# Dutch National Research Agenda
# Route Energy Transition


*Towards a sustainable and secure energy supply and a strong green knowledge-based economy*

NERA Netherlands Energy Research Alliance



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# Towards a sustainable and secure energy supply and a strong green knowledge-based economy: the Dutch National Research Agenda for the Energy Transition

## Energy transition as challenge *and* opportunity

To keep the global temperature rise well below 2°C and aim for 1.5°C while ensuring energy security, we need to make radical, and rapid changes to our energy system. The survey conducted by the Energy Transition Route shows that the Netherlands has a strong knowledge base that includes parties from the important areas of technology, society, economy and law. Joining these forces and working together to take the required integrated approach will enable the Netherlands to take its place among the world's leaders in the energy transition. This also provides an opportunity to build a strong green knowledge-based economy. In doing so, we will create new jobs in the sustainable energy sector and other sectors, such as high-tech systems and materials, ICT and services, and we will also strengthen our export position.

## Integrated, ambitious approach

The Netherlands has taken important steps in recent years towards achieving a sustainable energy system. Sustainable energy research and development takes place in a large number of technical and non-technical disciplines and Dutch energy science has acquired a leading position in several areas. This is vitally important if we are to achieve a successful transition and make the most of the economic opportunities presented, and we need to nurture and further expand this leading position. Even so, it is not enough: the urgency and complexity of the transition and increasing international competition imply that much more is needed, both in terms of quality and quantity. For example, even economically attractive technical solutions are not automatically implemented at a large scale and even a carefully developed policy incentive does not automatically result in market success for sustainable energy technologies.

***The game changer for a successful transition to a sustainable and secure energy system is an integrated approach to technical, social, economic, legal and spatial challenges that allows excellent building blocks to be implemented quickly and on a large scale.***

The core elements are: excellent building blocks, an integrated approach and broad support. This means that developments need to take place in a coherent, structured fashion. This requires cooperation between the humanities, social and behavioural sciences and the natural sciences; the government, knowledge institutes, the business community and non-governmental organisations; and between various economic sectors. The urgency, complexity and increasing competition also imply that a higher ambition level is required in terms of energy innovation if the Netherlands is to achieve optimum economic benefit from the opportunities that the global transition presents. The necessary resources are quantified in the chapter 'Required investments'.

## Context

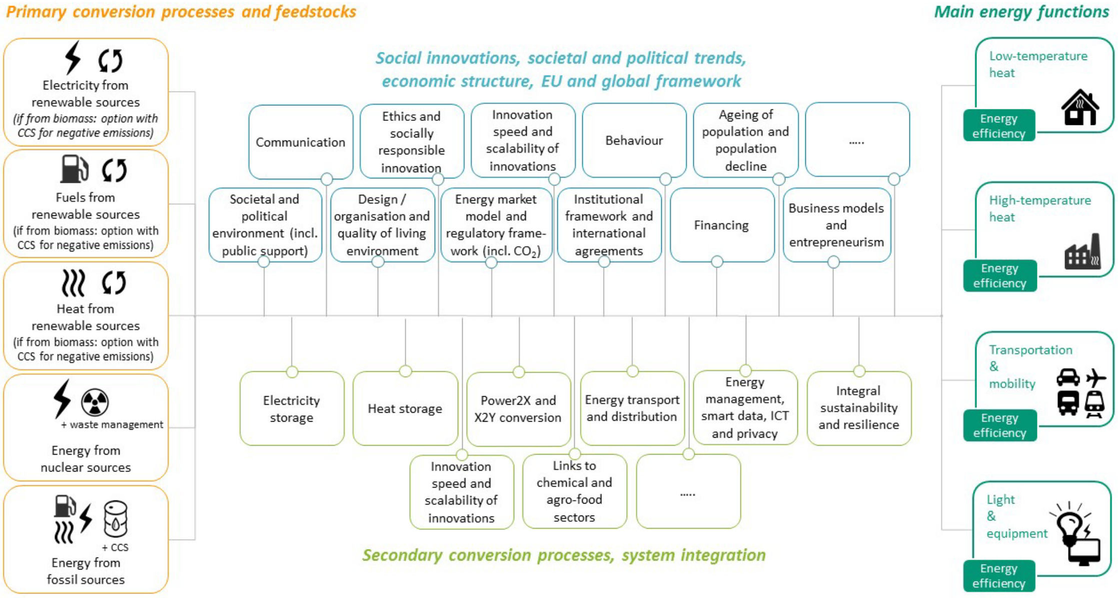
The Dutch National Research Agenda (NWA) Energy Transition Route does not stand alone. First of all, it is of course based on the energy-related NWA questions. It is also consistent with *Mission Innovation: Accelerating the Clean Energy Revolution*[1], an initiative taken by countries that aim to accelerate the transition and that made agreements at the COP21 Paris climate conference to do just that. The route also builds on the Council for the Environment and Infrastructure (Rli) report *A Prosperous Nation without* $CO_2$ . Furthermore, it provides essential input for development of the energy report *Transition to Sustainable* published in January 2016 and the corresponding Energy Dialogue. This route therefore touches on the core of the Dutch energy and climate policy. The Energy Transition Route is also strongly related to many other routes, in particular to Materials, Circular Economy and Resource Efficiency, Sustainable Production of Safe and Healthy Food, Smart Liveable Cities, Environmental Quality, Resilient and Meaningful Societies, Smart Industry, Logistics and Transportation, the Blue Route and Responsible Use of Big Data.

[1] www.mission-innovation.net.

## NWA route for an integrated approach to the energy transition

This route describes ten important and urgent Challenges that need to be addressed in long-term programming in close collaboration between public and private parties. Although the Challenges are by nature multidisciplinary, it is crucial that they are also addressed in mutual dependence. If it is to be successful, such a programme must include all aspects, from basic research to development, demonstration and implementation, and including ‘living labs’. Only then can pioneering innovations find their way into the public domain and the market, quickly and on a large scale, and truly accelerate the energy transition. And only then can the Netherlands seize the economic opportunities available in this highly competitive international sector.

This route description does not pretend to provide a comprehensive overview of all the challenges associated with the energy transition, nor does it suggest that the transition will end in 2050. What it does do is describe solutions that can make a substantial contribution to the transition in the period up to 2050. The reason for this is the urgency (as mentioned above) to achieve results in the transition. Options that are expected only to contribute in the longer term are not described explicitly in the challenges, but should be included in the final research portfolio.

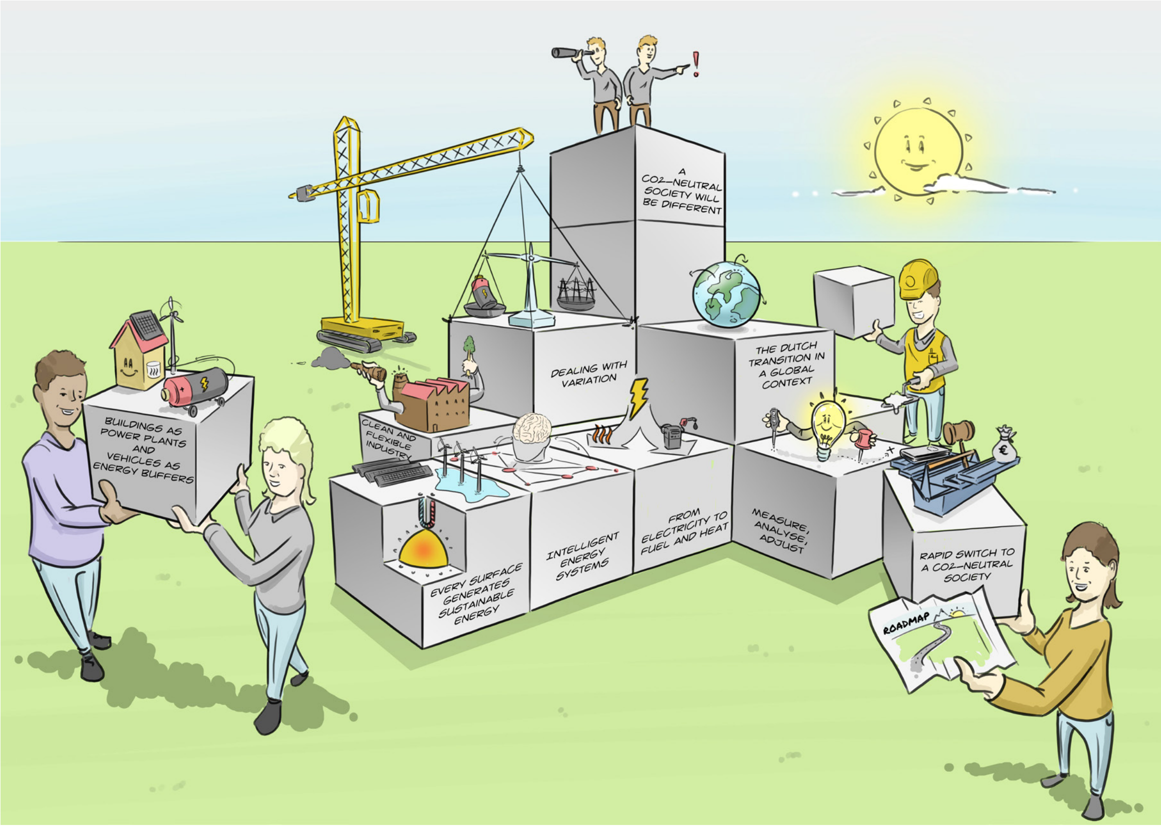



The ten challenges were developed through an intensive process of surveying, prioritising, integrating and formulating; a multidisciplinary process in which over 200 experts were involved with a wide range of backgrounds who together covered the whole of the spectrum required. The energy transition ‘playing field’ was outlined to enable a structured discussion in the preliminary stage (see above). To the right are the energy functions as defined in the Rli report mentioned above. To the left are the energy supply options in as far as they are consistent with the transition objectives. In the centre are the elements required to link the supply options and the functions in the transition process and in the integrated sustainable energy system. All ten Challenges link different sources and energy functions and make use of several technical and non-technical elements from the central part of the playing field. For all the Challenges, the connection to the underlying NWA questions is given.

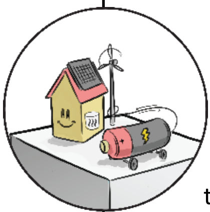
## Required investments

Total public investment in energy research and innovation in the Netherlands (excluding deployment subsidies such as the Sustainable Energy Incentive Scheme (SDE+)) currently amounts to about 250 million euros a year, divided roughly 50/50 between academic research and applied research and technology development. This investment needs to be doubled to at least 500 million euros a year if the ambitions described in this Energy Transition Route are to be realised, as shown by the quantification given for each challenge. Such a doubling is in line with the agreements made by the signatories to *Mission Innovation* (see ‘Context). The resources required for each challenge vary widely. Strong international competition and large export opportunities as well as the complexity of Challenges in some cases demand extra ambitions and resources.

## Ten Challenges for the energy transition




### Buildings as power plants and vehicles as energy buffers



Not only can buildings and vehicles be made much more energy-efficient, they can also be given an active role in the energy system. New and better technologies, products and services can optimise the energy performance of buildings, building clusters or urban areas (highly energy-efficient, energy-neutral or even energy-generating) and combine this with comfort, convenience, attractiveness and lower running costs, making large-scale application possible. In addition, the fast, cheap, low-risk and low-impact ‘deep renovation’ of existing buildings makes it possible for the large existing stock to successfully contribute to the energy transition. Buildings and vehicles act as buffers (for heat and/or electricity) between a variable energy supply and demand. Market models and legislation are optimised for such applications. Owners, operators and users are encouraged and motivated to use buildings and vehicles for this purpose.

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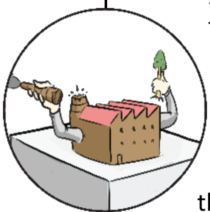
### Clean and flexible industry



Industry will go through a transformation: from being just a user to being an energy user *and* a supplier of flexibility and storage. Future production processes will have no net $CO_2$ emissions, they will be much more energy-efficient and will use sustainable resources. Sustainable energy (electricity and heat) will replace energy from fossil fuels. Biomass and captured $CO_2$ and nitrogen from the air will form new sustainable raw materials, with potentially negative emissions. This requires technologies and processes that are much more energy-efficient than those currently available, that have the flexibility to absorb fluctuations in the supply of raw materials and renewable energy, and that involve low investment costs. In the long term, this transformation will close loops (circular industry) and enable regions to be largely self-supporting in terms of energy and raw materials.

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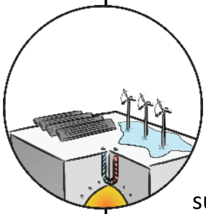
## Every surface generates sustainable energy



Sustainable energy generation is a corner stone for a sustainable energy economy. This means highly efficient and cheap solar, wind and geothermal energy applied on a large scale and in an attractive, socially acceptable way in the limited space available in the Netherlands: buildings, infrastructure, landscape (including inland waters and the sea) and the subsurface. Sunlight-to-electricity conversion efficiency needs to double. Flexible solutions need to be developed for integration and function combination in buildings and other objects. Fuel production using sunlight will become a fully-fledged component of the energy system. The potential for the compound use of the sea (combinations of wind, sun, bio-energy, bio-materials and energy storage) will be unlocked and the value of offshore wind energy will increase. The use of geothermal energy will be economically sound and sustainable. Integrated spatial development models will support the large-scale introduction of sustainable energy generation.

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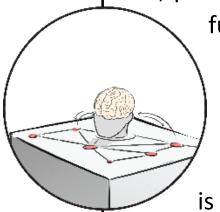
## Intelligent energy systems



ICT, partly based on new developments in mathematics and computer science, is needed to realise the future energy system as this will be more complex than the current one, both technically and organisationally. Advanced ICT combined with smart networks is required to get centralised and decentralised sections of the energy system and its users working effectively and efficiently together with the variations over various timescales (from very short to hours, days and seasons) and to guarantee reliability, availability and affordability. The collection and use of big data that is relevant for generation, storage, distribution and consumption is crucial in this. Furthermore, ICT can stimulate users to make sustainable use of energy and can be used to achieve energy savings. Critical design factors are public acceptance, ethical aspects, autonomy, robustness, privacy and cyber security.

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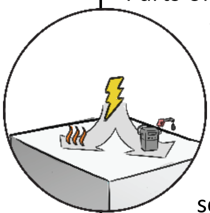
## From electricity to fuel and heat



Parts of the transport sector, such as aviation and freight transport, as well as industry, depend on fuels with a high energy density and on high-temperature heat. To increase the sustainability of these sectors, scalable, cheap and efficient chemical processes are required that convert electrical energy into fuel using biomass, captured $CO_2$, nitrogen or water. Technologies are also needed for the cheap and efficient conversion of electricity into high-temperature heat. This requires research into new, efficient electrocatalytic and electrochemical processes with a high product selectivity, including research into new catalysts based on abundant elements.

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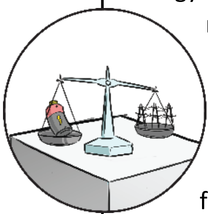
## Dealing with variation



Energy supply and demand will vary in time and place in the future energy system. This therefore requires research and development on flexibility on the side of the energy consumers, with user behaviour and acceptation as important factors. Also important is the development of balancing, transport, distribution and storage technologies for electricity and other energy carriers. These elements will be used in the design and realisation of the integrated energy system. This includes the development of an effective economic system, including markets, governance models and legal frameworks for a society in which an optimum match is achieved with the varying supply of sustainable energy at the various timescales (very short, hours, days, seasons).

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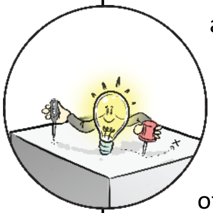
## Measure, analyse, adjust



It is crucial to measure the effect of the energy transition on emissions of $CO_2$ and other greenhouse gases and to analyse the impact of reduced emissions on climate change. Not just the direct emissions are important, but work must also continue on analysing the greenhouse gas emissions of individual products in the product chain ($CO_2$ footprint). As well as greenhouse gas emissions, secondary effects will be measured, such as improvements in air quality. Such analyses can be used to optimise the pathway chosen. Conversely, we also need to learn more about the effects of climate change on the energy system and beyond so that we can be proactive in limiting the negative effects. Effective communication of the results with all stakeholders, including end users, is important as well.

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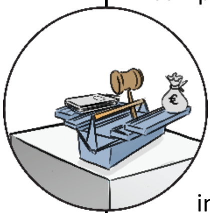
## Rapid switch to a $CO_2$-neutral society



A complete switch to a $CO_2$-neutral energy system within a few decades demands an unprecedented fast rate of innovation and social change. Social, economic and legal instruments that form the basis for very rapid innovation and the application of new practices will need to be developed. Attracting the investments needed for the transition to a sustainable energy system also presents a big challenge. An important theme is how to generate effective incentives to stimulate efficient and sustainable energy use and to reduce emissions. Well-founded policy choices and effective interaction between the general public, the public sector and the private sector are crucial in this. Particular attention is required for the opportunities available to achieve negative $CO_2$ emissions in order to further accelerate the switch to a $CO_2$-neutral energy system.

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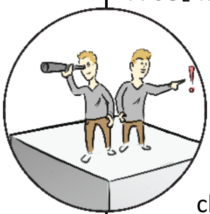
## A $CO_2$-neutral energy society will be different



A $CO_2$-neutral energy system will probably look very different from our current fossil fuel-based society. It is very important to properly understand the changes that will take place due to the transition to a $CO_2$-neutral energy society. Insight into the societal changes within and beyond the energy sector is important to be able to manage the transition process and to adjust it where necessary. Elements of this transition include a different spatial design, a transition to circular processes, new forms of transport, infrastructure for energy carriers (electricity, hydrogen, etc.) and changing lifestyles. Public acceptance of certain solutions will also determine the resulting transition process and societal structure.

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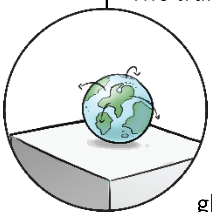
## The Dutch transition in a global context



The transition to a sustainable energy system is a global process and therefore requires a global approach. It involves international research and policy efforts to learn from one another, to understand the conflicting interests that hinder a sustainable energy transition and why these exist, and to learn how to harmonise interests. It also requires a coherent approach in which the costs and benefits of the transition are evenly distributed. Another requirement is an understanding of cultural differences in preferences, behaviour and acceptance, as well as opportunities for guaranteeing global access to energy while maintaining national security of supply and reducing climate problems. Finally, a comprehensive, global chain analysis of energy and material flows and insight into the effects on people and the environment will enable a socially responsible energy transition to take place. 'Think global, act local.'

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