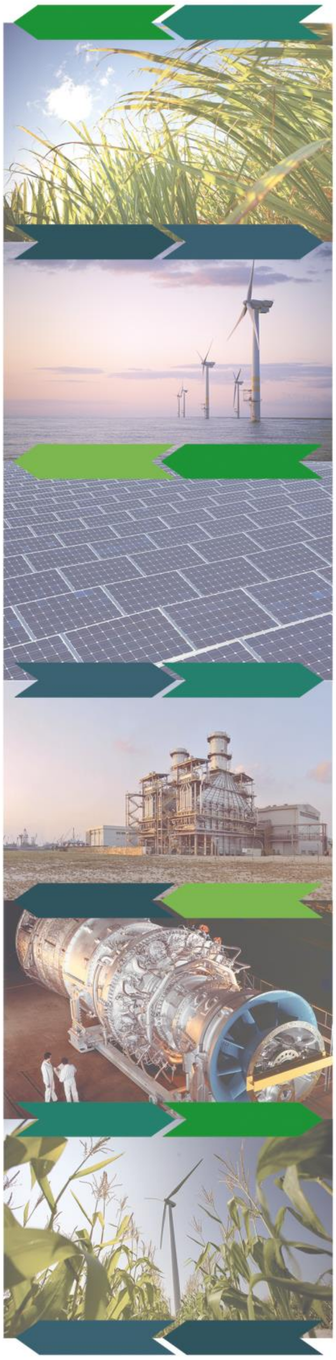
Navigating the Roadmap for Clean, Secure and Efficient Energy Innovation



Final Report on SET-Nav Policy Briefs

Author(s): Charikleia Karakosta, Katerina Papapostolou (NTUA);

Pedro Crespo del Granado, Ruud Egging (NTNU);

Marijke Welisch, Michael Hartner, Gustav Resch, Sebastian Forthuber, Lukas Kranzl, Eric Aichinger, Andreas Müller (TU Wien);

Charlie Wilson, Louis Coningsby, Yeong-Jae Kim (UEA);

Sara Lumbreras, Luis Olmos, Andrés Ramos (Universidad Pontificia Comillas);

Frank Sensfuss, Gerda Deac Christiane Bernath, Andrea Herbst, Stephanie Heitel, Michael Krail, Jonathan Köhler, Tobias Fleiter, Matthias Rehfeldt (Fraunhofer ISI);

Dawud Ansari, Franziska Holz (DIW Berlin);

Peter Kotek, Borbala Toth, Adrienn Selei (REKK);

Baptiste Boitier, Arnaud Fougeyrollas (SEURECO);

Gerardo A. Perez-Valdes, Ulf Johansen (SINTEF);

March / 2019

A report compiled within the H2020 project SET-Nav (work package 11, deliverable D11.14)

www.set-nav.eu

Project Coordinator: Technische Universität Wien (TU Wien)

Work Package Coordinator: National Technical University of Athens (NTUA)

SET-Nav
Strategic Energy Roadmap

The project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement no. 691843 (SET-Nav).

Project coordinator:

Gustav Resch, Marijke Welisch

Technische Universität Wien (TU Wien), Institute of Energy Systems and Electrical Drives, Energy Economics Group (EEG)

Address: Gusshausstrasse 25/370-3, A-1040 Vienna, Austria

Phone: +43 1 58801 370354
Fax: +43 1 58801 370397
Email: resch@eeg.tuwien.ac.at; welisch@eeg.tuwien.ac.at
Web: www.eeg.tuwien.ac.at

Dissemination leader:

Haris Doukas, Charikleia Karakosta (Project Web)

National Technical University of Athens (NTUA-EPU)

Address: 9, Iroon Polytechniou str., 15780, Zografou, Athens, Greece

Phone: +30 210 7722083
Fax: +30 210 7723550
Email: h_doukas@epu.ntua.gr; chkara@epu.ntua.gr
Web: http://www.epu.ntua.gr

Lead author of this report:

Dr Charikleia Karakosta

National Technical University of Athens (NTUA-EPU)

Address: 9, Iroon Polytechniou str., 15780, Zografou, Athens, Greece

Phone: +30 210 7722083
Fax: +30 210 7723550
Email: chkara@epu.ntua.gr
Web: http://www.epu.ntua.gr

Table of Contents

1 Introduction 1

2 Innovation Systems and the SET – Plan 1

2.1 Systemic Perspective on Energy Innovation 1

2.2 Research on Innovation Systems and the SET Plan 1

2.3 Policy Recommendations and the SET Plan 2

3 Policy implications and priorities from modelling in the SET-Nav project 3

3.1 What next steps and priorities for the SET Plan? 3

3.2 The SET-Nav pathways 4

3.3 What are the important elements, drivers and factors of the energy transition and their cost-effective solutions (for each pathway)? 4

3.4 Summary of key findings for the different pathways 5

4 SET-Nav Case Studies Conclusions and Policy Recommendations 6

4.1 Model integration & Global perspectives 6

4.2 Energy Systems: Demand perspective 7

4.3 Energy Systems: Infrastructure 8

4.4 Energy Systems: Supply perspective 9

5 References 11

1 Introduction

The Policy Brief: Final Report on SET-Nav Policy Briefs was developed to summarise the project's outcomes. This policy brief includes the main policy recommendations arisen from SET-Nav's implementation. More particularly, the brief highlights the ways that research on innovation systems can inform the SET Plan, investigates the energy and climate status development towards 2050 through the introduction of SET-Nav pathways, briefly presents the SET-Nav case studies and underlines the policy implications and priorities from modelling in the SET-Nav project.

2 Innovation Systems and the SET – Plan

This briefing uses a systemic perspective on energy innovation to inform the EU's Strategic Energy Technology (SET) Plan. The briefing makes five high level recommendations each of which is supported by a series of specific research insights. These insights are set out in a longer policy report which provides extensive examples, arguments, and links to relevant research literature[1]

2.1 Systemic Perspective on Energy Innovation

A systemic perspective on innovation (right panel of Figure 1) emphasises that innovation stages and processes like R&D and market diffusion are supported by a broader innovation environment comprising knowledge, actors & institutions, resources, and adoption & use.[2] A systemic perspective also identifies structural and transformational failures that provide a strong rationale for policy.[3] Innovation system policies involve a diverse range of policy instruments.[4] A systemic perspective on innovation emphasises multi-stakeholder governance of innovation processes, and enabling frameworks or conditions to direct innovation activity.

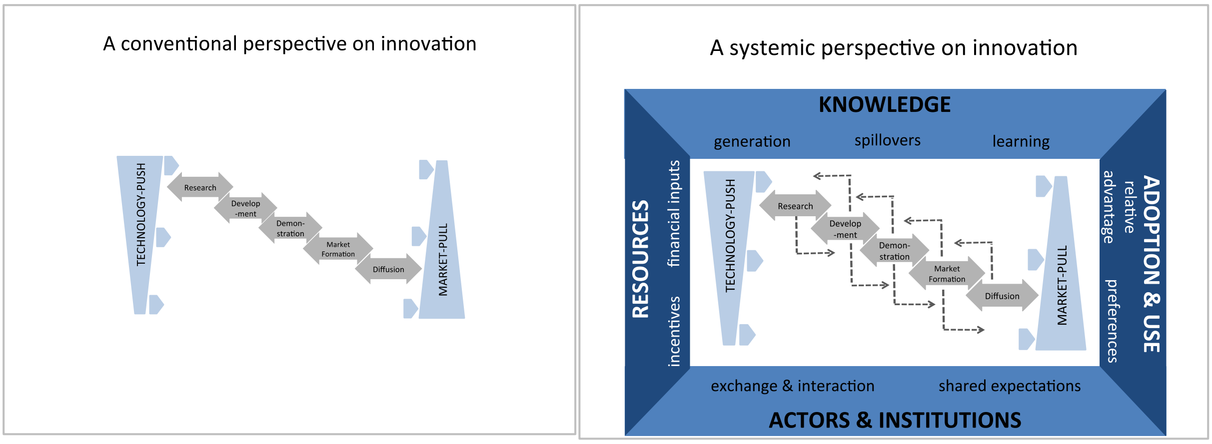


Figure 1. Conventional vs. systemic perspectives on energy innovation.[5]

2.2 Research on Innovation Systems and the SET Plan

1. ***Ensure the SET Plan is directed by a shared vision towards clear goals:*** Shared visions establish the legitimacy and credibility of directed system transformations, and should be articulated by a wide range of social and political actors.
2. ***Ensure the SET Plan builds strong networks among diverse innovation actors:*** Networks

between innovation actors support the availability and flow of information within an innovation system.

3. ***Ensure the SET Plan aligns institutions and builds user demand for technological innovations:*** Coordinated and aligned institutions complement technological innovation; misaligned institutions stagnate innovation.
4. ***Ensure the SET Plan coordinates an effective mix of stable innovation policies matched to specific innovation needs:*** Mix of policies is necessary to address the diverse structural and transformational failures in innovation systems. Policy mixes contain technology-push and market-pull instruments.
5. ***Ensure the SET Plan generates policy intelligence to support learning and adaptation:*** Policymaking for energy innovation is open-ended and uncertain. Policy intelligence helps anticipate emerging opportunities, risks of failure, and alternative options.

2.3 Policy Recommendations and the SET Plan

Table 1 maps the five high-level policy recommendations onto the main elements of the SET Plan. These elements are grouped under strategy, governance, and mechanisms. The mapping in Table 1 identifies how and where the SET Plan can incorporate the policy recommendations provided by a systemic perspective on energy innovation.

Table 1. Policy recommendations mapped onto SET Plan elements.

Notes: shade of green denotes strength of mapping (dark = strong correspondence … light = weak correspondence).

		STRATEGY		**GOVERNANCE**		**MECHANISMS**	
	Ensure the SET Plan …	**priority areas and actions**	**action-specific targets and roadmaps**	**steering group and management**	**stakeholder networks**	**monitoring and reporting**	**funding mechanisms**
1	*… is directed by a shared vision towards clear goals.*						
2	*… builds a strong network among diverse innovation actors.*						
3	*… aligns institutions and builds user demand for technological innovation.*						
4	*… coordinates an effective mix of stable innovation policies matched to specific innovation needs.*						
5	*… generates policy intelligence to support learning and adaptation.*						

3 Policy implications and priorities from modelling in the SET-Nav project

The SET Plan aims to accelerate the development and deployment of low-carbon technologies. It seeks to improve new technologies and bring down costs by coordinating national research efforts and helping to finance projects. In this policy brief, we focus on specific energy transition questions addressed by the SET Nav pathways. Through a large-scale modelling effort, we describe key insights based on the SET-Nav main modelling perspectives: demand side, energy supply and infrastructure, and the macroeconomic effects.

3.1 What next steps and priorities for the SET Plan?

According to SET-Nav analysis, the following key priorities for the SET-Plan should be made:

- The diversity of the energy technology portfolio across the full set of priority areas should be increased. At the same time, more consistency is needed, specifically by increasing SET Plan activity in the areas of generation, codification, spillover, and international flows of knowledge in the sustainable transport and energy efficiency areas. Furthermore, market activity and innovation efforts should be aligned, especially in the smart grid and sustainable transport areas.
- Regarding the different sectors, the main priorities from the demand side are decentralised heat supply, heat pumps and implementing corresponding activities. Furthermore, to decarbonise industry, extending the ETS with a minimum price as well as expanding public RD&I funding are important measures. Furthermore, a CO_2 tax as the central element of a broader energy tax reform could provide the incentives needed for fuel switching. Policies to overcome barriers to energy efficiency are also crucial, as is pushing sales of electric vehicles and inducing a modal shift from cars to public transport, car-sharing, cycling and walking.
- In terms of energy infrastructure, electricity network development for integrating new RES generation is a prerequisite, as is preparing grids for the integration of large volumes of Distributed Energy Resources (DER) and for new forms of storage. From the supply perspective, our analysis shows that direct electrification should be favoured wherever reasonable as it is more efficient and leads to fewer requirements on generation infrastructures (e.g., power grid upgrades or conventional generation).
- The final takeaway is that efficient decarbonisation via direct or indirect electrification requires efficient linkages between the energy markets by monitoring close to real-time carbon content of energy carriers.

3.2 The SET-Nav pathways

The EU Energy Roadmap 2050 [6] and various stakeholders' discussions with the European Commission have outlined four main decarbonisation routes for the energy sector. These are Energy Efficiency; Renewable Energy Sources (RES); Nuclear; and Carbon Capture & Storage. The **SET-Nav pathways** assess the *drivers, factors and scenario dimensions* that affect these decarbonisation options.

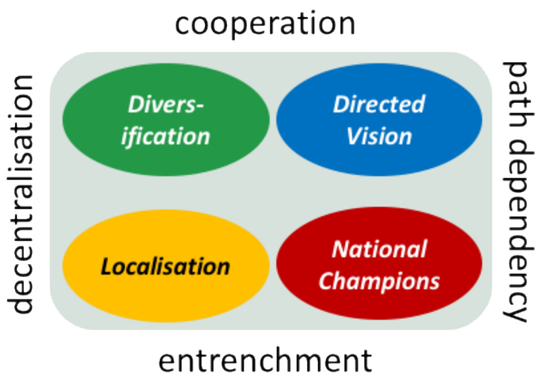


Figure 2: SET-Nav pathway storyline visualisation

The **diversification** pathway depicts a decentralised but cooperative world where many new entrants and heterogeneous actors determine the market. Digitalisation, prosumers and high support for coordination as well as regulatory opening characterise this pathway. The **directed vision** pathway goes in a different direction. Although the scenario is still a cooperative one, we see more path dependency and strong EU guidance in determining the shared vision. Large actors are favoured.

The other set of storylines is less cooperative: the **localisation** pathway focuses on the exploitation of local resources. National strategies differ according to country and public resistance leads to lower investment in big new infrastructure but rather favours the emergence of market niches and digitalisation. Finally, the **national champions** pathway minimises transition costs which allows a strong role for incumbent firms and utilities. This transition is highly path dependent and favours large-scale projects. For more details on pathway modelling and analysis, see the SET-Nav Pathways report.[7]

3.3 What are the important elements, drivers and factors of the energy transition and their cost-effective solutions (for each pathway)?

	Diversification	Directed Vision	Localisation	National Champions
Buildings	a mix of decentral heat pumps, biomass boilers and solar thermal systems in combination with IT solutions for smart heating are the cornerstones of CO_2 mitigation technologies	same technologies as in diversification, but with less focus on smart heating solutions and less use of decentral heat pumps	it is assumed that due to regulations higher market shares of district heating can be reached. Decentral renewable heating options still play a key role in areas with lower heat density	member states follow very different strategies. It is also assumed that member states with currently high shares of natural gas could opt for green gas solutions to avoid the decommissioning of gas grids

Industry	a stronger fuel switch to biomass, power-to-heat, power-to-gas and radical changes in industrial processes (e.g. switch to hydrogen, low carbon cement sorts) take place	no radical process improvements take place, as companies invest in CCS for major energy-intensive point sources instead of other radical process improvements	a stronger fuel switch to biomass, power-to-heat, power-to-gas and radical changes in industrial processes (e.g. switch to hydrogen, low carbon cement sorts) take place	no radical process improvements take place, as companies invest in CCS for major energy-intensive point sources instead of other radical process improvements.
Transport	transport system as a 'mobility as a service' system. Multi-modal information platforms and services, car-sharing and autonomous driving enter into the market early in this pathway and overall efficiency increases	joint decisions on technology across EU countries like overhead-cable infrastructure for trolley trucks and phase-out of pure fossil-fuel based cars, prices for new technologies decline fast. In addition, strong support for improving public transport also for national and international distances supports the modal shift to more efficient modes	car-sharing, public transport, walking and cycling increases. Decentral electricity production including roof-top PV increases incentives for households to buy electric cars. Overall technological learning is slower due to more technological diversity. Therefore, and due to the focus on using local resources, the demand for biofuels is relatively high	The strategy is to stay with internal combustion engine technologies but substituting fossil fuels by biofuels. Technological progress for sustainable biofuel production (incl. 2nd- and 3rd-generation biofuels) and optimal use is made of biomass and existing filling station infrastructure can be maintained

3.4 Summary of key findings for the different pathways

We identified a variety of actions to achieve a decarbonised future taking different pathways. The different pathways are based on storylines of different, largely political decisions regarding the future of the European Union. Depending on political realities, different key research questions will come into focus. Below, a few examples show how they might play out.

Diversification	**Directed Vision**
- innovation research - developing a variety of new technologies - strong use of local renewable resources with very high hydrogen demand	- more likely to call for ideas on how to expand the grid - manage cross-border flows of electricity in the most cos- efficient manner
Localisation	**National Champions**
- innovative solutions for decentralised energy and the distribution grid - radical changes in industrial processes, stronger switch to biomass, power-to-heat, power-to-gas - strong use of local renewable resources with very high hydrogen demand	- would need decarbonisation solutions for an incumbent energy sector - Green gas solutions - No radical changes in industrial processes and continued use of the internal combustion engine

4 SET-Nav Case Studies Conclusions and Policy Recommendations

Using SET-Nav's strengthened modelling capabilities in an integrated modelling hierarchy, multiple dimensions of impact of future pathways: sustainability, reliability and supply security, global competitiveness and efficiency are analysed. This analysis combines bottom-up "case studies" linked to the full range of SET-Plan themes with holistic "transformation pathways" described in the previous section. The conclusions and policy recommendations that emerged from each case study are presented in brief below.

4.1 Model integration & Global perspectives

Modelling the European energy system and taking account of the inter-dependence between European policy and the global demand and supply of fuels is no easy task. SET-Nav determines a number of important parameters regarding the global fuel markets (prices, import availability).

Scenarios or the global fossil fuel markets

Capturing the interdependence between European low-carbon policy interventions with other regions is of paramount importance. Incorporating the reaction of global fossil fuel prices to domestic demand for fuel imports and European technological progress is critical to understand issues, such as carbon leakage and technology spill-overs. Vice-versa, trends in global fossil fuel markets will influence decisions in Europe. This case study captures the interdependence between European policy and global fossil and renewable energy markets as well as technological progress.[8]

Conclusions and policy recommendations

International relations and the state of security are strongly tied to the renewable energy transition in the long-run.

Regional conflicts and resulting humanitarian crises have fuelled the re-emergence of protectionist policies and represent a risk not only for European integration, but also for the effectiveness of the European Union's energy and climate policies in the absence of multilateral climate cooperation. However, as some recent examples have shown, too, greater cooperation between countries in the form of investments as well as technological and financial transfers could well spur a new dynamic for international climate policy.

Energy transition needs to be integrated with wider economic objectives such as poverty alleviation, infrastructure modernisation, and private investment.

While that relationship appears to already hold in today's world, it is easily strained by political tensions and protectionist policies. Growing energy demand from the developing world can easily jeopardise mitigation efforts if coordination between economic and energy-related objectives is absent. The 'Green Democracy' storyline, however, conversely highlights the opportunities to be seized in the energy transition.

It is crucial to develop an inclusive approach to policy-making that combines both mitigation and adaptation options.

Adaptation technologies are not necessarily risk-free and failure to adopt a comprehensive approach could very well lead to new environmental, societal, and political problems that would further hinder the global energy transition. At the other end of the spectrum, balancing the use of both options can encourage new investments, stakeholders, and more dynamic relationships between the relevant actors.

4.2 Energy Systems: Demand perspective

The main objective of the simulation of energy in industrial processes is to set-up a modelling framework that allows simulating the transition to a low-carbon energy system for the industrial sector in an integrated manner. Technology solutions like RES, energy efficiency, CCS and the links to the power and gas sectors are considered. For the analysis the existing bottom-up model FORECAST-Industry is used that has been applied in various EU and national projects for similar research questions[9].

A combination of measures is required to accelerate the transition towards a decarbonized transport system. The diffusion of low and zero-emission technologies depends on several factors, in particular vehicle prices and running costs, sufficient filling and charging infrastructure, convenience and the variety of available vehicle models. Measures to push sales of electric vehicles include stricter fuel efficiency or CO_2 standards that put pressure on the automotive industry to develop and offer more and better electric vehicle alternatives to conventional ICE vehicles, infrastructure deployment to ensure reliability and to reduce range anxieties and measures to reduce costs for new technologies while increasing costs for conventional vehicles (such as fuel taxes and vehicle registration taxes based on the related emissions). Decisions on phasing out pure ICE cars are an effective intervention to accelerate the diffusion of alternative drive technologies and should be taken into consideration. By 2030, the infrastructure required for low-emission technologies should be implemented at least for the core motorway network. This includes depending on the chosen technologies overhead cables for trolley trucks, sufficient filling and fast charging stations including their supply with hydrogen and sustainable biofuels.

Modal shift from cars to the more efficient modes public transport, car sharing, cycling and walking can be achieved by making cars less attractive via urban policies (ban in cities at least for fossil-fuel based cars, parking policies) while promoting and increasing the convenience of more sustainable modes (multi-modal platforms enabling seamless ticketing, reduced waiting times and real-time trip planning; town planning measures to improve infrastructure for active modes).

The diffusion of zero-emission vehicles like battery electric cars, fuel cell electric trucks and hybrid trolley trucks generates an increasing electricity demand by the transport sector. Increasing biofuel shares as blend for fossil fuels leads to a growth of required biomass. Biofuel production capacities need to be built up. In contrast, the consumption of fossil fuels should decrease strongly over time.

The ambitious scenarios and pathways analysed reflect radical changes that need to be achieved within only three decades. Policies need to be in place soon to drive this transition considering the lifetime of vehicles, the required time for fundamental acceptance of new technologies and for changes in behaviour, supply chains and business models.

If there are coordinated joint approaches between countries, prices for new technologies could decrease faster due to learning effects and economies of scale. Intensive discussions are required on the best policy mix on European and national level. Relevant discussion points include the current strategy of technological openness versus a focus on the most cost-efficient technology pathway and most effective and cost-efficient policy measures. Moreover, measures for the transition should ensure affordability and inclusiveness of mobility. More research seems needed to evaluate alternative technologies and strategies for the deployment of new infrastructure. Studies on acceptance, economic, social and ecological impacts and secure supply of scarce resources should be considered when narrowing options down to specific technological solutions.

4.3 Energy Systems: Infrastructure

The security of energy supply is a key policy objective that presents a special significance in the case of natural gas, where imports dependency is particularly high. Strengthening and diversifying the connections to major suppliers, and investing in additional LNG regasification capacity will be instrumental to reduce this supply risk. These infrastructure upgrades have a deep impact in the future European energy system.

Three case-study analyses were conducted[10].

The first one, "Decentralised vs. centralised development of the electricity sector – impact on the transmission grid" evaluated the different needs for transmission when developing renewables either in a centralized way (for instance, large wind farms) versus the same capacity in distributed technologies (namely, rooftop PV). We could see that the centralised case is much more cost effective, although generation is much less costly in the centralised case, the infrastructure needs are high in both scenarios.

The second case study, "The role for carbon capture transport and storage in electricity and industry in the future", showed that with an optimistic perspective on CCTS costs and the availability of advanced CCS technology, one can expect the installation of 55 GW of CCTS capacity in the electricity sector until 2050, considering a moderate climate policy ambition in the Business as Usual Pathway, or even 189 GW in electricity and, in addition, 2 bn. t of CO_2 captured in the industry sector if the climate ambition is high, as in the Decarbonization Pathway. With pessimistic assumptions on the CCTS cost development, CCTS would not be deployed at all.

The third case study, "Projects of common interest and gas producing pricing strategy" evaluated a series of possible investments in the European gas network. The overall result is that investment is in general not needed above the current levels. According to the analysis, the following PCIs are to be commissioned: Shannon LNG terminal in Ireland, Krk LNG terminal in Croatia, Interconnector between Hungary and Slovenia, Interconnector between Turkey and Bulgaria, Baltic cluster (Tallin LNG and Baltic pipelines), Interconnector between Poland and Lithuania. Note that this investment need is highly influenced by the assumption that there is no Russian gas transited via the existing pipeline system in Ukraine after 2019. For several PCI projects none of the models provide support for their economic or welfare-based feasibility. These are the third interconnector between Spain and Portugal, the extension of capacities the Czech Republic and Poland (Stork II) and the BRUA pipeline due to high costs. This WP also analysed the impact of the pathways in the power grid, the gas network and CCS infrastructure.

Significant investment in the transmission network will be needed in any of the pathways considered. Thus, the transmission network will play a relevant role in any case. However, it should be kept in mind that this investment is only a fraction of the investments needed for generation infrastructure. In particular, those pathways where large amounts of renewable generation are deployed within some selected locations (Directed Vision and, mainly, Diversification) are the ones where transmission network developments will be largest. The interconnection between the Central region and the rest of the Continent will need to be significantly increased in all the pathways. Additionally, the level of investments to increase the transfer capacity between France and Spain will be very relevant in all the pathways as well. One last common feature of the development of the transmission network in all the pathways is the fact that interconnection between the UK and the rest of the Continent will be heavily developed.

In addition, HVDC comprises around 50% of the new transmission lines across all pathways, which highlights the importance of considering this type of technology in energy planning studies.

As opposed to the need for power infrastructure, a weak picture of the natural gas sector is shown across pathways. Although consumers realise considerable cost reduction compared to the reference case, infrastructure operators, producers, traders lose their traditional revenue streams and need to re-think the current business model.

The impact of CCS was also rather small in all pathways: the advantages in terms of system costs of a system with CCS are even less pronounced in the pathways than in the case study, which is why CCS use is rather small.

4.4 Energy Systems: Supply perspective

This case study presents the analysis of energy supply in strong decarbonisation pathways for Europe[11]. The developed bottom-up modelling framework is characterized by an unprecedented high level of detail in spatial temporal and technological resolution.

The modelling results demonstrate, that a stable European electricity and heat grid system is possible even for the ambitious decarbonisation goal of 96 % reduction. In order to achieve this GHG emission target, CO_2 prices will have to be much higher than today, in our results well above 100 €/t in 2050. However, energy prices do not show such a large increase, because the energy supply mix is dominated by low carbon technologies. In order to achieve this result efficient regulation of linkages between the different energy sectors is required. Heat supply and energy supply of other sectors such as the transport sector need to follow the real time situation of the electricity sector in an undisturbed way to react to weather situations.

The four scenarios show that there are different technology pathways to reach the target. But despite the differences it is a robust finding, that renewable energy sources and especially wind power will play a major role in the future energy supply. Furthermore, heat grids able to distribute heat from fossil or renewable fuels or power-to-heat are an important option to adapt to different developments in technology.

A strong power transmission grid helps to limit the energy system costs, because it allows to generate renewable electricity where generation costs are lowest, and it reduces the need for other (more expensive) flexibility options. Another important measure to keep costs low, is the direct use of electricity in other sectors such as power-to-heat in heat grids or electric vehicles for transport.

The direct use of electricity in other sectors reduces the requirements for the generation infrastructure compared to pathways with a stronger usage of hydrogen or "synthetic hydrocarbons", because these result in less efficient conversion processes.

Our results show that in world which is heavily dominated by renewable electricity generation electrolysis of hydrogen is a shoulder load technology rather than a base load technology. This results in a high share of capital costs in overall hydrogen production cost. The reconversion of hydrogen to electricity is mainly an option to cover rare peaks which cannot be covered with natural gas in a world with tight carbon budget.

The comparison of the pathways and the spatial results for the allocation of renewable generation units clearly indicates that public acceptance for generation infrastructure will be crucial aspect for the road ahead. All pathways show infrastructures which will raise acceptance issues, such as grid renewables deployment, CCS or nuclear. Even the localisation pathway requires large amounts of generation infrastructures which are concentrated in certain regions of Europe.

5 References

1 Coningsby, L. and C. Wilson (2016). Background Report: Innovation Systems and the SET Plan. SET-Nav Project Deliverable D3.1b. Available at: www.set-nav.eu

2 Wilson, C., et al. (2012). Marginalization of end-use technologies in energy innovation for climate protection. Nature Climate Change, 2(11): p. 780-788.

3 Weber, K.M. and H. Rohracher (2012). Legitimizing research, technology and innovation policies for transformative change: Combining insights from innovation systems and multi-level perspective in a comprehensive 'failures' framework. Research Policy. 41(6): p. 1037-1047.

4 Wieczorek, A.J. and M.P. Hekkert (2012). Systemic instruments for systemic innovation problems: A framework for policy makers and innovation scholars. Science and Public Policy. 39(1): p. 74-87.

5 Grubler, A., et al. (2012), Policies for The Energy Technology Innovation System, in Global Energy Assessment, T.B. Johansson, et al., Editors, Cambridge University Press: Cambridge, UK.

6 European Commission (2011). Energy Roadmap 2050, COM(2011) 885/2.

7 Crespo del Granado P. et. al. (2019). Comprehensive report "SET-Nav – Comparative assessment and analysis of pathways", SET-Nav project, http://set-nav.eu/content/pages/results

8 Ansari D. and Holz F. (2018). "Issue Paper on Scenarios of the global fossil fuel markets", SET-Nav project, available at: http://set-nav.eu/content/pages/issue-papers

9 Hartner M. et al. (2019). Summary report Energy Systems: Demand perspective, SET-Nav project, http://set-nav.eu/content/pages/results

10 Lumbreras S. et al. (2019). Summary report Energy Systems: Demand perspective, SET-Nav project, http://set-nav.eu/content/pages/results

11 Sensfuß F. et al. (2019). Summary report - Energy Systems: Infrastructure, SET-Nav project, http://set-nav.eu/content/pages/results