



And then there was light...

Transition paths to an emission-free energy system

English summary of Dutch publication

Energy is one of the main pillars of our current society and that will not change in the future. The way energy and other technologies are intertwined makes it a very broad subject that requires framing. Here, the subject is framed by taking the climate goals for 2050 as a starting point.

At the moment, climate change is high on the international agenda and also in the Netherlands it is the focus of much attention. Climate change is caused by the emission of greenhouse gases. These greenhouse gases – mainly CO₂ – come from fossil sources that were for millions of years withdrawn from the atmosphere and are now, through combustion, emitted. These gases cause the earth to retain more warmth, as a result of which gulf- and airstreams change, and rainfall patterns with them: in some places (a lot) more, in other places (a lot) less. What the exact consequences of this climate change are is as yet unknown, but we can be sure that – if we do nothing – the changes will have a major impact on our lives.

About three-quarters of greenhouse gas emissions come from our current energy system, which explains the enormous attention to the future of our energy system. In the Paris climate goals (2016), it has been agreed that the global warming may not exceed 2°C. This is only feasible if a lot of changes in the area of energy are realized, both in technological and social terms.

Technologies

To realize the agreed objectives, technological developments are very important. In research and in the private sector, there are already many developments that can contribute to a new energy system. These developments focus on generating, transporting, converting and storing energy, and on using it more efficiently.

New technologies to generate energy

In terms of generating energy, we see tremendous improvements when it comes to the efficiency and costs of existing applications. The continuously falling prices of generating solar and wind energy are a good example.

However, in the future our energy system will be based on a much broader diversity of energy sources, as becomes clear from the following developments:

- Using solar energy to generate heat, electricity and fuels;
- Airborne windmills;
- Using the oceans to generate energy from waves, tides and heat/cold differences;
- Using new types of biomass, like residual waste and seaweed;
- Nuclear energy as a large scale CO₂-neutral energy source: safer nuclear fission reactors, and applying nuclear fusion;
- Using the geothermal heat from the (deeper layers of the) earth;
- By capturing CO₂, it is possible to continue using fossil fuels longer and then slowly phase them out.

New technologies for transporting, converting and storing energy

The fuels we currently use are easy to transport and store, because they are solid (coal), liquid (oil) or gaseous (natural gas). New types of energy, like solar, wind and tidal energy, generate electricity, and as a result, electricity will play an increasingly important role in our future energy system. Electricity does not have a physical form of its own, which makes it harder to store and requires serious innovation in terms of its transportation, conversion and storage.

- With regard to the transportation of electricity, efficiency improvements are being realized, for example in the development of superconducting cables. Wireless energy can in this area also play an important role in the future.
- Due to the loss of energy during the transportation of electricity, some developments focus on converting electricity into fuels that can be transported in a more conventional way and which, consequently, are also easier to store. For example: splitting water into oxygen and hydrogen through electrolysis. The hydrogen can be converted into natural gas or ammonia. In the future, using photochemical cells, it can be possible to make high-quality fuel directly from electricity.
- For storage of electricity there will be developments in the area of batteries, but there are also ideas for large artificial storage reservoirs underneath the North Sea and for huge underground flywheels.

New technologies for the use of energy

A large share of realizing the climate goals focuses on using less energy. Because we use more and more (digital) technologies, in the Netherlands as well as elsewhere in the world, we need to deal smarter with how to use our energy. This can, for instance be done by smart meters in households that respond to the supply and demand of energy or by reusing industrial heat.

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It is, however, not only new technologies that will cause changes in our energy system. It is above all the effects these technologies have on society and on our daily lives that determine the future. There are a number of variables that are often mentioned in debates about our new energy system. Examples of variables are a fully electrified energy system or a system that still runs (partially) on fossil fuels. Or an energy system that is centralized or decentralized, or national/international. Or a system that is or is not accessible to everyone.

The STT foresight study included an online survey among energy experts and participants from society. In addition, in a series of workshops, we looked at differences in transition paths on the basis of four scenarios. In order to magnify these differences, we targeted a completely emission-free energy system for all scenarios and associated transition paths.

The four scenarios:

- 2050 – Focus on the Netherlands (a national and centralized scenario)
- 2050 – Global Power (an international and centralized scenario)
- 2050 – Energy Island (a national and decentralized scenario)
- 2050 – Stronger Together (an international and decentralized scenario)

The transition paths that followed from the four scenarios show that, in the case of a decentralized system, especially in combination with a national approach, there is a risk of major social differences. Ultimately, it is desirable for everyone to have access to affordable energy. In a transition towards a more centralized system, we need to maintain a focus on the knowledge position of the Netherlands. How does the government make sure that innovation is sufficiently encouraged while in the meantime the focus is not limited to energy delivery but also to seizing opportunities that the transition towards an emission-free energy system may bring?

Recommendations for the Netherlands

An important conclusion from the workshops is that, in all four scenarios, it is the government that needs to take the initiative to realize our future energy system. The policy choices that are made determine to a large extent the shape of that future system. If we translate this conclusion into what we need now to make sure that we have an emission-free energy system by 2050, then what we need especially is a clear vision of the energy system of the future, and soon.

To achieve a vision in which all relevant interests are included, we need more than the current Dutch intentions regarding the percentage of sustainable energy in 2023 and efficiency targets in 2050. There has to be given much more attention to the *entire* energy system, not only looking at the technological aspects, but also at the changes that are needed in terms of government policy, for instance when it comes to energy security, energy poverty and equal access for everyone. How can we make sure that these are all covered in the energy system of the future? All these considerations have to be taken on board in the current policy, with the government taking the initiative, but working together with the business community and with society.

In addition to the challenges within the Netherlands, there are also challenges as well as possibilities in relation to international developments. What will, for instance, be the impact of worldwide population growth and increasing wealth on the amount of energy we use. Will the increase in electronic devices, as part of the energy transition, create a new problem in the form of a shortage of the natural resources needed to build those devices? Especially when it comes to the minerals and metals needed for these devices, scarcity will play a role in the future.

Energy in a sustainable world

The publication also addresses the future of energy after we manage to realize the climate goals. What will the future of energy look like and what does that mean for our daily lives? An inspiring way to get an idea about this is to write stories that take place in 2050. Following, an example of one of those stories. Other stories involve developments like wireless energy, circular economy and a changing society.

THE GREEN HIGHWAY – MUSINGS FROM 2050

“People used to say that everything would be different in the future, but actually that is not the case. Look at how we transport ourselves, we still use bicycles, cars and buses. Big cities are still connected by trains and we still fly.

Of course, some things have changed In Europe, there are *hyperloops*¹ in a number of places and, while we used to own our cars in the past, transportation has now become more of a service. Let's face it, there is a lot to be said for having access to a car within five minutes, while never having to worry about maintenance and fueling.¹ Because the cars drive themselves and have become electric, they take care of all that themselves.

Actually, now that I think about it, a lot has changed, it's just that you don't often pay attention to it. Because these days we share cars and as a result many parking spaces have become redundant. We have used the available space to build broader sidewalks and create more parks. As a result, streets look different.

Also, there are fewer gas stations. They still exist, mind you – for the hobbyists and their vintage cars – but over time they will disappear because drones increasingly take care of deliveries, which means they can also deliver fuel. Whenever cars need energy on the highway, they can move to the loading lane where their batteries will be charged as they drive along.¹ However, this is usually not necessary, because if a car is in between passengers, it can go to one of the many parking flats and recharge.

Perhaps that is progress, those new technologies are so normal that you think everything is still the same.”

Finally

The future will come along and if we want to avoid irreversible climate changes it is important to develop a long-term vision **now** on how to keep the world livable and what that means for our society. Three quarters of the greenhouse gases causing global warming are produced by our current energy system. That is why we need to develop a new, emission-free energy system and that is a challenge that still requires a lot of innovation. Technological and social innovation.

The backcasting study that was conducted during the research shows that the government will have to take a leading role, after which the market can create an acceleration. We need to focus on research and development. The government, together with business and society, has to reflect on a new energy policy with clearly formulated and formal objectives and their (long-term) consequences. It is important to consider the long-term consequences of the various choices now, and not to sacrifice those choices to political or social short-term priorities.

Because it is better to make a choice now and later make the necessary changes than to discover in 2050 that we have chosen the wrong path.

The future of our energy system in 2050 starts now!

¹ The idea of the hyperloop is that of a vehicle similar to a metro in which the cabin is propelled by magnets in a vacuum tube, capable of reaching speeds of up to 1200 km/h

² The development from product to service is something that has already started. With regard to music, for instance, CD's are being replaced by streaming services. If this trend continues, most of us will no longer own a car in the future. Only hobbyists will own a race car or a beautiful vintage car.