gasunie
crossing borders in energy

Survey 2050

Discussion Paper

crossing borders in energy

Survey 2050

Discussion Paper

May 2016

LET'S DESIGN OUR ENERGY

Contents

Foreword

The aim of the debate on the energy transition is to achieve a CO_2-neutral energy supply in the Netherlands by 2050. Gasunie's Survey 2050 provides an outline of how the energy supply might look if this target is met.

The intention of our Survey is to help participants in the energy dialogue to form an image of the scope and nature of the measures that are, in our opinion, necessary to achieve a CO_2-neutral energy supply by 2050. It is an image based on our current knowledge. We have to base our assumptions on this current knowledge even if the reality, in the distant future, will probably be different. That's why the image presented is mainly seen as a contribution to the currently ongoing discussion on energy transition.

It are the present-day discussions and dialogues about choices and considerations which will lead to policy, activities and collaborations for the intended CO_2-neutral energy supply of the future. We have clearly indicated where choices have already been made in this paper itself. For example, we are assuming that the Netherlands will choose to maintain its industry and business activities and that economic opportunities will be exploited. Naturally this will have an impact on the energy picture for 2050 outlined here.

The dialogue on energy transition is characterised by major variations in insights into and approaches towards sustainability but three central elements can always be distinguished. The preconditions for a successful transition are invariably reflected in these words: sustainable, reliable and affordable. The challenge we face with the energy transition is to make informed choices which take all three aspects into account.

Our survey shows that a CO_2-neutral energy supply can be realised if we make every effort to commit to renewable energy sources such as solar PV, wind and biomass, focussing at the same time on energy savings and CCS.

Implementing an energy transition in this way costs money; everyone knows that. We want to make this (often rarely mentioned) aspect more tangible and include it in the dialogue. Keeping a close eye on the costs of measures results in well-supported choices and consequently the success of the energy transition. We asked consultancy firm Berenschot, in cooperation with Quintel, to calculate the financial consequences of our 2050 image in order to provide insight into how a CO_2-neutral future would look for the Netherlands in financial terms. The report shows that the costs will double. In the coming period, we must continue to work out, through dialogue, the smartest and most desirable approach and how this can or must lead to cost adjustments. We appeal to everyone who is participating in the debate on energy transition also to consider cost aspects. A summary of the report by Berenschot can be found at the back of the booklet. You can consult the full report via www.letsdesignourenergy.nl. Additional or alternative insights are welcome via LetsDesignOurEnergy.nl.

Introduction

Gasunie explored how the energy sector can become CO_2-neutral in the future within the scope of its Energy Report 2015. This Gasunie Survey presents an image of a Dutch energy supply in 2030 and 2050 which meets European CO_2-reduction targets. In that image, the energy sector in the Netherlands is almost fully CO_2-neutral[1] by 2050.

This Survey is based on existing technologies. Lock-in investments are avoided and revolutionary game changers are disregarded. Applied technologies do not necessarily need to be economically viable already.

In order to achieve a 100% reduction in CO_2 in the energy sector by 2050, radical, and sometimes extreme, choices must be made with regard to energy savings required, realisable supply volumes and capacities from sustainable sources, cost levels, social acceptance of techniques and technological innovation. The choices to be made will only be achievable through significant large-scale projects: setting up wind turbines, sinking wells to obtain geothermal energy, installing heat pumps in residential and utility buildings and making huge efforts to insulate homes and introduce energy savings in industry.

These measures will involve costs[2] for manufacturers, transporters and consumers. The costs involved in the image shown in this Survey have been independently calculated by Berenschot, in cooperation with Quintel. A summary of this analysis can be found at the back of this publication.

1 *Quintel's Energy Transition Model was used for the calculations (reference year 2012), supplemented by our own calculations.*

2 *Source: 'Kosten van de Gasunie Verkenning 2050 – Kostenberekening van het energiesysteem in 2050 van de door Gasunie opgestelde Verkenning 2050 [Cost calculations of the energy system in 2050 described in the 'Gasunie Survey 2050'] by Berenschot, June 14, 2016*

For the sake of simplicity, unambiguous choices have been made, although in practice there will probably also be (temporary) niche markets.

The future image outlined in this Survey deviates significantly from the scenarios shown in the Network Development Plan (NOP)3[3] published by Gasunie Transport Services. The reason for this is that the Gasunie Survey and the NOP are pursuing different objectives. The NOP considers which transport measures are necessary to meet a reasonably foreseeable future transport demand based on the current situation (forecasting). A period up to 2035 is considered and the focus is mainly on gas. The Survey, on the other hand, takes a CO_2-neutral energy supply in 2050 as its starting point and, from there, examines which measures are required to realise this goal (backcasting). The focus here is much wider than just gas; it looks at the energy sector as a whole. The outlined future image in this Survey is therefore not an expectation or scenario, but a survey of a CO_2-neutral energy situation.

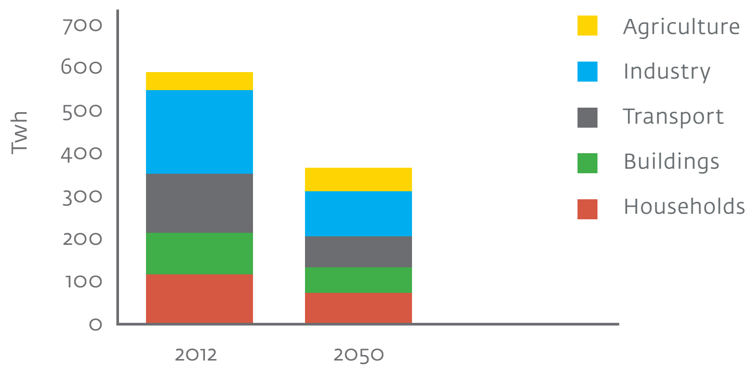
3 *Gasunie Transport Services - Network Development Plan 2015, July 16, 2015*

Part 1

Survey 2050 – an image of the future

It is 2050. The Netherlands is using considerably less energy than in 2015. Coal and oil are considered to be too polluting and have disappeared from society. The energy demand has fallen by more than 40% compared to 2015 due to home insulation, the application of efficient technologies in industry, the built environment and the mobility sector. CO_2 emissions in the energy sector are negligible; hence the ambition of making the Dutch energy sector fully CO_2-neutral by 2050 has been fulfilled.

Energy demand in The Netherlands



Homes and other buildings are very well insulated in 2050. They are often heated by geothermal energy and residual heat (via heat networks). Electric geothermal heat pumps are used in newly built houses. Older houses are heated by hybrid heat pumps (an air source heat pump with a high-efficiency boiler) and (green) gas is still used. The number of electrical appliances in households has significantly increased by 2050 but considerable efficiency improvements mean that the demand for electricity for lighting and appliances is roughly the same as it was in 2015.

Houses and buildings 2050

- *Electricity demand for lighting + appliances (excl. heat pumps) is roughly the same as 2015.*
- *Heat demand down by 60%.*
- *Supply: 50% heat network, 25% all-electric heat supply (ground source heat pump), 25% hybrid heat pump (air source heat pump with Condensing boiler).*

By applying the best available techniques, industry in 2050 is using over 45% less energy than in 2015. The scope of the industrial sector in the Netherlands in 2050 is comparable to 2015.

Industry 2050

- *The scope of industry in 2050 is comparable to 2015.*
- *Over 45% energy savings compared with 2015 by using best available techniques.*

In 2050, cars are fully electrically-powered, meaning that sustainable energy sources can also be used in this sector. Switching to all-electric power is not an option for lorries, therefore most of them will be running on biofuels by 2050.

Mobility 2050

- *By 2050, cars are powered by electricity (34 TWh); an alternative is hydrogen with a comparable reduction in CO_2.*
- *In 2050, lorries are running on biofuels (35 TWh), consisting partly of bio-LNG.*
- *International aviation and shipping are not included in the target.*

By 2050, the country's own sustainable electricity will come mainly from the shallow North Sea, which will have been developed into the biggest wind site in Europe. Decentralised electricity is also being produced on a large scale (solar electricity). In 2050, every building in Northwest Europe will have solar panels. In addition, 'unproductive' public spaces (along motorways, at airports, etc.) will be used for solar fields where possible. This decentrally generated sustainable electricity will be supplemented by a limited quantity of electricity from onshore wind parks.

Solar and wind 2050

- *Solar PV: 66 GW, 60 TWh/y*
- *Offshore wind: 34 GW, 119 TWh/y*
- *Onshore wind: 8 GW, 14 TWh/y*

Particularly in summer, a lot of electricity will be generated from solar and wind which cannot be used immediately. The electricity and gas infrastructure is designed in such a way as to allow this electricity to be converted into hydrogen (P2G) so that it can be used elsewhere, or stored for use later. Storage in batteries is possible for some of the excess electricity and can be useful for bridging imbalances between daytime and night-time. Electricity can also be converted into (both high-temperature and low-temperature) heat (P2Heat). Using the highest peak values in electricity production is not profitable and therefore these peaks are not used.

Uses for sustainable electricity which cannot be used immediately

- *P2G: 35 TWh/y; minimum operating time 4000 hours*
- *P2Heat: 25 TWh/y*
- *Batteries: 10 TWh/y*

Biomass will be a scarce resource which must be managed carefully. In 2050, large quantities of biomass will come to the Netherlands via the Dutch ports, which will be used according to the cascading use principle. Part of this will be used for non-energy-related purposes such as for raw materials in (semi-finished) products, the rest will be converted into energy carriers that can be stored and used at times when too few other sustainable energy sources are available, such as green gas or biofuels for mobility. Biomass in the form of bio-LNG and green pipeline gas will also be imported from areas such as Scandinavia and East Europe.

Biomass in the Netherlands 2050

- *Use for NL: 800 PJ of which 600 PJ imported*
- *Use: 33% non-energy-related,*
  44% for green gas, 66% efficiency
  22% for biofuel

In places where residual heat and/or deep geothermal heat is available and can be provided to the market locally via heat networks, these energy forms can play an important part in supplying heat for homes, utility buildings and horticultural businesses. Residual heat will be more important initially but, by around 2050, geothermal energy will be the main source of heat for heat networks. (Green) gas will be available for peak demand.

Geothermal energy and residual heat 2050

- *Input from heat networks:*
  - *45 TWh geothermal heat*
  - *10 TWh residual heat and back-up*
- *Output from heat networks:*
  - *25 TWh homes + buildings*
  - *20 TWh horticulture*
  - *10 TWh efficiency loss (20%)*

The variable supply of sustainable electricity from solar and wind will have to be harmonised to the demand for electricity. Supply and demand must be balanced not only on an annual basis, but also on an hourly or shorter-term basis. There is an insufficient supply of electricity from wind and solar typically during windless winter weeks, but also on grey or foggy days when the proportion of solar and wind drops below a certain level; at these times, gas (preferably green) is activated for electricity production. In 2050, natural gas is only used if there are no other options.

Power stations and CHP units in 2050

- *Coal-fired power stations: phased out*
- *Gas-fired power stations: 22 GW capacity, 4 TWh production*
- *CHP units: 2 GW capacity, 7 TWh electrical + 8 TWh heat production*

Industry needs large quantities of energy to generate high-temperature heat. Sustainable electricity and geothermal heat are not sufficient to meet this need. Biomass, hydrogen and green gas may offer a solution but, even by 2050, they will still not be plentiful enough to make industry fully sustainable. To avoid CO2 emissions as much as possible, natural gas will be used as the least polluting fossil fuel. Industry will be supplied by a mix of green gas and natural gas, CO2 emissions being captured and stored as far as possible. CO2 emissions released when biomass is converted to green gas will also be captured and stored which will lead to negative CO2 emissions. In 2050, depleted (offshore) gas fields will be used for storing CO2 released during the combustion of (natural) gas.

CCTS

- *Not used at power stations due to low operating hours.*
- *Will be used in industry at 35% of installations.*
- *CCTS used when green gas produced.*
- *The Netherlands has many decades of CO2 storage capacity in depleted offshore fields.*

CHP installations will still be in use. It is only in horticulture and the built environment that flexible CHP units will still be used to a limited extent.

There has been extensive system integration at national level and gas, heat and electricity are interlinked as far as possible through, inter alia, Power-to-Gas (P2G), Power-to-Heat (P2Heat), hybrid heat pumps, electric power stations (centralised and decentralised) and gas for peak demand from heat networks. All this has given the Netherlands, also in 2050, a very robust and reliable energy infrastructure, in which changes in the supply or production of energy or technical faults can be easily handled within the system (electricity, gas, heat). To this end, the Dutch electricity network has expanded pentalaterally and forms a whole with neighbouring countries, just like the gas network. The networks are managed jointly with other European countries, energy flows freely throughout the whole of Europe and adjoining areas. Links to South European networks mean that solar power from the south can flow towards North Europe. Hydrogen produced from solar energy is fed into the European energy system from North Africa.

Price incentives encourage citizens and businesses to save energy every day and to choose the form of energy which is most readily available; this also stops people wasting the energy available.

By 2050, the gas transmission network is transporting considerably less gas than in 2015 but it still serves as the backbone to an uninterrupted energy supply. The role of gas is shifting more towards offering flexibility. According to an initial analysis, in 2050, gas consumption in the Netherlands will be approximately 133 TWh, consisting of a mixture of natural gas (35 TWh), green gas (65 TWh) and hydrogen from P2G (33 TWh). This is a significant drop (-68%) compared to current gas consumption. However, in periods when energy demand is high and supply from sustainable sources (solar, wind) is low, large quantities of gas can be transported and, if required, converted into electricity or heat.

Domestic gas demand (volumes TWH/y)	**2015**	**2030**	**2050**
Power stations	80	62	7
Households & commercials		61	22
Industry	338	143	89
Agriculture & Horticulture		12	4
Mobility	0	0	10
Total	**418**	**278**	**133**
		-33%	-68%

The demand for gas capacity is falling much less rapidly than the demand for volume because the role of gas is shifting from bulk to flexibility. Gas capacity will remain necessary to be able to supply (admittedly less) 'gas by design'.

Part 2

Justification

Reduction in energy demand

One important aspect of reducing CO_2 is reducing the energy demand. Households are managing to reduce their energy demands significantly (-38%):

- Significant reductions in the energy demand for space heating can be achieved by building new energy-efficient homes, insulating existing buildings extensively and using efficient heating technologies.
  Energy savings ranging from 40% to 60% are feasible[4]. Every effort must be made to reach top predicted values in order to achieve a fully CO_2-neutral energy sector; this is the reason why Gasunie takes 60% as its starting point in this Survey. This requires considerable effort.
- The demand for hot tap water depends very much on residents' behaviour and is therefore assumed to remain constant compared with 2015.
- Cooking with gas is only possible in homes with a gas connection. This is only a small proportion of the energy demand of households and that proportion is expected to remain constant.
- Electrical appliances will become considerably more efficient. The development of more efficient electrical appliances will, however, be outweighed by the growing use of these appliances. Therefore, we assume that electricity demand will increase in line with the growth of the population.

Building insulation efforts

- *Newly built homes EPC=0 or lower*
- *Existing buildings*
  - *2030: minimum RC2 insulation rating*
  - *2050: Existing buildings virtually at RC5 insulation rating (current insulation rating for zero-energy homes)*
- *Number of buildings in 2050: approx. 8.5 million, of which*
  - *approx. 5 million built before 1991*
  - *approx. 1.5 million built between 1991 and 2012*
  - *approx. 2 million built after 2012*

➔ *insulate 140,000 to 190,000 homes per year*

Efforts involving (hybrid) heat pumps 2030: Approximately 750,000 hybrid heat pumps

- *2050: 25% of 8.5 million houses = more than 2 million hybrid heat pumps, the same for all-electric pumps*

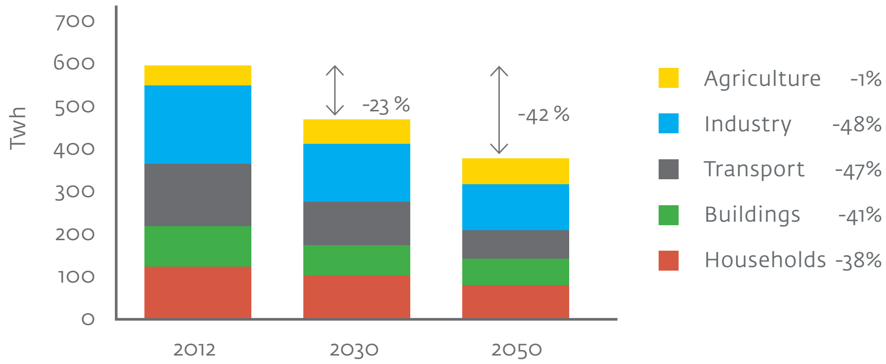
➔ *install 100,000 (hybrid) heat pumps per year*

4 *Source: 'De systeemkosten van warmte voor woningen' ['System costs of heating for homes'] by Energieonderzoek Centrum Nederland (ECN) and consultancy firm Ecofys, in cooperation with network administrators TenneT, Gasunie Transport Services and Alliander, among others. November 2015. http: //www. ecofys. com/nl/press/keuze-verwarmingstechnologie-huishoudens-grote-invloed-op-netwerkkosten/*

We assume that demand trends for electricity and heat will be almost the same for so-called "commercials" (utility buildings) as for households.

Due to the more rapid replacement of this type of building and the significant demand for cooling, applicable technologies will possibly be somewhat different, but given the large variations in building within this category, for the sake of simplicity the same proportions as for households has been retained.

Energy demand in The Netherlands



Due to an improvement in production technologies, we expect the demand for energy in industry to fall by 48% in 2050 compared to current levels[5]. This assumes that the scope of the industrial sector in the Netherlands in 2050 is comparable to that of 2015; some industries will have gone or disappeared, others will have grown. The Netherlands will, to some extent, be able to develop an export position in these sectors. Certain industrial activities, which had moved to other continents during the twentieth century, will also return to Europe. In addition to developments such as 3D printing and robotisation, the following factors will play an important part: overseas production will not lead to a reduction in global CO_2 emissions in the production process but will increase global CO_2 emissions from maritime transport.

The demand for agricultural products will, due to global population growth, be slightly higher in 2050 than in 2015. There will also be a slight increase in energy demand from the horticultural sector in the Netherlands.

5 *Sources: (1) http://pro.et-model.com - Input public scenarios ETM model. Our input is in line with the average input, and is in line with the VEMW choices; (2) Industriële energiebesparing vanuit bedrijfsperspectief ['Industrial energy savings from a business perspective'], ECN-E-15-054, October 2015: The MJA Agreement 2005-2020 requires participants to improve energy efficiency by 2% each year.*

The demand for energy will decline sharply in the mobility sector (approx. 45%). Considerable efficiency improvements will be achieved by switching from cars fuelled by petrol and diesel to those powered by electricity. In 2050, lorries will mainly run on biofuel, including a proportion of bio-LNG, instead of diesel. For the sake of simplicity, this Survey assumes that all cars will be electrically-powered but hybrid solutions will also undoubtedly apply. Hydrogen also offers strong potential for making car transport greener.

It is assumed, for all sectors, that changes in demand for types of energy will show a linear trend between now and 2050. This also applies to the electrification of cars, although it is expected that some of the cars will run on biofuel at the stage of the transition reached by 2030.

Energy supply: solar and wind

A significant expansion in installed solar PV and wind power capacity is necessary to meet the prescribed CO_2 targets. This commitment will be both at centralised (wind and solar fields) and decentralised (solar panels) level, but it presents, at the same time, two dilemmas:

- Significant expansion to the high- and medium-voltage grid is required to cope with large quantities of wind and solar energy.
- The marginal revenues from additionally installed capacities will decrease meaning that the business case is no longer viable and the expansions will not take place.

At a time when considerable investments are being made, it is not acceptable simply to discard electricity that cannot be used immediately. Significant expansions to electricity generated from solar PV and wind can, consequently, only take place in combination with solutions for the storage and use of electricity via P2G, P2Heat and day/night batteries. Storage can also contribute towards the necessary incentives for ensuring that future substantial investments in solar PV and wind are effected. The electricity and gas infrastructure will be designed in such a way as to facilitate the conversion of renewable electricity that cannot be used immediately. We are assuming a significant commitment to solar PV for our energy needs in 2050.
We are assuming a total installed capacity of 66 GW on the roofs of residential and other buildings and in solar fields. This will generate 58 TWh of electricity from solar PVs in 2050.

We are assuming an installed capacity of 42 GW, of which 34 GW offshore, for the production of electricity from wind. This will generate 133 TWh of electricity from wind in 2050.

Sources for maximum potential wind energy

- *ECN: 34 GW offshore wind, 8 GW onshore wind*

Efforts required for 34 GW offshore wind energy

- *Average capacity of a wind turbine 5 MW*
- *Number of wind turbines needed (for 34 GW) = 6800*
- *Construction period approx. 30 years*

→ *20 new turbines per month, excluding any replacements*

Based on these figures and the Energy Agreement, we are assuming non-linear trends for solar and wind energy:

Solar panels Solar fields Onshore wind Offshore wind

	Solar panels	Solar fields	Onshore wind	Offshore wind
2014	1 GW (solar panels and solar fields combined)		3 GW	0.2 GW
2030	8 GW	7 GW	8 GW	12 GW
2050	32 GW	34 GW	8 GW	34 GW

Some of the electricity produced which cannot be used immediately will be stored in batteries, some will be used as P2Heat and a large quantity will be stored via P2G. P2G still requires a lot of research and development before it is economically feasible and large-scale application of this method will not be possible until 2030. However, we do expect that, by 2030, P2G development will have progressed to a stage where it will be economically viable in the years thereafter. There will be large-scale application of this technology by 2050; at this point, there will also be sufficient electricity available from solar and wind for the production of 33 TWh of hydrogen from non-directly-usable electricity[6].

6 *Calculations by Gasunie. We are assuming 12 GW in P2G installations with an operating time of approx. 4,000 hours.*

Energy supply: biomass

Biomass will be a scarce resource which must be managed carefully. Biomass is used according to the cascading use principle. Biomass components are an excellent substitute for oil and gas for non-energy use as a raw material in the energy chain. In the Survey 2050, we assume that one-third of the biomass will be used for non-energy-related purposes[7]. The remainder will be converted into energy carriers that can be stored and used at times when too few sustainable energy sources are available, such as green gas or fuels for mobility (biodiesel, bioethanol); this applies both to imported and domestic biomass.

Biomass

- *Efficiency from fermentation ('wet' biomass): 55%*
- *Efficiency from gasification ('dry' biomass): 70%*

2030

- *150 PJ domestic production, 200 PJ imported (total 97 TWh)*
- *Non-energy-related use (1/3): 32 TWh*
- *Used as green gas (1/3) @ 64% efficiency = 20 TWh*
- *Used as biofuel (1/3) @ 50% efficiency = 17 TWh*

2050

- *200 PJ domestic production, 600 PJ imported (total 222 TWh)*
- *Non-energy-related use (1/3): 74 TWh*
- *Used as green gas (4/9) @ 66% efficiency = 68 TWh*
- *Used as biofuel (2/9) @ 50% efficiency = 25 TWh*

Over time, 200 PJ of mostly 'wet' biomass will be produced in the Netherlands, from Dutch sources. The technologies required for using this biomass for energy-related and non-energy-related use are already largely in place, ethical aspects (including environmental aspects) and certification still require some attention. Our Survey assumes that this form of biomass can be brought into use relatively quickly and that 150 PJ is already available by 2030.

7 *Assumption by Gasunie. As a result of this, approximately 65% of the required amount of gas and oil for non-energy-related use in industry is replaced by biomass by 2050*

Based on globally available biomass volumes, relative population size in the Netherlands and use of biomass in the Netherlands for efficient and high-quality applications, we are assuming possible future imports of around 600 PJ of mostly 'dry' biomass[8]. Technology, infrastructure, solutions to ethical issues and certification still require further development meaning that it will take until 2050 before the full 600 PJ can be brought into use on the Dutch market. We are assuming 200 PJ of imported biomass for 2030.

Gasification technology (for 'dry' biomass) still requires a lot of research and development before it is economically feasible. By 2030, development of this technology will have reached the stage of economic viability and the following years will see further upscaling.

Energy supply: geothermal energy

Heat networks will supply heat in places where residual heat and/or heat from geothermal energy is available and can be made available to the market locally on economic terms. Here the decisive factors are the availability of geothermal energy and the development of heat networks at the right location.

Heat networks 2030:

- *Input: 20 TWh geothermal heat*
- *20 TWh residual heat + back-up*
- *Output: 20 TWh homes + buildings*
- *15 TWh horticulture*
- *5 TWh efficiency loss (20%)*

Heat networks 2050:

- *Input: 45 TWh geothermal heat*
- *10 TWh residual heat + back-up*
- *Output: 30 TWh homes + buildings*
- *15 TWh horticulture*
- *10 TWh efficiency loss (20%)*

8 This assumption is in line with CE Delft and Urgenda.

Over time, 30% to 50%[9] of the total heat supply to houses and utility buildings can be provided by heat networks. Every effort must be made to reach top predicted values in order to achieve 100% CO_2 savings in the energy sector; this is the reason why we assume, in this Survey, that 50% of heat supplied to houses and utility buildings will come from heat networks in 2050. This requires considerable effort.

Geothermal energy will have to be developed further in the next decade and residual heat will be an important source for heat networks. In the longer term, falling use of power stations and efficiency improvements in industry will mean a reduction in the quantities of residual heat available and these heat sources will be replaced by geothermal energy. Estimates regarding the potential for deep geothermal energy are not consistent[10]. In this Survey, we assume that, in 2050, at least 45 TWh of geothermal energy and 10 TWh of residual heat[11] are available, enabling the provision of 50% of the heat supply to houses and utility buildings through heat networks[12].

Efforts required for 45 TWh geothermal energy

- *Thermal capacity per well at 10 MW: ~80 GWh*

2030

- *Number of wells needed (for 20 TWh) = 2 x 250*
- *Construction period up to 2030: 15 years*

➔ *3 new wells per month*

2050

- *Number of wells needed (for 45 TWh) = 2 x 560*
- *Construction period up to 2050: 35 years*

➔ *3 new wells per month*

9 *Source: CE Delft 2015, Op weg naar klimaat neutrale gebouwde omgeving 2050 ['On the way towards a climate-neutral built environment']. CE Delft argues that heat networks can provide 50% of the heat demand. For simplicity, this is interpreted as 50% of houses and utility buildings.*

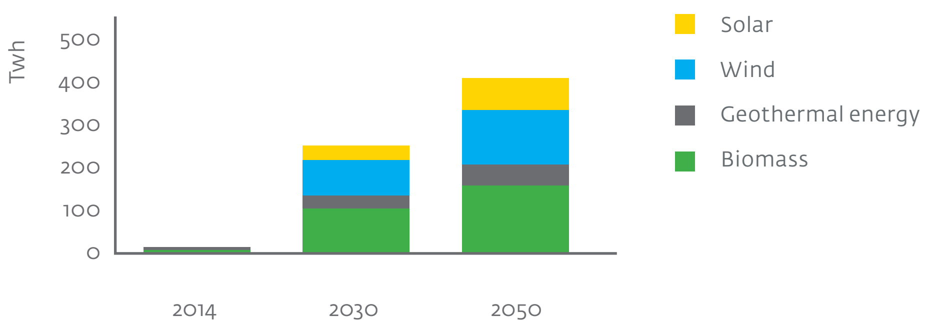
10 *Sources for deep geothermal energy in 2050: ECN 7-28 TWh, DNV-GL 63 TWh, NO/Ecofys 63-90 TWh.*

11 *Sources for residual heat in 2050: CE Delft 60 PJ (18 TWh), PBL 45-90 PJ (14-27 TWh)*

12 *Heat demand 2050 for households is 50 TWh, of which (based on 50% connection to heat networks) 23 TWh will come from heat networks (source: BDH). We have assumed the same proportion for utility buildings, resulting in 14 TWh heat through heat networks.*

The required quantity of (green) gas for heat network peak demand is 20% of the total heat network volume demand[13].

Green energy supply in the Netherlands (input)



Ground source all-electric heat pumps supply 25% of the houses and utility buildings (mainly newly built and detached houses) with heat.

In 2050, the remaining 25% of houses and utility buildings will have a hybrid heat pump (an air source heat pump combined with an Condensing boiler)[14].

Hybrid heat pumps generate approximately 85% of the heat from electricity, (green) gas is used for the remaining 15% [15]. This is necessary to be able to generate enough heat, also in very cold weather (when the air source heat pump cannot extract sufficient heat from the outside air), without requiring major grid reinforcements. This hybrid input contributes towards the reliability of the energy supply.

13 20% assumption based on heat network output identified by GTS.

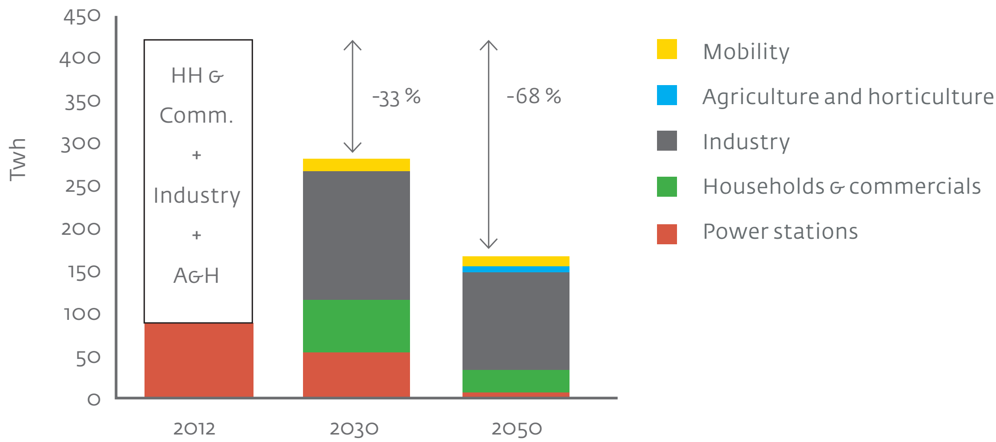
14 Only the "major" technologies have been mentioned. The heat network also includes local CHP, heat/cold storage etc., and the hybrid heat pump group also includes fuel cells, Condensing boilers etc

15 Source: energy consultancy agency Business Development Holland (BDH).

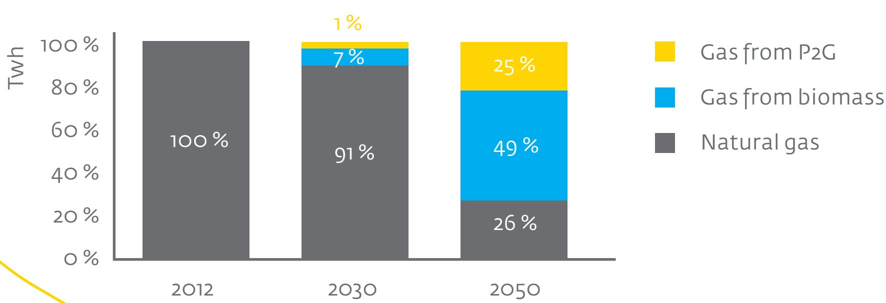
Energy supply: fossil energy

Calculations show, from the energy supply and demand assumed above, that there will be insufficient renewable energy available for a fully sustainable energy supply in 2050. To avoid CO_2 emissions as much as possible, a limited quantity of natural gas will be used as the least polluting fossil fuel. Coal and oil are too polluting and will have disappeared from society as far as possible. An exception to this is the use of oil in international aviation and shipping and coal is still being used, to a limited extent, in some industrial production processes.

Domestic gas demand



Development gas mix The Netherlands



Energy supply: CHP units

CHP units represent an efficient method for producing energy, provided that there is sufficient simultaneous demand for heat and electricity. In general, centralised and industrial CHP units are only used when it can be ensured that any 'must-run' situations will not result in wasting the electricity or heat produced. At times of abundant solar and wind, there is a surplus of renewable electricity. Then there is no demand for electricity from CHP units, but, generally, there is a demand for heat to ensure the continuity of industrial processes. This leads to 'must-run' situations and the production of superfluous electricity. For that reason, our Survey assumes that centralised and industrial CHP units are not used[16].

Flexible CHP units are used in horticulture. Here too, the business case for new CHP units is under pressure due to future surpluses of sustainable electricity but the effects will be smaller as a result of the potential for flexible use. In our Survey, we assume that the use of CHP units in horticulture will halve between now and 2030 and then remain constant.

Carbon Capture Transport and Storage (CCTS)

Using CCTS is unavoidable if the very challenging target of 100% CO2 reduction in the energy sector by 2050 is to be met. From the point of view of cost, CCTS is only feasible if sufficiently high operating times can be achieved, particularly in industry. Whether CO2 capture can be applied in an economically viable manner in industry depends on the production process (one or more points of combustion, operating times). European research[17] shows that CCTS can be applied in around 35% of industrial installations.

CCTS

- *Not used at power stations due to low operating hours.*
- *Used in industry: 2030 - 10% of installations, 2050 - 35% of installations.*
- *Used in the production of green gas, capture percentage 40% from fermentation, 14% from gasification.*
- *Theoretical storage capacity in NL excluding Groningen: 2340 MTon CO2 of which more than 50% offshore, sufficient for many decades.*
- *By comparison: CO2 emissions in NL 1990 = 152 MTon.*
- *Other countries are less well equipped.*

16 *It is expected that local CHP units will still be used but there are also alternatives.*

17 *Source: ECF Roadmap 2050*

The availability of renewable electricity and batteries is enough to be able to meet the electricity demand for much of the year but sometimes other sources will also be necessary. In 2050, gas-fired power stations, in particular, will offer flexibility at times when insufficient renewable electricity is available and they have very low operating hours. For those reasons, using CCTS is not feasible on economic grounds[18].

Due to its non-sustainable features and the efficiency losses resulting from the use of CCTS, we consider CCTS[19] to be the least preferred but necessary option. The production of green gas from biomass also creates CO_2. As this gas is already removed, it is relatively simple also to transport and store the CO_2. There are even negative CO_2 emissions as the CO_2 has already been removed from the atmosphere at an earlier stage of the biological cycle. This is the advantage of using gasification and fermentation to convert biomass into green gas. A separate transport system is also necessary for CO_2 capture. Part of this transport system will be superfluous if a field is "full" or when the availability of sufficient green gas makes CO_2 capture unnecessary. As well as Carbon Capture Transport and Storage, Carbon Capture Utilization can also be considered, which, combined with sustainable energy and closing the CO_2 cycle, might lead to a sustainable solution. There is, as yet, little perspective for this, however, and innovation policies or game changers will be necessary.

The Netherlands is well equipped for CO_2 storage capacity. Theoretically, the storage capacity in the Netherlands comes to 2340 MTon CO_2 (excluding Groningen: 7000 MTon) of which more than 50% is offshore. CO_2 emissions in the Netherlands are currently at around 150 MTon per year, of which roughly 35% come from the industrial sector. Of this, CO_2 can be captured from around 35% of the installations, amounting to 20 MTon per year. If we abstract from efficiency improvements and assume even a limited CO_2 capture of 10 MTon from power stations, then Dutch offshore storage capacity is enough for another 40 years. Other countries are less well equipped.

18 *In this Survey 2050, we are assuming CCTS will only be used in industry but not at power stations, in contrast to some experts (such as Prof. Dr. W. C. Turkenburg) who believe that CO_2 capture should also be applied at power stations.*

19 *Source: IEA ETSAP October 2010, CO_2 Capture & Storage: efficiency 85%, efficiency loss: 10% (coal-fired power station from 45% to 35%). According to an Internet discussion (source: Shell) 20% would become 10% in the future (i.e. from 45% to 40%). Moreover, CCS technology does not capture all CO_2 and a capture percentage of around 90% must be assumed.*

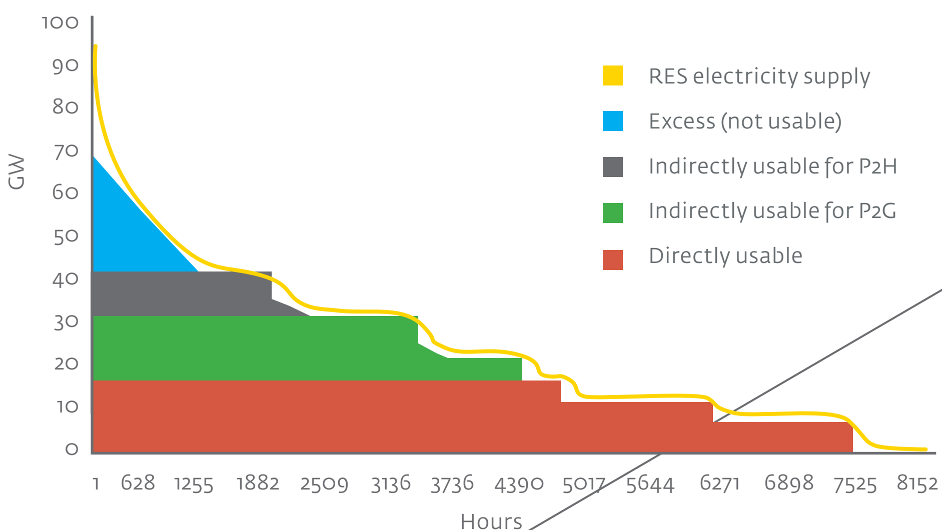
Power to Gas

The quantities of established solar PV and wind capacity used in this Survey result in a Load Duration Curve for electricity production as shown in the graph.

Conclusions:

- There are still sizeable periods when shortages occur. Typically, these will occur in the winter (no solar and periods with less wind) or at night in some of the shoulder months (batteries are not sufficiently charged during the day).
- There will also be long-term electricity production which exceeds demand.
- At 93 GW, capacity peaks arising are five times higher than the current peak demand for electricity, approximately 18 GW. Even if increasing electrification leads to grid reinforcement (which is also assumed here) a lot of the surplus electricity will have to be converted locally into other forms of energy or stored as electricity.
- There is scope for 12 GW of installed P2G capacity; this assumes that P2G installations can be used in an economically viable manner with an operating time of 4000 hours.
- In addition to converting non-directly usable electricity via P2G, around 25 TWh can be used for P2Heat. This assumes that a maximum capacity of 10 GW of P2Heat can be used in industry.
- Adding more solar PV and wind will ultimately lead only to the production of more electricity surpluses and limited, but economically non-viable, P2G revenues.

Load duration curve



Basic principles and game changers

This Survey 2050 gives priority to existing technologies and a "no regret" philosophy. Lock-in investments must be avoided and complete game changers are disregarded. Applied technologies do not necessarily need to be economically viable already. Given the time horizon (2050), ideas that are currently not economically feasible may very well develop into economically viable techniques. More specifically, we are applying several concrete principles:

- Battery technology is developing sufficiently (significant cost reductions) to be used for electromobility and to bridge day-and-night storage in the electricity market. Seasonal storage with batteries is still not feasible.
- Thermochemical technologies (salt hydration) may also offer a solution for seasonal heat storage in the long term. This will still not be feasible on a large scale in 2050.
- There will be a significant reduction in P2G technology costs, making its use economically efficient (where operating times are high enough for the electricity surpluses).

An overview: what do we need to do?

Substantial efforts will be required to meet European CO_2 reduction targets in the Netherlands, including:

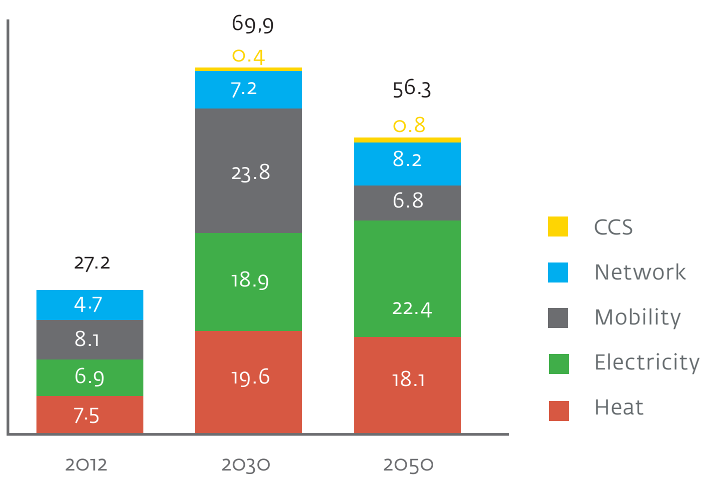
- Newly built homes: EPC=0 or lower
- Existing buildings: insulation of 140,000 to 190,000 homes per year for the next 35 years
- Installation of 100,000 (hybrid) heat pumps per year
- Installation of 20 new wind turbines (5 MW) per month
- Installation of 66 GW of solar PV on roofs and in solar fields (total capacity in 2014: 1 GW)
- Development of biomass production and import: 350 PJ (100 TWh) in 2030, 800 PJ (220 TWh) in 2050
- Development of biogas production: 20 TWh in 2030, 68 TWh in 2050
- Geothermal energy: construction of 3 new wells per month
- Installation of heat networks for 50% of the heat requirements of households
- Installation of CCTS network for capturing and transporting CO_2 (in particular, industrial capture from 2020)
- Development of P2G for application from 2030 onward

We asked consultancy firm Berenschot, in cooperation with Quintel, to calculate the financial consequences of our 2050 image in order to provide insight into how a CO2-neutral future would look for the Netherlands in financial terms. The report shows that the costs will double. A summary of the report by Berenschot is shown below. You can consult the full report via www.letsdesignourenergy.nl.

Summary of the conclusions by Berenschot:

- According to Gasunie's Survey, the total annual costs for the energy system in 2050 come to € 56.3 billion. A large proportion of these costs come from electrification (offshore wind, solar PV and additional network investments, inter alia). Consequently, the costs of producing electricity in 2050 will be more than € 22 billion.
- Final heat production costs will vary. Although fuel costs take up a considerable proportion of the € 18.1 billion/year (mainly through the costs of insulation and fuel), costs are also assumed for heat pumps and geothermal energy, inter alia.
- The higher network costs in 2050 arise mainly due to electricity grid reinforcement as a result of the high level of electrification. The heat network is also more expensive compared with 2012. Gas infrastructure costs are falling.
- Substantial future cost reductions are assumed for technologies that will cater for electricity surpluses. Not only will batteries become cheaper towards 2050, Power2Gas prices will also fall (particularly due to adopting newer techniques). Relatively speaking, however, batteries will remain more expensive than Power-to-Gas and Power-to-Heat.
- The costs of the energy system will be considerably higher in 2030 than in 2050. This is due in particular to the adoption of electric transport (resulting in a reduction in fuel costs) and to cost reductions in other technologies.

Total costs of the energy system: 2012 - 2030 - 2050 (in €B)



Colophon
N.V. Nederlandse Gasunie
Concourslaan 17
9727 KC Groningen
+31 50 – 521 9111
www.gasunie.com
www.letsdesignourenergy.nl

Design
Graphic Design Gasunie, Groningen

Questions after reading this publication?
communicatie@gasunie.nl

May 2016