Grid for the Future: a summary

If the Netherlands is to become CO_2-neutral by 2050, our energy systems will need to undergo a radical transition over the coming decades. How exactly is as yet unclear, though, and depends on a host of socio-cultural and political considerations. It is against this backdrop that the companies administering the country's energy grids operate, but they are at the same time keen to start work on a "*Grid for the Future*". After all, what kind of infrastructure they decide to invest in can either speed up the transition or hold it back, and they want to facilitate the coming changes the best they can.

To get a handle on potential developments, grid operators need to explore lternative futures. In the *Grid for the Future* study, four different scenarios for the Netherlands were therefore elaborated and the numbers crunched by a taskforce comprising grid-operator representatives, working under the umbrella of the Association of Energy Network Operators in the Netherlands and supported by CE Delft.

The scenarios differ in the kind of society they envisage and how the transition process is steered: the degree of government coordination and reliance on imports, for example. The *Grid for the Future* study thus explores the possible contours of the future energy supply, depending on how socio-cultural and political factors play out and on the choices underlying the vision of tomorrow's world. Crucially, it seeks to establish the consequences this will have for the various kinds of energy infrastructure.

Each scenario reflects an entirely different country, with radically different energy systems. We have mapped out the likely changes in industry, heat supply, transport, and power and light. We have looked at how energy will be sourced, how supply can be matched to demand, and what impacts the new grid infrastructure will have. The costs of that infrastructure have been calculated and a price tag put on the country's overall energy system.

Four scenarios for a climate neutral society

National Steering

- Conviction that the process requires tight coordination; national government are in the driving seat, work on 'big projects'.
- National government pursues both centralized and decentralized energy sources; energy independence for NL.
- Broad support for new technologies and solar/wind; awareness of scarcity.

International

- Focus on international trade; free trade is good for economic prosperity.
- National government goes all out in pursuit of an innovative economy based on international flows of biomass and renewables. International cooperation.
- Rejection of Dutch energy independence

Now

Regional Steering

- Much of the process is steered locally; people are very pro-active and entrepreneurial.
- Provincial and local policy-makers put their full weight behind regional energy self-sufficiency and decentralized technologies.
- Broad support for new technologies and solar/wind; awareness of scarcity.

Generic Steering

- Citizens and business/industry want to make their own decisions.
- No acceptance of targeted government steering; energy is a 100% free-market affair.
- Generic policies are fair, transparent, robust and binding (incl. a tax on CO_2).
- The energy transition is an organic process of change made up of countless small steps.

Regional Steering

In this scenario, provincial and local policy-makers are very much in the driving seat. Power and heat are generated as far as possible using local sources like solar, wind, biomass and geothermal. There is a far greater need for new energy infrastructure and hydrogen-based storage to tackle the temporal and spatial mismatch between supply and demand. Electricity-to-hydrogen conversion takes place at numerous locations across the country.

National Steering

In this scenario, the national government is the big coordinator and goes all out for national energy self-sufficiency via a mix of mainly centralized energy sources like offshore wind. There is a substantial need for hydrogen-based storage, given the temporal mismatch between supply and demand. Electricity-to-hydrogen conversion takes place on the coast or even offshore.

International

In this scenario, the Netherlands is a globally-oriented country importing various forms of renewable energy, including biomass and solar-generated hydrogen. There is international production and trade of hydrogen from climate-neutral sources (renewable and fossil with CCS).

Generic Steering

In this scenario, the future energy system is shaped organically, steered only by a solid CO_2 price signal but with no further government intervention. Energy is sourced from a mix of local and global options. Collective options and measures like home insulation are ignored, or used only late in the transition process. Dutch industry contributes far less to solutions than in the other scenarios.

The table summarizes the technical parameters of the energy system in the four visions of society.

	Regional steering	National steering	International	Generic steering
Power & Light	25% base-load savings through more efficient appliances. Substantial electrification of industry.		25% savings through more efficient appliances.	25% savings through more efficient appliances.
Low-temperature heat*	Numerous heat grids and all-electric (restrictions on green gas, no H_2 distribution) Savings: 23%	Numerous hybrid heat pumps burning H_2 (and green gas) (restrictions on green gas) Savings: 16%	Numerous hybrid heat pumps burning green gas and H_2 (mild restrictions on green gas) Savings: 12%	Mix of individual options (no overarching collective, no other restrictions) Savings: 17%
High-temperature & feedstock industry**	Circular industry and ambitious process innovation: 60% savings 55% electrification 97% lower CO_2 emissions		Biomass-based industry and CCS: 55% savings 35% biomass 14% electrification 95% lower CO_2 emissions	Gradual development, business as usual and CCS: 20% savings 12% electrification 85% lower CO_2 emissions
Passenger transport	100% electric	75% electric 25% hydrogen fuel cell	50% electric 25% green gas 25% hydrogen	50% electric 25% green gas 25% hydrogen
Freight transport	50% green gas; 50% hydrogen		25% biofuels; 25% green gas; 50% hydrogen	
Renewables generation in NL	84 GW solar 16 GW onshore wind 26 GW offshore wind	34 GW solar 14 GW onshore wind 53 GW offshore wind	16 GW solar 5 GW onshore wind 6 GW offshore wind	18 GW solar 5 GW onshore wind 5 GW offshore wind
Conversion and storage in NL	75 GW electrolysis 60 GW battery storage 9 bcm gas buffer	60 GW electrolysis 50 GW battery storage 11 bcm gas buffer	2 GW electrolysis 5 GW battery storage 10 bcm gas buffer	0 GW electrolysis 2 GW battery storage 10 bcm gas buffer

* Results of cost-effective options calculated with the CEGOIA model.

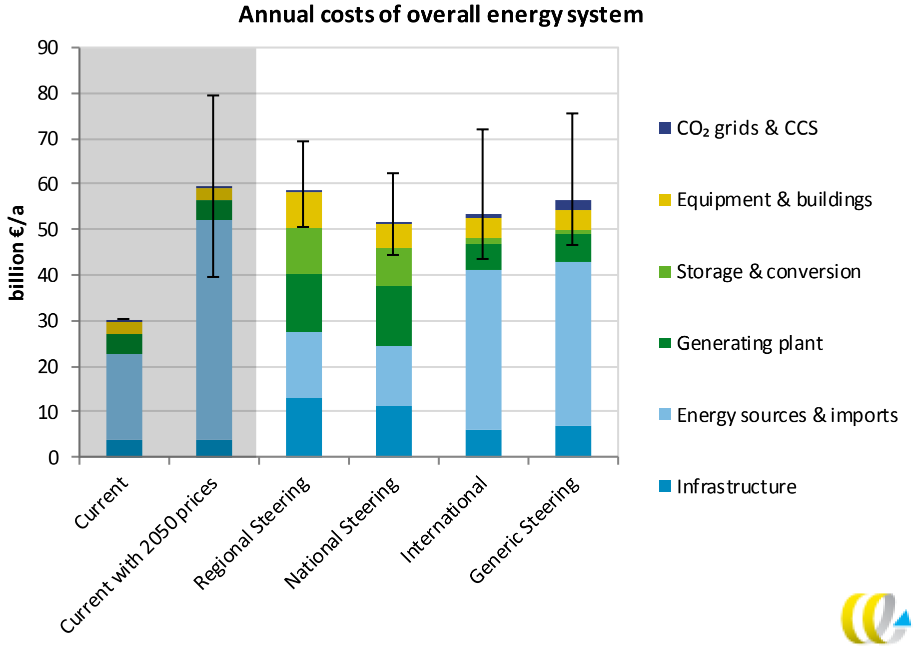
** Industry scenarios developed by Wuppertal Institute.

Analysis

In all likelihood, none of the four scenarios describes exactly how reality will pan out in 2050, given the likelihood that the technologies of that era will be different from today's, on both the production and consumption side. This study nonetheless demonstrates the importance of the choices made today for technological elaboration of the coming energy transition.

One thing is clear: in all the scenarios our energy system is set to change dramatically. In contrast to what some may expect, energy will not come free. While the variable costs of electricity will decline sharply as more and more wind and solar are brought on stream, there will have to be serious investment in generating plant before this capacity is up and running. In addition, there is no way wind and solar can immediately cover the country's entire energy requirements. Per kWh, the price of electricity will remain roughly the same. The variable costs of energy carriers like renewable gas will be far higher than the current cost price of natural gas, though.

The aggregate costs of the energy system will be higher than today, roughly doubling by 2050. In the climate-neutral scenarios this is because renewables cost more than today's cheap fossil fuels, and thanks to capital outlay on generating plant, storage, conversion and infrastructure. It is also the case, though, in the 'business-as-usual' scenario, where today's energy system is modelled using 2050 energy prices, as calculated in one of the 'WLO scenarios' published in a study at the end of 2015 by the Netherlands Bureau for Economic Analysis (CPB) and the Netherlands Environmental Protection Agency (PBL) that assumes minimum efforts on climate policy.



There are major uncertainties, with scenarios involving large imports sensitive to the price of (zero-carbon) fuels in the global marketplace, and those involving regional or national energy independence sensitive to capital costs. In the import scenarios the financial risks are clearly greater, though, as history shows that energy costs are subject to far greater volatility. Besides costs, there are also other impacts that differ from scenario to scenario, including macro-economic structure, added value, innovation, employment and economic trade balance. There are also differences in environmental impacts, air quality, control of climate change and impacts on the use of space and the landscape. And there are differences in more 'subjective' aspects of the energy system like energy independence and security of supply, and social autonomy and freedom of choice for Dutch citizens.

How will energy infrastructure be affected?

The country's energy infrastructure will undergo considerable change. There seems to be just one exception: if the Netherlands relies mainly on imports to meet its energy requirements. In the Regional scenario, electrical grids will have to ensure local and regional solar and wind power get to industry via the national grid and are converted to hydrogen for use in transport and industry as well as the built environment. In the National scenario, changes will be less far-reaching and much of the energy – both power and gas – will be sourced in the North Sea. The least drastic changes will be in the International and Generic scenarios, which both import a lot of energy.

Required capacity of electrical grids, 2050

Capacity [GW]	Current	Regional	National	International	Generic
Offshore wind	1	26	53	6	5
High-voltage	20	36	57	18	19
Medium-voltage	10	53	22	10	10
Low-voltage	11	24	13	11	11

Boosting the capacities of the electrical grids – by a factor 5 for some elements – will mean more work for grid operators as well as more space for the grids themselves. That space is required for transformer stations and additional high-voltage lines and must be found in ever more densely populated areas. Besides impacts in the spatial-planning realm, landscapes will also be affected.

In all the scenarios the gas infrastructure will remain just as important, at both the regional and national level. The grid will no longer be distributing natural gas, though, but zero-carbon gases, the most important of which is hydrogen. These fuels will be used in industry, in transport and in some scenarios also in significant quantities in the built environment. While today's gas grids have sufficient capacity, they will need to be adapted.

In the Regional scenario, particularly, some form of district heating will be implemented in half the country's residential neighbourhoods. Some of this heat will be geothermal, some from large-scale sources of waste heat. Small-scale, locally-sourced heat plays a role in all the scenarios. In many cases, heat demand during the 'winter peak' will be met by zero-carbon gas, both directly and indirectly.

From the various scenarios a number of general conclusions emerge:

- There are many routes to a climate-neutral energy system, but with major differences in energy sources and reliance on imports.
- Electricity will become far more important as an energy carrier, because it will be renewably sourced from solar and wind and will be used for energy functions now covered by petrol and natural gas.
- Hydrogen will be an indispensable element of tomorrow's energy system; it is a good way to avoid having to use wind and solar power directly, storing some of the energy instead.
- Demand-side flexibility on the part of energy consumers will help lower the costs of the electricity system.
- Even in scenarios with massive roll-out of solar and wind, there will still be a need for power plants burning zero-carbon fuels with the same capacity as today's coal- and gas-fired plants to supply sufficient power on cloudy and windless days.
- In the transport sector, biogas, hydrogen and electricity will take over from petrol and diesel.

Finally

The social and political choices we make today will determine what tomorrow's energy system looks like. Because grid operators are already working on preparing and building the grids of the future, the most efficient strategy is to make timely choices about the direction we want to head in. Whatever the case, the government can actively steer the process through regulation or pricing, as well as coordinating it more actively. Such coordination can facilitate creation of hydrogen infrastructure or heat grids in specific areas, or effectuate a minimum level of heat insulation across the country, to cite just a few examples. Government, grid operators, market parties and consumers must therefore start a conversation on where we want to go with our future energy system and what investments it will require. We need to make 'system decisions' for the longer term; by delaying them we will eventually block an efficient energy transition. Waiting too long will lead to bottlenecks in implementation, with insufficient time or personnel available for timely construction and adaptation of generating and conversion plant as well as transmission and distribution grids.

The term 'system decisions' refers to issues like the desired degree of energy autonomy and its scale level, and the freedom of choice for citizens and local authorities when it comes to heat infrastructure. There is also the related question of how much additional solar and wind is desirable compared with what we can use directly for 'light and power' and must therefore store or convert to gas, for instance.

Until such time as it is clear which direction we are heading, grid operators will have to allow for each and every possibility. They will need to be prepared for a Regional scenario, for example, which requires a mass of infrastructure for wind and solar as well as high-cost storage facilities – while in thirty years' time the energy system may in fact prove to be internationally oriented, with far less need for infrastructure because so much energy is being imported. It will be clear that grid operators can save a lot of money if they no longer have to allow for all options.

Support

Another issue to come very much to the fore in this study is that society-wide support for the energy transition is essential, mainly because all categories of energy consumer will need to take (often far-reaching) measures to make the transition a success. This will mean shouldering a higher cost burden. There will be greater support if energy users are not under the impression they are being pushed in a specific direction but still have a certain freedom of choice. This could be achieved by keeping the natural gas grid up and running longer in certain neighbourhoods, where technically feasible, or even parallel with a district heat grid. What we see emerging here is a dilemma for society, involving on the one hand a pursuit of lowest cost (for distribution grids, among other things) by means of dedicated choices, but on the other resistance from both citizens and industries who have the feeling that a particular solution is being thrust on them. Greater grid capacity (and therefore higher costs) and/or more frequent retention of the gas grid increases the scope for energy consumers to choose the solutions that suit them best. One precondition for this route, though, is that we must always take maximum advantage of replacement opportunities to implement change – whether it be boiler replacement and home renovation (direct upgrade to the right efficiency level) or, when the time for structural replacement of infrastructure arises, serious thought about what exactly to invest in.

Next steps

Grid operators are well aware of the need for a debate with stakeholders about the various issues affecting their business activities. These include the supply of climate-neutral heat to the built environment (for which solutions will differ per region); weighing up regional energy sources against imported renewables; the 'greening' of industry; and battery charging systems for electric vehicles. The aim of this debate is clear: to ensure the country's grid infrastructure facilitates the required energy transition as efficiently as possible. The grid operators have drawn up a discussion agenda: '*10-point plan for a successful energy transition*' [in Dutch], setting out the ten key issues that need addressing to speed up the inevitable energy transition.