of national gas resources. In other words, if gas is considered as an important transition fuel and the Netherlands does not want to depend too much on imports after 2020, production and exports will have to be curtailed to decrease the depletion rate of indigenous resources.

The conclusion of this paper could also be applicable to other countries with a strong gas profile such as the UK or Italy, but also to less gas-dominated markets such as Germany. On the other hand, it is not self-evidently applicable for countries where gas currently plays a minor role.

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Appendix: Potential Emission Reductions for Onshore and Offshore Wind

Table 1. Potential emissions reduction (onshore wind)

	Emission (Lifecycle) kg CO2 (eq)/MWh	Operating hours (MWh/year)	Emission (1MW) Mton CO2	Emission (4GW) Mton CO2
Technology				
Wind onshore	11	2200	0,00002	0,10
Coal PCC	820		0,002	7,22
CCGT	420		0,001	3,70

Note: Assuming a capacity factor of 25%

Source: European Commission(2008), Second Strategic Energy Review, *Energy Technologies for Power Generation – Moderate Fuel Price Scenario*.

Table 2. Potential emissions reduction (offshore wind)

	Emission (Lifecycle) kg CO2 (eq)/MWh	Operating hours (MWh/year)	Emission (1MW) Mton CO2	Emission (6GW) Mton CO2
Technology				
Wind offshore	14	3000	0,00004	0,25
Coal PCC	820		0,002	14,76
CCGT	420		0,001	7,56

Note: Assuming a capacity factor of 35%

Source: European Commission(2008), Second Strategic Energy Review, *Energy Technologies for Power Generation – Moderate Fuel Price Scenario*.