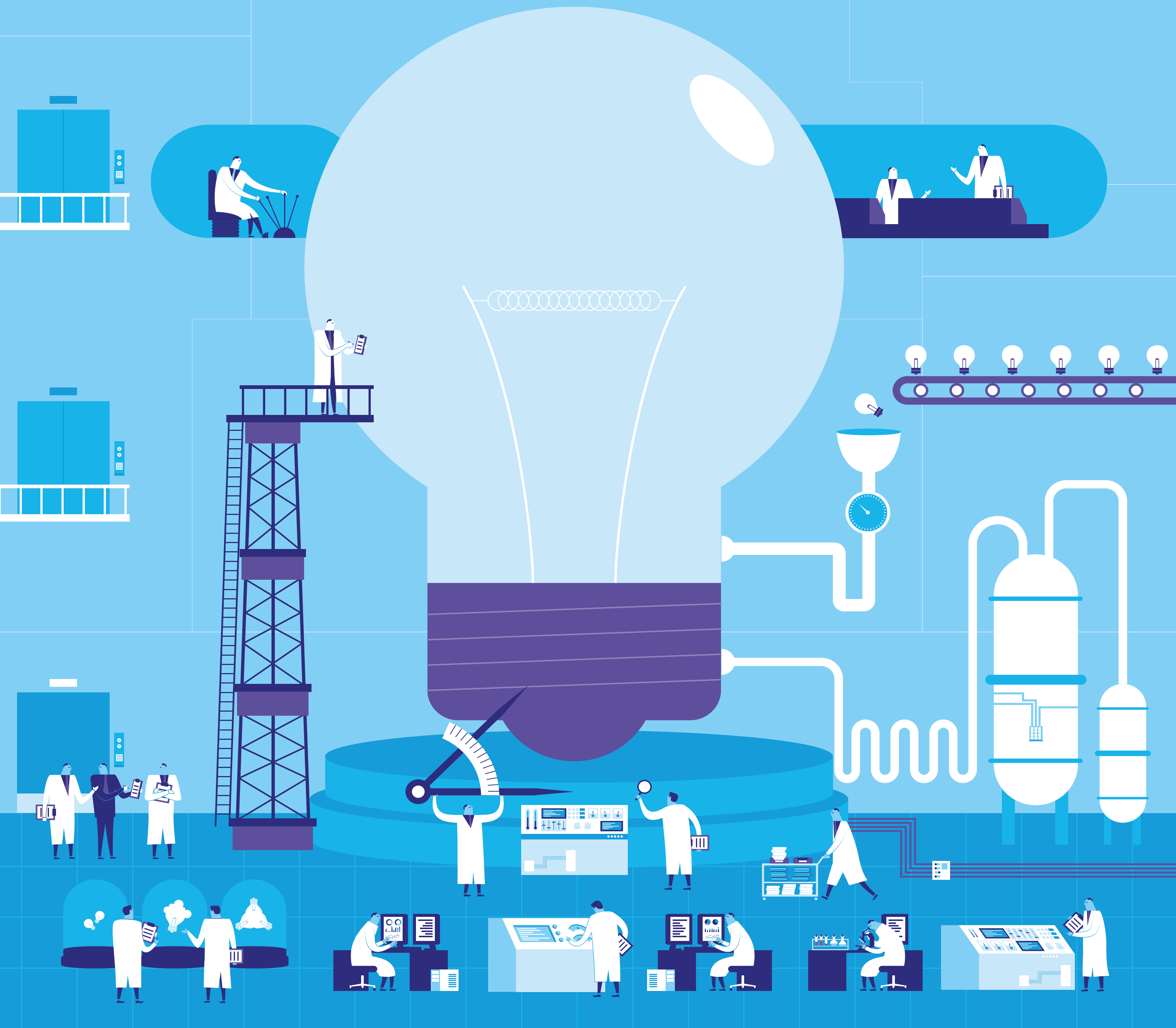
A LOOK AHEAD AT THE ENERGY SUPPLY IN 2050

GRIDS FOR THE FUTURE



SUMMARY

On the road to a CO_2-neutral society in 2050, energy supply will change dramatically over the coming decades, but no one knows exactly how. The way in which the transition takes shape will have an impact on the energy infrastructure. Vice versa, investment choices made by grid operators can affect the direction, and the speed with which the transition takes place. The energy transition, of course, is not only about infrastructure and cost-effective technological solutions, but also about the level of support for the changes that need to be made.

In order to highlight the correlation between the direction society takes and the required infrastructure, this report places the necessary technological challenges in the context of social and political choices and considerations.

THE ENERGY SUPPLY IN 2050 IN DIFFERENT SOCIETAL SCENARIOS

In this research, four societal scenarios have been developed and, in doing so, we have calculated the political and social consequences and what they mean for the energy supply in 2050. These societal scenarios differ in how the transition would be likely to be managed, the scale in which this is governed, and to what extent self-sufficiency can be achieved.

1. **Regional management**
   In this scenario provinces and municipalities have a lot of the control. To a large extent, energy for the production of electricity and heat comes from local energy sources such as solar, wind, biomass and geothermal energy.
2. **National management**
   In this scenario central government has control and maintains energy autonomy for the Netherlands through a mix of central energy sources, particularly wind at water.
3. **International**
   In this scenario the Netherlands is a globally oriented country that imports different forms of renewable energy.
   There is an international production and trade in hydrogen from climate-neutral sources (renewable and fossil + CCS).
4. **Generic direction**
   In this scenario, the energy supply is created through an organic process, driven by a strong CO_2 price signal, but without further government control. The energy supply includes a mix of local and international options.

For each scenario we looked at how the energy demand for power and light, low temperature heat, industry and transport, is met. The following table contains an overview of the technological characteristics for each scenario.

	Regional management	National management	International	Generic direction
Power and light	25% reduction minimum demand more efficient equipment. Furthermore a strong electrification industry.		25% reduction due to efficient equipment	25% reduction due to efficient equipment
Low temperature heat*	Many heat networks and all-electric. (Limiting green gas, no H_2 distribution). Reduction 23%	Many hybrid heat pumps on H_2 (and green gas) (Limiting on green gas). Reduction 16%	Many hybrid heat pumps on green gas and hydrogen (mild limiting of green gas) Reduction 12%	Mix of individual options (no large collective, no other limitations) Reduction 17%
High temperature & feedstock industry**	Circular industry and ambitious process innovation: 60% reduction; 55% electrification; CO_2-emission -97%.		Biomass-based industry and CCS: 55% reduction; 35% biomass; 14% electrification; CO_2 emission -95%	Gradual development, business as usual and CCS: 20% reduction; 12% electrification; CO_2 emission -85%.
Transport for people	100% electric	75% electric, 25% H_2 fuel cell	50% electric; 25% green gas; 25% H_2	50% electric; 25% green gas; 25% H_2
Transport of goods	50% green gas; 50% H_2		25% biomass; 25% green gas; 50% H_2	
Renewable generated 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 stored 9 bcm gas buffer	60 GW electrolysis 50 GW battery stored 11 bcm gas buffer	2 GW electrolysis 5 GW battery stored 10 bcm gas buffer	0 GW electrolysis 2 GW battery stored 10 bcm gas buffer

* Results cost effective option calculations made with the CEGOIA-model.** Future scenarios for the industry from the Wuppertal Institute.

ANALYSIS

The research shows the extent to which the technological development of the energy supply transition and the consequences for the energy infrastructure, are dependent on (political) choices, even though none of the four scenarios describes exactly what will ultimately happen. All societal scenarios change the energy system dramatically.

A number of points stand out:

- Electricity becomes more important in the energy supply, also for industry. In the regional scenario, local and regional electricity is generated from solar and wind power and transported to industry via the national grid and converted into hydrogen. In the national scenario, in particular added infrastructure (both electricity and gas) is required to transport energy generated at sea. The (heavy) reinforcement of electricity grids means not only a lot of work for the network operators, along with the need for sufficient technical personnel, but it also places large demand on public space in order to install more transformers and extra power lines.

Required capacity electricity grid 2050 (GW)

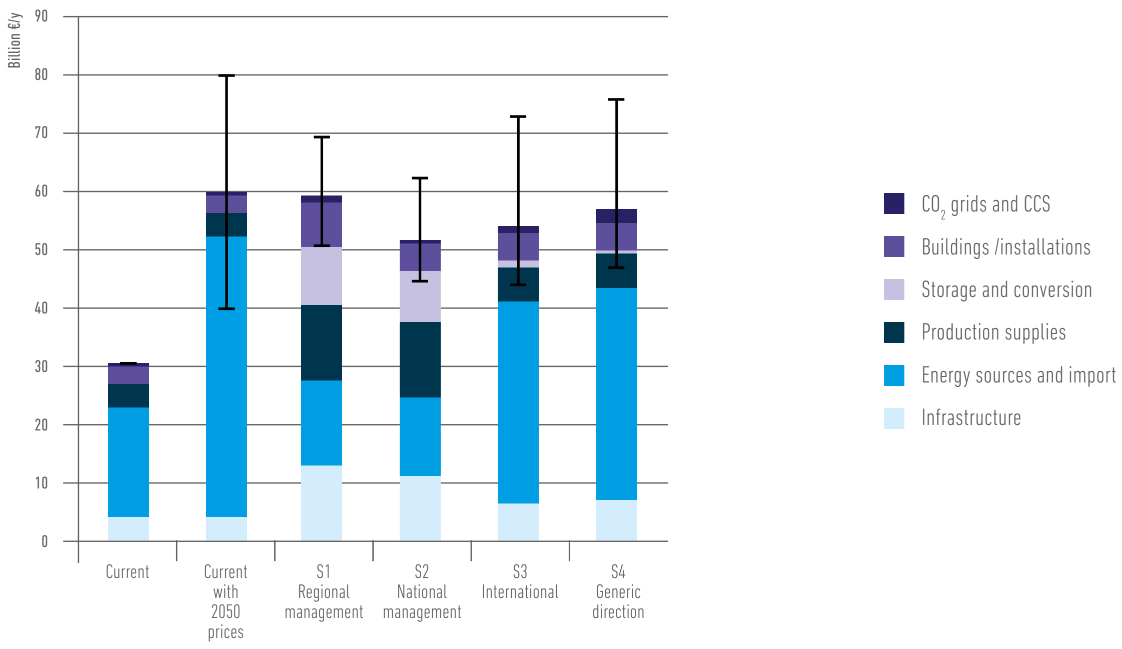
	Current	Regional	National	International	Generic
Offshore wind	1	26	53	6	5
Hight-voltage	20	36	57	18	20
Medium-voltage	10	53	22	10	20
Low-voltage	11	24	13	11	5

- Flexibility of users contributes to the optimisation of the costs of the electricity system.
- In societal scenarios in which solar and wind energy are important sources, power plants based on CO_2-free fuels are also required with the same power equivalent as the current coal and gas plants, as a solution for grey and windless days.
- Hydrogen is indispensable in the future energy supply; a good solution is for energy from solar and wind sources not only to be aimed at electricity consumption, but to include transport, fulfilling the demand for heat, and for use as feedstock for the chemical industry.
- In all scenarios, rural and regional gas infrastructure is needed for CO_2-free gases. The capacity of the current grids should suffice. CO_2-free gas will, in many cases, directly and indirectly, ensure that the demand for heat during winter peak is met.

The total costs of energy supply in the future will be about twice as high as they are now, whether we are dependent on fossil fuels or headed towards a CO_2-neutral energy supply. Differences in total costs between the various scenarios are small. Climate-neutral scenarios, in terms of renewable sources, tend to be more expensive than the current cheap fossil fuel. In addition, more investment in plants, isolation and infrastructure is required. If we didn't change anything about the current energy system, the cost price of fossil fuels could double if global climate policy is not effective, making the energy supply twice as expensive.

The cost included in the international scenario and the scenario in which there is generic direction depends very much on market prices, because the total cost in this scenario, to a large extent, includes variable costs for importing energy sources. In these scenarios there are much larger amounts of money going abroad compared with the self-sustaining scenarios.

Annual costs energy supply



Aside from the 'costs', there are other effects that differ between each future scenario. This concerns macroeconomic structure, added value, innovation, high and low-skilled employment, economic trade balance, as well as environmental effects, air quality, mitigation of climate change and the impact on public space/landscape. However, there are differences in a number of more subjective characteristics of energy consumption, such as energy self-sufficiency, security of supply, autonomy and freedom of choice for citizens.

CONCLUSIONS

The investments in infrastructure that are required and the spatial impact of a sustainable energy supply depends on the direction of the energy transition and therefore it depends on who controls it. Because grid operators are already working on building the grids for the future now, choosing a timely direction is the most effective way. Governments, system operators, market players and consumers need to be able to enter into this conversation. The government can actively steer, for example, regulation or pricing or in terms of direction and general choices that are to be made.

On a regional scale, energy-neutral power requires (a lot of) local sources, with a major impact on public space and infrastructure. It is important to identify the impact, and the costs, self-sufficiency, demand on space, support, risks, and the ability to import, must all be taken into account when it comes to making choices.

Making choices in the foreseeable future, for the long term, is important for a fast and efficient energy transition. Waiting too long eventually leads to issues in the implementation, for example, because there isn't enough time left or not enough staff for the timely adjustment of all conversion installations and the grids. For example, in system choices we understand the degree of desired self-sufficiency, the freedom of choice for citizens or for municipalities in the infrastructure for heating, how much extra production of electricity from solar/wind sources is desirable etc.

As long as it is unclear which side we are on, grid operators must take into account every possible scenario. Grid operators must be prepared for a regional scenario in which much of the infrastructure is still needed (at high cost), even though in 30 years' time we might be dealing with an internationally oriented market for energy supply, with a much smaller need for infrastructure. From this point of view, grid operators can reduce costs by not having to be prepared for all these possibilities.

Furthermore, merely looking for the lowest possible cost scenario could limit the level of support that can be generated. Support is essential for the energy transition, because all energy users must take (radical) measures in order for the energy transition to succeed. More space in the grids (and therefore higher costs) gives the energy users more opportunities to create their own solutions. An example of this is maintaining the gas networks for renewable gas in addition to a heating network. This creates a social dilemma between striving for the lowest costs and generating support.

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