Technology Opportunities in Nordic Energy System Transitions (TOP-NEST)

Final report

Editors: Antje Klitkou, Simon Bolwig, Lars Coenen, Ola Solér and Lisa Scordato

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Preface

This report summarizes the outcomes of the 4-year research project “Technology Opportunities in Nordic Energy System Transitions (TOP-NEST). The project was funded by Nordic Energy Research, under the Sustainable Energy Programme 2050.
We thank Nordic Energy Research for the funding. The project partners were NIFU Nordic Institute for Studies in Innovation, Research and Education (project leader), CIRCLE Centre for Innovation, Research and Competence in the Learning Economy and the Faculty of Engineering at Lund University, The Technical University of Denmark, VTT Technical Research Centre of Finland, and the Institute of Energy Systems and Environment at Riga Technical University in Latvia.

The report is structured in four chapters:

1. Introduction,
2. The chapter on the scientific output,
3. The chapter on TOP-NEST as a collaborative endeavour, and
4. Policy Brief.

Oslo, October 16 2015

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1. CIRCLE
2. DTU
3. LTH
4. VTT
5. RTU

Contents

Executive summary

This report summarizes the outcomes of the 4-year research project “Technology Opportunities in Nordic Energy System Transitions (TOP-NEST). The project addressed the linkage between the Nordic energy systems and road transport.

In a short introduction, we reflect on the background and research agenda for the project and discuss the theoretical frameworks applied in the project. Drawing upon a combination of approaches, like the technological innovation systems and sustainability transition studies, TOP-NEST has opened up for an analysis of a greater variety of transition pathways. The project has investigated more closely interactions between different regimes (e.g. between energy and transport regimes), and the role of incumbents and niches for regime transformation.

The second chapter presents the scientific output of the TOP-NEST project thematically, presenting both articles and conference papers. The researchers in TOP-NEST published twelve scientific articles, three articles are still under review and five articles are in preparation. The project resulted also in 24 conference papers.

The scientific output of the TOP-NEST project has evolved around the avenues of the six work packages:

1. Development of a common conceptual and analytical framework;
2. Energy future modelling;
3. Analysis of path-dependencies;
4. Prospective studies of new value chains;
5. Assessment of viable transition pathways and required changes in institutional and organisational conditions; and
6. Assessment of governance implications.

The third chapter sums up the experiences working with the project. Here we touch upon issues, such as project management, the PhD project, scientific networking and achieved additionality.

The final chapter highlights issues and possibilities relevant for governance of the transition to sustainable road transport in the Nordic countries. First, we sum up policy relevant results for the different technology platforms. Then, we discuss energy system interactions and sustainability challenges. Finally, we highlight a number of cross-cutting issues:

- Path Creation and technological advantage
- Spatial perspective on transition
- Policy coordination, policy mixes and institutional learning
- European and Nordic development
- Transition strategies and infrastructure systems
- Political targets and regulations favouring collective solutions.

Sammendrag

Denne rapporten oppsummerer resultatene av det fireårige forskningsprosjektet «Teknologiske muligheter i overgangsprosesser innenfor nordiske energisystemer» – TOP-NEST. Prosjektet adresserte krysningspunktet mellom de nordiske energisystemene og veitransport.

I en kort introduksjon reflekterer vi over prosjektets bakgrunn og forskningsagendaen. Vi diskuterer det teoretiske rammeverket som ble anvendt i prosjektet. TOP-NEST har anvendt en kombinasjon av tilnærminger, som brukes for å analysere teknologiske innovasjonssystemer og bærekraftige overgangsprosesser. Samtidig har TOP-NEST analysert et utvalg av overgangsbaner. Prosjektet har undersøkt interaksjonen mellom forskjellige sosio-tekniske regimer, og her spesielt mellom energi- og transportregimer, og hvilken rolle etablerte bedrifter og nye nisjer spiller for en forandring av regimet.

I det andre kapitlet presenteres de vitenskapelige resultatene til TOP-NEST prosjektet. Bidragene er tematisk gruppert, og omfatter både artikler og konferansebidrag. Forskerne i TOP-NEST prosjektet har publisert tolv vitenskapelige artikler. I tillegg kommer tre artikler som er under vurdering av fagfeller samt fem artikler som skal sendes inn til et tidsskrift i den nærmeste fremtid. Prosjektet har totalt resultert i tjuefire konferansebidrag.

Det vitenskapelige resultatet av TOP-NEST prosjektet er blitt utviklet rundt seks arbeidspakker:

1. Utvikling av et felles begrepsmessig og analytisk rammeverk;
2. Fremtidssimuleringer av energisystemet
3. Analyse av stiavhengighet innenfor ulike områder
4. Fremtidsstudier av nye verdikjeder
5. Vurdering av mulige overgangsbaner og nødvendige endringer i institusjonelle og organisatoriske forhold
6. Vurdering av implikasjoner for styring og ledelse.

Det tredje kapitlet oppsummerer erfaringene med prosjektarbeidet. Her berøres temaer som prosjektledelse, ph.d.-prosjektet, vitenskapelig samarbeid og prosjektets merverdi.

I det avsluttende kapitlet peker vi ut noen temaer som er særlig relevante for styring av overgangen til en bærekraftig veitransport i de nordiske landene. Først oppsummerer vi policyrelevante resultater for de forskjellige teknologiplattformene. Så diskuterer vi interaksjoner med energisystemet og utfordringer for bærekraften av slike prosesser. Avslutningsvis peker vi ut noen overordnete temaer:

- Path creation og teknologisk forsprang;
- Stedsperspektiv på overgangsprosesser;
- Policy koordinering, policy miks og institusjonell læring;
- Europeisk og nordisk utvikling;
- Overgangsstrategier og infrastruktursystemer; og
- Politiske mål og reguleringer som støtter opp under kollektive løsninger.

1 Introduction

Grand societal challenges are increasingly becoming the focus of policymakers at various levels: it is in particular advocated by supranational organisations such as the OECD and the European Union (EU), but is gradually also taken on board by local and regional authorities. In a European context, the Lund Declaration (2009) played a key role in highlighting the importance of finding solutions to problems associated with ageing societies, pandemics, public health, security, global warming and the increasingly difficult access to sources of energy, water and food.

Since then, grand challenges have progressively become a policy discourse, most often associated with the need for development and diffusion of innovation. Attention for grand challenges has even found its way into EU's new 2020 growth strategy, which emphasises the importance of "exploring new development paths to generate smart, sustainable and inclusive growth … Various long-term challenges such as globalization, pressure on natural resources and an ageing population are intensifying. If we are to adapt to this changing reality, Europe can no longer rely on 'business as usual" (European Commission 2013).

This TOP-NEST project has addressed one specific grand challenge, namely that of decarbonizing our energy and transport systems. The Nordic countries are aiming to go beyond European targets and to achieve fossil independence or carbon neutrality in the energy sector by 2050. This will not only require the identification of technical solutions to cut fossil usage, but also that these countries find strategies that strengthen, rather than hinder, their competitiveness throughout this dramatic transition.

Transport systems remain a major challenge for reducing fossil fuel use. They demand huge amounts of energy, via systems and technologies built up at great expense, over very long periods. Transport systems also tend to involve a tangled web of national infrastructure and substantial private-sector services and investment.

All of this makes any piecemeal solution, policy intervention or incentive unlikely to work. Indeed, any truly sustainable transport systems will have to emerge through system transition and creative destruction – precisely the sort of change that may intimidate policy makers and major industrial actors – and so can lead to paralysis.

Energy technology foresight and future studies suggest that transitions are possible, but require active and concerted action from policy and industry. The main challenge is to find potential configurations of industrial stakeholders and institutional set-ups to facilitate both environmental sustainability and economic competitiveness. Incremental innovation is not enough: achieving such a win-win scenario will require renewal of networked value chains, patterns of use and consumption, infrastructures and regulations. At the same time, current path-dependencies and inertia must be considered, as existing energy and transport systems are deeply embedded in industrial and societal structures. It has been the ambition of TOP-NEST to contribute to a sophisticated understanding of new value chains in the Nordic energy and transport systems and to facilitate informed decisions on industrial strategies and associated policy in the Nordic countries.

The project has focused on three technology platforms for the development of sustainable transport solutions:

1. Electricity systems based on renewable solutions and e-mobility
2. Hydrogen systems and fuel cell electrical vehicles
3. Advanced liquid and gaseous biofuels

Together, the Nordic countries already occupy a leading technical position for the three renewable technology platforms (Sweden, Norway, and Denmark in renewable electricity and power systems; Finland and Sweden in biofuels; and Denmark, Norway and Iceland in hydrogen systems). Retaining and developing this position is crucial for Nordic economic development, energy security, environmental and climate policy goals. There is strong evidence that the transition necessary to meet the 2050 goals must entail increased integration, both between different parts of the energy system (e.g. between various supply systems and between supply and demand) and between the Nordic countries (e.g. via a Nordic power grid with a high share of variable power production and flexible demand, including transport). Joint and coordinated approaches to technology and system development, as well as integrated and coherent policy are therefore pivotal to this transition.

In the EU and global context, where major investments in energy and transport technology and infrastructure are expected in the coming decades, continued Nordic leadership offers a driver for export-driven green growth and job creation. A pioneering attitude to development in these areas will create innovation-based competitive advantages for Nordic industry. Due to the necessity of increased integration between systems and countries, Nordic cooperation is an important prerequisite for such leadership.

The research in the project has been guided by the following research questions:

1. What are the main path-dependencies and potential new value chains arising from the three technology platforms when applied in sustainable energy and transport systems?
2. What changes in organisational and institutional conditions are needed to facilitate sustainable transition pathways?
3. What are the governance implications, in terms of industrial strategies, public policy and public-private cooperation?

To answer these questions the project integrates technological and systems expertise with socio-economic and policy perspectives, combining several disciplinary approaches including political and economic sciences; research and innovation studies; foresight and socio-technical change, transportation and logistics, technology assessments and energy systems studies. The rationale for this approach is to arrive at well-grounded potential solutions for sustainable energy supply and end-use systems, and an integrated framework to analyse transition pathways and governance challenges.

In recent years, foresight and scenario methods have moved centre stage both at the level of individual strategy formulation of firms or as tools to coordinate different actors in politics or industry (Truffer et al., 2008). While these approaches acknowledge that the future cannot be predicted and a broad range of alternatives is possible, forecast and scenario methods have been criticized for de facto extrapolating from past experiences and current trends and paying little attention to the co-evolution of technological and societal processes (Elzen et al., 2004). Furthermore, they often lack a theoretical underpinning that explicitly elaborates on the interaction between different actor strategies, the role of specific actor networks and institutions as well as learning processes and other cumulative effects (Markard et al., 2008). In other words, existing technology roadmaps, foresight and scenario methods cover insufficiently the explorative strategies as well as the socio-economic and political complexities and contingencies that prevail in trajectories to zero-carbon futures.

In the past decade, the literature on socio-technological transitions is primarily concerned with specifying the conditions for transformative shifts in systems of production and consumption that unfold as disruptive technological change co-evolves with changes in markets, user practices, policy, discourses and governing institutions (Geels, 2002; Smith et al., 2010; Markard et al., 2012). This literature calls attention for the co-evolution of a broad range of innovations, which highlights technological, social, organisational, institutional, and business model novelty. It shares many theoretical roots with innovation studies, most notably a system perspective on innovation and a neo-Schumpeterian evolutionary understanding of change and industrial dynamics (Coenen and Diaz Lopez, 2010). However, compared to innovation system approaches, it claims to comprise a wider set of institutions and networks of heterogeneous actors including firms, user groups, scientific communities, policy makers, social movements and special interest groups. As a result, it stresses the importance of directionality, resistance and contestation in (radical) innovation processes.

Drawing on the Schumpeterian notion of creative destruction, research on socio-technological transitions has emphasized the role that technological niches play in radical change in the face of relatively stable regimes (Schot and Geels 2008). A regime refers to an entrenched socio-technical system whose institutional logic structures perception and behaviour of actors, thus favouring incremental change and innovation. A central and recurrent proposition in socio-technical transition research is that system transition requires the destabilisation of an existing regime. A niche is defined as an ‘incubation space’ for radically new technologies characterized by high technological, institutional and market uncertainty. Niches protect radical innovations against market selection and institutional pressures from a regime and allow actors to learn about novel technologies and their uses through experimentation (Geels, 2002). System transition can occur when niches gather sufficient momentum so that these relatively loose configurations become institutionalized and create capacity for emergent technologies and radical innovations to challenge and substitute a regime. This is often referred to as niche upscaling. However, regime destabilization would also be required in order for niche upscaling to have a window of opportunity to induce system transition. The distinction between niches and regimes has been proven to be a useful heuristic to capture processes of new path creation in the emergence of radically new sustainable technologies while at the same time accounting for processes of path-dependence and resistance when such technologies start to substitute and dislodge existing socio-technical systems (Smith et al., 2010). More recent contributions in this literature have started to question an exclusive emphasis on niche-driven transition pathways and opened up for different pathways for system transition, including regime transformation or partial upscaling of niches (Geels and Schot, 2007). Opening up for a greater variety of transition pathways has been a key issue that also TOP-NEST addressed. Furthermore, the project has investigated more closely interactions between different regimes (e.g. between energy and transport regimes).

In addition the technological innovation system (TIS) approach has been used to perform an analysis of the characteristics of the innovation systems for the respective technological platforms (power systems, biofuels, hydrogen), including technological, market, environmental and socio-economic aspects, important actors and networks and relevant institutions. TISs are defined as a “network of agents interacting in a specific economic/industrial area under a particular institutional infrastructure or set of infrastructures and involved in the generation, diffusion, and utilization of technology” (Carlsson and Stankiewicz, 1991, p. 111). One does typically divide between TIS structure and processes (or ‘functions’). Structure is defined as the actors, networks and institutions that conjointly support the generation, diffusion and utilization of a new technology (Bergek et al., 2008a). A structural analysis is complemented with a dynamic view on innovation system build-up, by focusing on a set of functions, namely knowledge creation, entrepreneurial experimentation, market formation, influence on the direction of the search, resource mobilization and creation of legitimacy.

The project has been organised in six research-related Work Packages:

WP1: Development of a common conceptual and analytical framework: One of the key conditions to successful multi-disciplinary research is the development and use of a common conceptual and analytical framework. Drawing on the project's different disciplinary and methodological approaches, this WP makes sure that all partners 'speak the same vocabulary'. The project combines research and innovation studies, foresight and socio-technical transitions, transportation and logistics and energy systems studies as well as economic geography. An important aspect of this WP has been to develop an analytical framework that allows to capture the spatial dimensions of transitions in order to investigate place-specific factors in and across the Nordic countries.

WP2: Energy future modelling – Given the project's long-term future orientation, there is a need for 'technology intelligence' about a range of possible energy futures. Energy modelling, scenarios and roadmaps are used to get an indication how future energy and transportation systems may look like in quantitative, concrete terms. More importantly, these 'future blueprints' are used as heuristics to discuss technology opportunities, new value chains, institutional set-ups and innovation strategies with respective stakeholders.

WP3: Analysis of path-dependencies in technological configurations, actor constellations and institutional set-ups for (1) renewable electricity, (2) liquid and gaseous biofuels, and (3) hydrogen supply systems in the Nordic countries. The WP has performed a context analysis of currently dominating socio-technical regimes for the selected technologies, currently dominating value chains including the transportation sector, related infrastructures, standards, public procurement, complementary and competing innovations, stakeholder capabilities & strategies and institutional set-ups. This analysis integrates the consortium's technical expertise with socio-economic innovation and transition analyses. It draws on focus group and individual interviews with external experts and desk research on developments also outside the Nordic region.

WP4: Prospective study of new value chains examines future ways in which alternative primary energy sources are converted to support road transport sector. Full chains are analysed including primary energy sources, energy production, storage & distribution, use in road transport vehicles and related businesses. Attention is paid to competition and synergies between the future value chains in these three technology areas, and the differences in their development phases. The future perspectives of the three technology areas are compared according to technologies, value chains, related infrastructure, stakeholder capabilities & strategies and institutional set-ups.

WP5: Assessment of viable transitions pathways and required changes in institutional and organisational conditions. This WP assesses the potential for new value chains identified in WP4 on the basis of existing path dependencies identified in WP3 and prospective energy futures in WP2. As such, this WP develops a synthesis of previous WPs and includes: a) socio-economic and policy analyses of institutional framework conditions for sustainable energy and transport systems in the Nordic countries, b) studies of the alignment of institutional framework conditions and industrial and policy scenarios in energy and transport systems, and c) identification of the organisational and institutional conditions that facilitate transition pathways. This synthesis is validated and complemented by focus-group interviews with industry experts, end-user organisations, politicians and NGOs.

WP6: Assessment of governance implications. This WP focuses on the role of public policies and industrial strategies in managing transition towards a low carbon economy based on the pathways studied and developed under WP5. Although technological change is a process involving many actors with diverse interests and capabilities, governments have a special responsibility to develop effective policy instruments to orient technological change in desirable directions. Public policy and industrial strategies have to be aligned to achieve a successful transition process. The analysis assesses policies (taking a systemic perspective that a. o. includes technology push and market pull mechanisms) industrial strategies as well as their interaction (synergies, complementarities and conflicts). Again, focus groups have been employed to validate and complement our findings.

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2 Scientific output

The TOP-NEST project had significant outcomes with regard to capacity building, scientific results and networking. In this chapter we concentrate on the scientific results.

2.1 Short overview

The following section will present the scientific output of the TOP-NEST project thematically. The scientific output of the TOP-NEST project has evolved around the avenues of the six work packages:

- Development of a common conceptual and analytical framework;
- Energy future modelling;
- Analysis of path-dependencies;
- Prospective studies of new value chains;
- Assessment of viable transition pathways and required changes in institutional and organisational conditions; and
- Assessment of governance implications.

The thematic classification is not always straightforward. Sometimes papers can belong to two work packages. We will point this out when relevant. We used the abstracts of the scientific papers and standardised keywords to capture the thematic orientation of the papers.

The researchers in the project pursued a stepwise approach for the dissemination of the scientific results. After writing reports, we presented conference papers and finally we wrote scientific articles. We attended important international scientific conferences with a focus on sustainability transitions and policy for grand societal challenges, such as:

- International Sustainability Transitions Conferences
- Annual International Sustainable Development Research Conference
- Annual Meetings of the Association of American Geographers
- Eu-SPRI Conferences

In addition, we presented our research results at a number of international conferences, which were more specialized in the field of energy and transport, such as:

- Transport Research Arena
- International Conference on Energy, Environment and Climate Change

National scientific conferences with international guest have been used as well as arena for the dissemination of our research:

- *COBREN: Copenhagen Biofuels Research Network, Copenhagen*
- *Nordic Hydrogen and Fuel Cell Conference, Oslo*
- *Renewable Energy Research Conference (RERC), Oslo*
- *Environmental and Climate Technologies – CONECT, Riga*

The scientific output in the different work packages came at different project periods. The work on the conceptual framework was mainly done in the first years of the project and resulted in several scientific articles, which have been published. Other parts of the projects, like the fifth and the sixth work package, have been very active in finalising the scientific results until the end of the project and scientific papers are therefore either in the process of reviewing or in preparation of submission to a scientific journal. We highlight in this report the published scientific articles, but we will make reference to scientific papers, which are under reviewing or in preparation as well as related conference papers.

2.2 Scientific articles, book chapters and conference papers

Development of a common conceptual and analytical framework

The published articles focus on the role of spatial aspects for sustainability transition processes, contributing to the development of a geography of transitions. Results of this work package have been important also for work package 3 and 5.

Environmental Innovation and Sustainability Transitions in Regional Studies (Truffer & Coenen, 2012)

Sustainable development and environmental innovations have received increasing attention in regional studies and the related literature. In how far sustainability concerns might also lead to fundamental transformations in technologies, industries and lifestyles (so-called sustainability transitions) has, however, found much less resonance. Sustainability transitions have been in the focus of scholars from the field of innovation studies. However, until recently, these approaches mostly disregarded spatial aspects. This paper therefore maps out a field of future research - the geography of sustainability transitions - that might be beneficially laboured by both traditions. The paper introduces the core concepts, but also the limitations of the transitions literature. After reviewing salient lines of sustainability-related research in regional studies, the paper specifies promising research areas at the interface between both fields. Empirical illustrations will be provided from recent work in sustainability transitions research venturing into this interface.

Keywords: Sustainability; Environmental innovations; Geography of transitions.

Towards a spatial perspective on sustainability transitions (Coenen, Benneworth, & Truffer, 2012)

In the past decade, the literature on transitions toward sustainable socio-technical systems has made a considerable contribution in understanding the complex and multi-dimensional shifts considered necessary to adapt societies and economies to sustainable modes of production and consumption. However, transition analyses have often neglected where transitions take place, and the spatial configurations and dynamics of the networks within which transitions evolve. A more explicit spatial perspective on sustainability transitions contributes to the transitions literature in three ways. Firstly, it provides a contextualization on the limited territorial sensitivity of existing literature. Secondly, it explicitly acknowledges and investigates diversity in transition processes, which follows from a 'natural' variety in institutional conditions, networks, actor strategies and resources across space. Thirdly, it encompasses not only greater emphasis but also an opportunity to connect to a body of literature geared to understanding the international, trans-local nature of transition dynamics. Concerned with the prevalent lack of attention for the spatial dimensions of sustainability transitions in most studies, this paper seeks to unpick and make explicit sustainability transition geographies from the vantage point of economic geography. The paper argues that there are two interrelated problems requiring attention: the institutional embeddedness of socio-technical development processes within specific territorial spaces, and an explicit multi-scalar conception of socio-technical trajectories. Following these arguments, the paper concludes that transitions research would do well to take a closer look at the geographical unevenness of transition processes from the perspective of global networks and local nodes.

Keywords: Geographies of transitions; Multi-level perspective; Technological innovation systems; Economic geography.

The geography of sustainability transitions: Review, synthesis and reflections on an emergent research field (Hansen & Coenen, 2014)

This review covers the recent literature on the geography of sustainability transitions and takes stock of achieved theoretical and empirical insights. The review synthesises and reflects upon insights of relevance for sustainability transitions following from analyses of the importance of place specificity and the geography of inter-organisational relations. It is found that these contributions focus on the geography of niche development rather than regime dynamics, and that there is an emphasis on understanding the importance of place-specificity at the local level. While there is a wide consensus that place-specificity does matter, there is still little generalizable knowledge about how place-specificity matters for transitions. Most contributions add spatial sensitivity to frameworks from the transitions literature, but few studies suggest alternative frameworks to study sustainability transitions. To address this, the review suggests promising avenues for future research on the geography of sustainability transitions, drawing on recent theoretical advancements in economic geography. The authors argue that concepts such as related variety, natural resource-based enclaves, multi-level governance, varieties of capitalism, value creation and proximity may be valuable to the analysis of sustainability transitions.

Keywords: Geography of transitions; Place; Sustainability transitions; Space; Scale.

Conference papers

Coenen, 2012. Scaling-up local niche experiments for transitions to low carbon transport systems. *Third International Sustainability Transitions Conference*. 29-31 August 2012. Copenhagen, Denmark.

Coenen, 2013. Scaling-up local niche experiments for transitions to low carbon transport systems. *19th Annual International Sustainable Development Research Conference*. 1-3 July 2013. Stellenbosch, South-Africa.

Energy future modelling

The project has applied STREAM models to simulate different energy and transport scenarios for the different national energy and transport systems in the four Nordic countries. The article on scenarios for electrical vehicles and hydrogen fuel cells vehicles in Denmark shows that an increased share of electric vehicles could significantly reduce the socio-economic cost of the energy system in 2050. Whether the Hydrogen scenario is more costly to implement than the electrical vehicle scenario mainly depends on the improvement on the efficiency of the conversion from electricity to Hydrogen.

Our Latvian partners have actively contributed to the dissemination of research results based on modelling and survey results. Their research concentrated on modelling sustainable regional transport systems in the Baltic States, on the effects of the introduction of smart meters in Latvia, on the effect of the deployment of low-carbon technologies – electric vehicles and solar photovoltaics on GHG emissions, and finally on the deployment of waste-to-bio-methane approaches.

Use of electric vehicles or hydrogen in the Danish transport sector in order to ensure a stable and sustainable energy system in 2050? Wiley Interdisciplinary Reviews: Energy and Environment (Skytte, Pizarro, & Karlsson, 2015, Under review)

Denmark is one of the Northern European countries that have set up ambitious long-term targets to reduce GHG emissions from the transport as well as from other sectors. In Denmark, the target is to make the transport sector independent of fossil-fuel consumption by 2050 at the latest. This paper compares a likely scenario with two alternative ways to achieve the goal - either with a high percentage of electric vehicles (EV) or with a high percentage of hydrogen (H_2) use in the transport sector. The STREAM model - an energy scenario simulating tool - provides insight into different potential energy mixes and calculates socio economic costs. It is used to model the different transport scenarios and their system integration with the electricity and heating sectors.

The major findings of this paper are that an increased share of electric vehicles could significantly reduce the socio-economic cost of the energy system in 2050. Electricity demand for H_2 generation via electrolysis is more flexible than EV charging and the production can therefore, to a larger degree be used to out-balance variable electricity surplus from a high share of wind and solar energy in the power system. H_2 production may generate heat that can be used as district heating - replacing traditional heating plants, heat pumps and in some cases combined heat and power plants. Therefore, the energy generation mix (electricity and heat) is more affected in the H_2 scenario than in the EV scenario. Whether the H_2 scenario is more costly to implement than the EV scenario mainly depends on the technological development - especially the improvement on the efficiency of the conversion from electricity to H_2. It is found, that a higher efficiency in the H_2 production via electrolysis plays a more important role in decreasing the total cost of the energy system than a lower level of electrolyser capital cost. Therefore, the major driver of a successful H_2 scenario is a high efficient and flexible H_2 production in 2050. In other words, from a socio-economic view point this paper estimates that the technological path in innovation should have efficiency as its main driver towards 2050.

Keywords: Energy, Environment, Electric vehicles (EV); hydrogen fuel cell vehicles; renewable energy; e-mobility; STREAM model

Assessment of changes in households' electricity consumption (Laicāne, Blumberga, Rosa, & Blumberga, 2013)

This study reports on an initial assessment of a pilot project for smart meters installation. As a starting point serves a literature review on the assessment of household electricity consumption and CO_2 emission savings. The methodological approach is based on a survey for involvement of households in the pilot project. This research serves in turn as a basis for further research to explore factors influencing the user behaviour and to improve analyses on electricity consumption reduction in households, as well as the further development of smart metering in Latvia.

Keywords: Electricity consumption; energy efficiency; assessment of electricity savings; smart metering; survey

Modelling transition policy to a sustainable regional transport system: A case study of the Baltic States (Barisa & Roša, 2015)

The purpose of this paper is to address the difficulty of implementing the European Union renewable energy policy in the transport sector. The authors describe a case study illustrating the capacity of the three Baltic States to meet the binding target of 10 per cent renewable energy in the transport sector by 2020. An excel-based mathematical model is developed and applied to evaluate the effect of a selected set of measures according to the sustainable transportation concept. The findings demonstrate that the projected renewable energy targets in the transport sector of the Baltic States cannot be achieved without unwavering political commitment towards the promotion of alternative fuel vehicles. Increasing the share of mandatory biofuel blends has a major effect. However, it is not sufficient to meet the 10 per cent goal. Other measures such as lower transport demand and mode shift are included but do not offer significant benefits under a realistic scenario. The findings are expected to serve as a basis to conduct further studies into sustainable transport development in the Baltic region. Moreover, policy makers may find these results useful in formulating a national position. The methodology and the findings reported in this study could be also used for analysing renewable transport policies in other European countries.

Keywords: Transport, Biofuels, Policy, Climate, Electricity, Energy, Estonia, Latvia, Lithuania, Renewable energy; Modelling

Application of Low-Carbon Technologies for Cutting Household GHG Emissions (Barisa, Roša, Laicāne, & Sarmiņš, 2015)

This article attempts to evaluate the potential of greenhouse gas emission reduction from power and transportation needs in a household by introducing a solar photovoltaic array and an electric vehicle. The study is based on analysis of data collected from a case study household and a photovoltaic unit located in Latvia. Results show that a small-sized photovoltaic system can ensure around 40 % of daily electricity demand of a four-person household on an average summer day. In addition, introducing additional electric vehicle load is helpful for cutting greenhouse gas emissions related to household mobility. In the best case scenario, CO_2 balance can be improved by 60-90 %.
Keywords: Electric vehicle; Solar photovoltaics; GHG emissions; Modelling.

Conference papers

Savicka, Rošā & Vaiškūnaitė, 2013. Behavior change in use of transport to reduce CO_2 emissions. In: *Proceedings of the 16th Conference for Junior Researchers "Science – Future of Lithuania": 16th Conference for Junior Researchers „Science – Future of Lithuania", Aplinkos apsaugos inžinerija. 16-osios Lietuvos jaunųjų mokslininkų konferencijos "Mokslas – Lietuvos ateitis" straipsnių rinkinys*, Lietuva, Vilnius, 11 April, 2013. Vilnius: 2013, p. 1-5.

Laicāne, Blumberga, Rošā, Blumberga, Bariss, 2013. The Effect of the Flows of Information on Residential Electricity Consumption: Feasibility Study of Smart Metering Pilot in Latvia. In: *Smart Objects, Systems and Technologies (SmartSysTech): Proceedings of 2013 European Conference: 2013 European Conference on Smart Objects, Systems and Technologies (SmartSysTech)*, 11-12 June, 2013, Erlangen/Nuremberg, Germany.

Skytte, Pizarro Alonso, Karlsson, 2015. Use of electric vehicles or hydrogen in the Danish transport sector in order to ensure a stable and sustainable energy system in 2050? *International Conference on Energy, Environment and Climate Change (ICEECC 2015),* Mauritius.

Barisa, Dzene, Rošā, Dobrāja, 2015. Waste-to-biomethane concept application: a case study of Valmiera city in Latvia. Submitted to *International Scientific Conference "Environmental and Climate Technologies – CONECT 2015*", Riga, Latvia.

Dzene, Barisa, Rošā, Dobrāja, 2015. A conceptual methodology for waste-to-biomethane implementation in an urban environment. Submitted to *International Scientific Conference "Environmental and Climate Technologies – CONECT 2015"*, Riga, Latvia.

Dobraja, Barisa & Rošā, 2015. Cost-Benefit Analysis of Integrated Approach of Waste and Energy Management. Submitted to *International Scientific Conference "Environmental and Climate Technologies – CONECT 2015"*, Riga, Latvia).

Analysis of path-dependencies

This work package has been based on a number of case studies, which have been presented in number of conference papers. A comparative paper on the role of lock-in mechanisms in transition processes is to be seen as one of the final results of the work package. This paper uses the theoretical concepts of lock-in mechanisms to analyse transition processes in energy production and road transportation in the Nordic countries. Two other papers are still in preparation. They have more national focus: one paper on advanced biofuels in Norway and one paper on the Danish renewable energy innovation system.

The role of lock-in mechanisms in transition processes: the case of energy for road transport (Klitkou, Bolwig, Hansen, & Wessberg, 2015)

This paper revisits the theoretical concepts of lock-in mechanisms to analyse transition processes in energy production and road transportation in the Nordic countries, focussing on three technology platforms: advanced biofuels, e-mobility and hydrogen and fuel cell electrical vehicles. The paper is based on a comparative analysis of case studies. The main lock-in mechanisms analysed are learning effects, economies of scale, economies of scope, network externalities, informational increasing returns, technological interrelatedness, collective action, institutional learning effects and the differentiation of power. We show that very different path dependencies have been reinforced by the lock-in mechanisms. Hence, the characteristics of existing regimes set the preconditions for the development of new transition pathways. The incumbent socio-technical regime is not just fossil-based, but may also include mature niches specialised in the exploitation of renewable sources. This implies a need to distinguish between lock-in mechanisms favouring the old fossil-based regime, well-established (mature) renewable energy niches, or new pathways.
Keywords: Path dependence; lock-in; transition process; road transport; renewable energy

Emerging Technological Innovation Systems for Advanced Biofuels in Norway (Fevolden & Klitkou, In preparation)

This article sets out to explain why Norway has failed to develop a vibrant advanced biofuel industry. It investigates three competing hypotheses that have been proposed to explain Norway's lacklustre performance in this field: (i) a lack of available risk capital, (ii) an absence of relevant technological expertise and (iii) a failure of the government to provide adequate incentives and support measures. The paper applies an event-history analysis to chart the development of the most important advanced biofuel companies – Borregaard (bioethanol), Cambi (biogas), Weyland (bioethanol) and Xynergo (biodiesel) – and uses their success and eventual failure as a key indicator of the condition of the emerging technological innovation system within this field in Norway. The paper finds that the advanced biofuel companies were hampered mostly by inconsistent and insufficient government incentives and support measures and concludes that hypothesis iii best explains Norway's limited success in advanced biofuels.
Keywords: advanced biofuels; technological innovation; policies

Putting all eggs in one basket? The promotion of renewable energy industries in Denmark (Coenen, Hansen, & Hansen, In preparation)

The Danish wind turbine industry has been heralded as a prime example of successful industrial policy and the Danish renewable energy policy has since the mid-1970s predominantly been focusing on wind power. The support given to other technologies has been less coherent, thus, the penetration of alternative technologies such as biogas and solar power is much smaller in Denmark (Meyer, 2004). Also in comparison with other leading countries in wind turbine production, the Danish wind industry policy support schemes are extensive and favourable, especially in the fields of export credit assistance, and research, development, and demonstration programs, which specifically target domestic companies (contrary to e.g. local content requirements) (Buen, 2006; Lewis & Wiser, 2007; Lipp, 2007). The energy policy priority in Denmark continues to focus on transforming the energy system towards more wind power (IEA, 2011).

This paper analyses the implications of this relatively one-sided focus on wind energy on the broader renewable energy innovation system in Denmark. Drawing on theory of path-dependence and lock-in, which highlight reinforcing mechanisms that condition specific outcomes in terms of technological development through positive feedbacks or increasing returns to adoption (Arthur, 1994; David, 1985; Sandén & Azar, 2005), our aim is to examine if the focus on the wind turbine industry leads to an emphasis on some and a marginalisation of other renewable energy technologies? Specifically we focus on the implications for downstream technologies within the field of sustainable transport. As highlighted by Sandén and Hillman (2011), there is a need to go beyond the standard focus on competition between technologies and develop a more detailed framework building on interactions in value chains in order to fully understand relations between technologies. In this way, lock-in on a

specific technology may have implications further down the value chain in the form of lock-in on some technology pathways and lock-out of other.
Keywords: path-dependence, lock-in, renewable energy; wind energy; innovation system; Denmark

Standards and technological substitution: the case of e-mobility (Iversen, 2016, in preparation)

This chapter focuses on the role of standards to promote the (re)entry of technological systems in markets already dominated by a well-established incumbent technological system. It starts from the recognition that the innovation process does not necessarily proceed neatly along a single (S-shaped) path of technological substitution. New technologies may indeed emerge, grow, and subsequently establish dominance on markets after a period of rivalry, as the S-shaped path assumes. There is however the possibility that the rivalry does not end in substitution but that the rivalry carries on in different ways, depending on different factors (e.g. Dattee & Weil, 2007). If they do not, the implication is that the emergence of a standard (or a dominant design) in a market does not necessarily lead to the complete substitution of an original rival but instead contributes to the dynamics of a longer-term process.
Keywords: Standards; e-mobility

Conference papers

Hunsberger, Bolwig, Corbera & Creutzig, 2012. Livelihood impacts of biofuel crop production: mediating factors and implications for governance. *COBREN: Copenhagen Biofuels Research Network*. 19-20 November 2012, Copenhagen, Denmark.

Klitkou, Bolwig, Hansen, Nikoleris & Wessberg, 2014. The role of path-dependencies in transition processes: the case of energy for road transport. 27-29th August 2014, *5th IST 2014 Conference, Utrecht,* The Netherlands.

Klitkou & Scordato, 2013. Path dependencies in transition processes: a study on hydrogen and fuel cells value chains in Norway. *Nordic Hydrogen and Fuel Cell Conference*. 31 October–1 November 2013, Oslo, Norway.

Klitkou & Fevolden, 2012. Emerging technological innovation systems for second generation biofuels in Norway. International Conference on Governing Sustainable Biofuels: Markets, Certification and Technology. *COBREN: Copenhagen Biofuels Research Network*. 19-20 November 2012, Copenhagen, Denmark.

Hansen, T., Coenen & Hansen, U., 2013. Putting all eggs in one basket? The promotion of renewable energy industries in Denmark. *AAG 2013 Annual Meeting*. 12 April 2013. Los Angeles, USA.

Iversen, Klitkou & Borup (2014). Standardization and emerging strategies to escape technological lock-in. 27-29 November 2014, *5th Asia-Pacific Innovation Conference.* The University of Technology, Sydney, Australia.

Prospective studies of new value chains

This part describes an innovative participatory foresight approach that has been developed. Under the topic prospective studies of new value chains up to 2050, we have carried out several national studies. The article demonstrates the methodology for this approach and the achieved results for the Finnish case. The two conference papers have served as stepping stones for a broader discussion of the theoretical framework and the methodological approach.

Participatory and prospective value network analysis: supporting transition towards biofuels in Finnish road transport (Tuominen, Wessberg, & Leinonen, 2015)

If the European energy and transport sectors are to meet the 2050 energy and climate policy targets, major socio-technical change (transition) is necessary. Along with new technologies, changes are required also in other societal functions such as business models and consumer habits. The transition

will require cooperation between public and private actors. This paper discusses the socio-technical change towards a 2050 road transport system based on renewable energy. More precisely, it proposes a novel, participatory foresight approach in the context of biofuels in Finland. The participatory and prospective value network analysis outlined in the paper combines elements from the fields of foresight, socio-technical change on multiple levels and value network analysis. It presents a novel, policy and business-relevant application with a set of practical tools to support development of implementation strategies, but also to boost new business opportunities in the fields of energy and transport. The paper concluded that that in the future transport and energy systems will need to be more integrated and that the potential for new business will lie in the intersections of the current transport and energy systems.
Keywords: Participatory foresight; Multi-level perspective; Value network; Transport system; Energy system; Transition process

Conference papers

Wessberg, Leinonen, Tuominen, Eerola & Bolwig, 2013. Creating prospective value chains for renewable road transport energy sources up to 2050 in Nordic Countries. *International Foresight Academic Seminar*. 16-18 September 2013, Winterthur, Switzerland.

Tuominen, Wessberg, Leinonen, Eerola & Bolwig, 2014. Creating prospective value chains for renewable road transport energy sources up to 2050 in Nordic Countries. *Transport Research Arena*. 14-17th April 2014, Paris, France.

Assessment of viable transition pathways and required changes in institutional and organisational conditions

Research results under this topic centre on organisational conditions for future transition pathways. They build on results achieved in the first four work packages and develop them further. The following issues have been addressed in the scientific articles: i) the commercialisation of cleantech technology innovations, ii) a comparative analysis of path-creation processes in e-mobility, hydrogen and fuel-cell electrical vehicles, and advanced biofuels in the Nordic countries, and iii) a comparative paper on value chains for cellulosic ethanol in the Nordic countries and Southern Europe.

Commercializing clean technology innovations: the emergence of new business in an agency-structure perspective (Avdeitchikova & Coenen, 2015)

Studies on the commercialization of new technology in entrepreneurship literature have often failed to explain why some new technologies reach markets while others do not, as well as why some technological solutions ultimately become industry standards while others quickly disappear from the market (Garud and Karnoe, 2003). Technology commercialization models are often linear, based on technology-push logic, and focus rather exclusively on micro-level issues such as characteristics of technology and product, entrepreneurial experience and access to resources. This chapter takes stock with a linear approach to cleantech commercialization processes and, instead, suggests an alternative approach to analyse the entrepreneurial process of commercializing cleantech. In particular, this approach underlines the duality concerning structure and agency that entrepreneurs tend to encounter in the commercialization of cleantech. In contrast to the seemingly appealing simplicity of linear commercialization models, this framework seeks to acknowledge the complexity and uncertainty involved in bringing new technology to the market.
Keywords: clean tech; innovation; commercialisation

Path renewal in old industrial regions: possibilities and limitations for regional innovation policy (Coenen, Moodysson, & Martin, 2015)

This paper analyses the potential, barriers and limitations for regional innovation policy to facilitate industrial renewal in old industrial regions. It draws on a case analysis of the policy programme 'Biorefinery of the Future' geared to promote renewal of the forest industry in Northern Sweden. It is shown that infusion of radical emergent technology is necessary for new regional path development, but not sufficient. To avoid a singular focus on technology-push, policy should pay more attention to

complementary experimentation processes in relation to demand-side characteristics, firm strategies and business models as well as regulatory aspects. Moreover, coordination between regional innovation policy and adjacent domains and levels of policy-making is needed as some of the most pressing obstacles for renewal are not specific to the region but instead to the industry at large.
Keywords: Old industrial regions, Regional innovation policy, Evolutionary economic geography, Socio-technical transitions

Path creation in Nordic energy and road transport systems (Hansen, Klitkou, Borup, Scordato, & Wessberg, Under review, under review)

This paper reviews path-creation processes in Nordic road transport systems. The study employs an analytical framework of recent path creation literature and transition theory. The path creation theory re-introduces social agency in the analyses of change and development in society. Departing from initial conditions of path-dependency we analyse how new niche experiments in energy and road transport have developed and how they have been strengthened into possible pathways by the actors involved. In a comparative analysis of case studies on path-creation processes in e-mobility, hydrogen and fuel-cell electrical vehicles, and advanced biofuels in the Nordic countries we attempt to analyse how these countries address barriers to the new paths. The cases highlight that initial conditions such as energy-production systems and other infrastructures significantly influence path-creation processes. However, the degree of public support to path-creation experiments and path-establishment processes are also of crucial importance for the transition to sustainable transportation technologies. We argue that the creation of new paths towards sustainable transport technologies requires an acknowledgement of the different logics of the energy and transport systems. The differences between the Nordic countries require also greater policy coordination between the countries. Finally, the authors conclude that path creation towards sustainable transport should be considered as a continuous, iterative process. The danger of early inflexibility and sub-optimal options can be avoided by developing, applying and regularly reviewing a portfolio of solutions rather than selecting just one option.

Keywords: Path creation; road transport; renewable energy; biofuels; electrical vehicles; hydrogen fuel-cells

Value chain structures that define European cellulosic ethanol production (Sterling Gregg et al., In preparation)

Current European cellulosic ethanol (CE) production facilities are examined from a value chain perspective. For each case study we identified the feedstock, the supply chain, the technology and industrial process, production materials and output. We also identified the main value chain, supporting value chains, and the actors involved that result in ethanol production being scaled up beyond pilot or demonstration scale. We hypothesize that CE development process is structured by: 1. the nature of the feedstock and resource availability; 2. the industrial actors (competences, existing capital stock/investments, incentives, objectives); and 3. coordination between various actors in the value chain. From this perspective, this paper seeks to identify the barriers to greater diffusion of CE, and how current policies (fail to) address these barriers. The authors claim that these barriers could be addressed more effectively by considering economies of scope in the national and EU policies that intend to promote greater production of CE.
Keywords: cellulosic ethanol; value chains; demonstration; policies

Conference papers

Nilsson, 2013. Keynote speaker. Conference on Strategic Research in Transport and Infrastructure, June 11-12 2013, DTU, Lyngby. Denmark.

Klitkou, Hansen, Wessberg, Borup, 2014. Path creation in Nordic energy and road transport systems. 16-18th June, *Renewable Energy Research Conference (RERC) 2014*. Oslo, Norway.

Assessment of governance implications

The scientific articles, which address governance implications concentrate on following topics: the evaluation of different policy domains for transition processes, the organisational implications of investment decisions for biorefineries, and finally different governance and policy approaches for electrical mobility. Related conference papers followed similar lines of research.

Using Transition Management concepts for the evaluation of intersecting policy domains ('Grand Challenges'): the case of Swedish, Norwegian and UK biofuel policy (Upham, Klitkou, & Olsen, 2016)

The notion of 'Grand Challenges' is increasingly used in international research and innovation discourse, but risks being used rhetorically to justify business as usual policy approaches. We draw on a study that maps the characteristics of policy problems and proposals referred to in association with 'Grand Challenges', showing how transition management fits well as a response to these characteristics. We then use the transition management perspective to evaluate prevailing research and innovation policy for one specific policy sector (biofuels), in countries with differing policy histories for that sector (the UK, Norway and Sweden). We argue that transition management functions well as a means of highlighting not only policy shortcomings in a sector, but also policy directions appropriate to the scale of grand challenges.
Keywords: Grand challenges; biofuels; transport; transition management; innovation policy; Research, Development and demonstration; critical; normative; governance

Livelihood impacts of biofuel crop production: Implications for governance (Hunsberger, Bolwig, Corbera, & Creutzig, 2014)

This paper addresses the social and livelihood impacts of the expanded production of first generation biofuels. Policy and governance measures aimed at improving the social effects of biofuels have proliferated but questions remain about their effectiveness across the value chain. This paper performs three tasks building on emerging insights from social science research on the deployment of biofuel crops. First, we identify livelihood dimensions that are particularly likely to be affected by their cultivation in the global South – income, food security, access to land-based resources, and social assets – revealing that distributional effects are crucial to evaluating the outcomes of biofuel production across these dimensions. Second, we ask how well selected biofuel governance mechanisms address livelihood and equity concerns. Third, we draw insights from literature on non-energy agricultural value chains to provide one set of ideas for improving livelihood outcomes. Our analysis demonstrates that biofuel policies treat livelihoods as a second-degree problem, specifying livelihoods as an afterthought to other goals. We suggest integrating livelihoods into a multi-criteria policy framework from the start – one that prioritizes equity issues as well as overall outcomes. We also show that the instruments with strongest provisions for safeguarding livelihoods and equity appear least likely to be implemented. Together, shifting both the priorities and the relative hierarchy of biofuel governance instruments could help produce strategies that more effectively address livelihood and equity concerns.
Keywords: Biofuels; certification; governance; sustainability; multi-criteria policy; livelihood

Unpacking investment decisions in biorefineries (Hansen & Coenen, Under review)

The development and diffusion of biorefineries is a central factor in the transition towards a bioeconomy. Such biorefineries, which produce multiple products based on biological material, are heralded as an important opportunity for renewal of the pulp and paper industry in developed countries, facing increasing competition and environmental requirements. However, pulp and paper firms have only made few investments in biorefineries.
Examining investment decision in Swedish and Finnish pulp and paper firms, this paper highlights the importance of considering decision-making processes within companies in order to understand the limited diffusion of biorefinery technologies. Further, the paper identifies organisational innovations in the form of new divisions, forward vertical integration, and creation of new value chain relations as central to commercialisation of biorefinery technologies. Theoretically, it argues that the technological

innovation systems framework should be complemented with insights on decision-making processes within companies in order to understand the development of emerging technologies.
Keywords: Biorefineries; investment decisions; organisational innovation; pulp and paper industry

Forks in the road to e-mobility: a North-West European perspective on the role of national policy mixes (Dijk, Iversen, Klitkou, Kemp, Bolwig & Borup, In preparation)

This paper compares the recent uptake of battery electric vehicle (BEV) mobility in Norway, The Netherlands and Denmark. Our focus is on the role that policy mixes have played in the uptake of BEV in these three countries. Although the countries are quite similar in socio-economic terms, each country has pursued a different approach for stimulating BEV mobility during the past two decades and has experienced different levels of BEV penetration. This paper does three things: it describes and analyses the national policy mixes relevant to BEV, the penetration of BEV and the effectiveness and (in)efficiencies of the policy packages. In a national policy mix we consider policies related to BEV demand-side, BEV supply-side, BEV infrastructure, cleaner ICE cars and renewable energy. Our analysis offers an empirical contribution to the literature on policy mixes, focusing on the effectiveness and (in)efficiencies of policy packages that seek to stimulate E-mobility, as well as policy lessons regarding for transition to E-mobility.
Keywords: E-mobility; Policy mix; Denmark; Norway; The Netherlands

Conference papers

Klitkou, Scordato & Olsen, 2012. Research and innovation policy approaches and responses to grand societal challenges: a comparative analysis of research and innovation systems in Norway and Denmark. *Eu-SPRI Conference*. 12-13 June 2012, Karlsruhe, Germany.

Barisa & Rošā, 2012. Policy Instruments to Support Biofuels in the European Union. In: 5th International conference "*Environmental science and education in Latvia and in Europe: resources and biological diversity*" compendium, Latvia, Riga, 19 October, 2012. Riga: 2012, pp.7-8. ISBN 9789984496849.

Coenen, Moodysson & Westendorf, 2012. Renewal of mature industry in an old industrial region: regional innovation policy and the co-evolution of institutions and technology. *Association of American Geographers Annual Meeting 2012*. 24-28 February 2012. New York City, USA.

Upham, Klitkou & Olsen, 2013. The Implications of Transition Management for 'Grand Challenge' policies: the cases of Nordic and UK biofuel research and innovation policy. *Eu-SPRI Conference*. 10-12 May 2013, Madrid, Spain.

Rosa, Barisa & Olsen, 2014. Implementing renewable energy in European transport: barriers and opportunities. *Transport Research Arena*. 14-17th April 2014, Paris, France.

Iversen & Klitkou (2014). Forks in the road to e mobility: Path dependency and policy choice in Scandinavia. *Innovation Research Centre Presentation.* The University of Tasmania, Australia.

Wesseling & Coenen, 2015. Explaining differences in electric vehicle policies across countries: implications for transition studies. *6th IST Conference,* Brighton, UK.

2.3 List of conference papers

2012

Barisa & Rošā (2012). Policy Instruments to Support Biofuels in the European Union. In: 5th International conference "*Environmental science and education in Latvia and in Europe: resources and biological diversity*" compendium, Latvia, Riga, 19 October, 2012. Riga: 2012, pp.7-8. ISBN 9789984496849.

Coenen, Moodysson & Westendorf (2012). Renewal of mature industry in an old industrial region: regional innovation policy and the co-evolution of institutions and technology. *Association of American Geographers Annual Meeting 2012*. 24-28 February 2012. New York City, USA.

Klitkou, Scordato & **Olsen** (2012). Research and innovation policy approaches and responses to grand societal challenges: a comparative analysis of research and innovation systems in Norway and Denmark. *Eu-SPRI Conference*. 12-13 June 2012, Karlsruhe, Germany.

Coenen (2012). Scaling-up local niche experiments for transitions to low carbon transport systems. *Third International Sustainability Transitions Conference*. 29-31 August 2012. Copenhagen, Denmark.

Hunsberger, **Bolwig,** Corbera & Creutzig (2012). Livelihood impacts of biofuel crop production: mediating factors and implications for governance. *COBREN: Copenhagen Biofuels Research Network*. 19-20 November 2012, Copenhagen, Denmark.

Klitkou & **Fevolden** (2012). Emerging technological innovation systems for second generation biofuels in Norway. International Conference on Governing Sustainable Biofuels: Markets, Certification and Technology. *COBREN: Copenhagen Biofuels Research Network*. 19-20 November 2012, Copenhagen, Denmark.

2013

Hansen, T. Coenen & Hansen, U-E. (2013). Putting all eggs in one basket? The promotion of renewable energy industries in Denmark. *Association of American Geographers Annual Meeting*. 12 April 2013. Los Angeles, USA.

Upham, **Klitkou & Olsen** (2013). The Implications of Transition Management for 'Grand Challenge' policies: the cases of Nordic and UK biofuel research and innovation policy. *Eu-SPRI Conference*. 10-12 May 2013, Madrid, Spain.

Nilsson (2013). Keynote speaker. *Conference on Strategic Research in Transport and Infrastructure*, June 11-12 2013, DTU, Lyngby. Denmark.

Coenen (2013). Scaling-up local niche experiments for transitions to low carbon transport systems. *19th Annual International Sustainable Development Research Conference*. 1-3 July 2013. Stellenbosch, South-Africa.

Wessberg, Leinonen, Tuominen, Eerola & Bolwig (2013). Creating prospective value chains for renewable road transport energy sources up to 2050 in Nordic Countries. *International Foresight Academic Seminar*. 16-18 September 2013, Winterthur, Switzerland.

Klitkou & **Scordato** (2013). Path dependencies in transition processes: a study on hydrogen and fuel cells value chains in Norway. *Nordic Hydrogen and Fuel Cell Conference*. 31 October–1 November 2013, Oslo, Norway.

Savicka, **Rošā** &Vaiškūnaitė (2013). Behavior Change in Use of Transport to Reduce CO_2 Emissions. In: *Proceedings of the 16th Conference for Junior Researchers „Science – Future of Lithuania": 16th Conference for Junior Researchers „Science – Future of Lithuania", Aplinkos apsaugos inžinerija. 16-*

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Laicāne, Blumberga, **Rošā,** Blumberga & Bariss (2013). The Effect of the Flows of Information on Residential Electricity Consumption: Feasibility Study of Smart Metering Pilot in Latvia. In: *Smart Objects, Systems and Technologies (SmartSysTech): Proceedings of 2013 European Conference: 2013 European Conference on Smart Objects, Systems and Technologies (SmartSysTech)*, Germany, Erlangen/Nuremberg, 11-12 June, 2013.

2014

Tuominen, Wessberg, Leinonen, Eerola & **Bolwig** (2014). Creating prospective value chains for renewable road transport energy sources up to 2050 in Nordic Countries. *Transport Research Arena*. 14-17 April 2014, Paris, France.

Rošā, Barisa & **Olsen** (2014). Implementing renewable energy in European transport: barriers and opportunities. *Transport Research Arena*. 14-17 April 2014, Paris, France.

Klitkou Hansen, Wessberg & Borup (2014). Path creation in Nordic energy and road transport systems. *Renewable Energy Research Conference (RERC),* 16-18th June *2014*. Oslo, Norway.

Klitkou, Bolwig, Hansen, Nikoleris & Wessberg (2014). The role of path-dependencies in transition processes: the case of energy for road transport. 27-29th August 2014, *5th International Sustainability Transitions Conference, Utrecht,* The Netherlands.

Iversen & Klitkou (2014). Forks in the road to e mobility: Path dependency and policy choice in Scandinavia. *Innovation Research Centre Presentation.* The University of Tasmania, Australia.

Iversen & Klitkou (2014). Standardization and emerging strategies to escape technological lock-in. 27-29 November 2014, *5th Asia-Pacific Innovation Conference.* The University of Technology, Sydney, Australia.

2015

Skytte, Pizarro Alonso, **Karlsson**, 2015. Use of electric vehicles or hydrogen in the Danish transport sector in order to ensure a stable and sustainable energy system in 2050? *International Conference on Energy, Environment and Climate Change (ICEECC 2015),* 8-9 July 2015, Mauritius.

Wesseling & **Coenen** (2015). Explaining differences in electric vehicle policies across countries: implications for transition studies. *6th International Sustainability Transitions Conference,* 25-28 August 2015, Brighton, UK.

Barisa, Dzene, **Rošā**, Dobrāja, 2015. Waste-to-biomethane concept application: a case study of Valmiera city in Latvia. Submitted to *International Scientific Conference "Environmental and Climate Technologies – CONECT 2015*", 14-16 October 2015, Riga, Latvia.

Dzene, **Barisa**, **Rošā**, Dobrāja, 2015. A conceptual methodology for waste-to-biomethane implementation in an urban environment. Submitted to *International Scientific Conference "Environmental and Climate Technologies – CONECT 2015"*, 14-16 October 2015, Riga, Latvia.

Dobraja, **Barisa** & **Rošā**, 2015. Cost-Benefit Analysis of Integrated Approach of Waste and Energy Management. Submitted to *International Scientific Conference "Environmental and Climate Technologies – CONECT 2015"*, 14-16 October 2015, Riga, Latvia).

3 TOP-NEST as a collaborative endeavour

In summer 2011, we started the TOP-NEST project as a collaboration between research organisations in four Nordic countries:

- NIFU Nordic Institute for Studies in Innovation, Research and Education, located in Oslo, Norway;
- CIRCLE Centre for Innovation, Research and Competence in the Learning Economy and the Faculty of Engineering at Lund University, both located in Lund, Sweden;
- The Technical University of Denmark, located in Lyngby, Denmark; and
- VTT Technical Research Centre of Finland, located in Espoo, Finland.

All partners had contributed actively to the development of the research proposal, both in the first round and in the second round. After the second round, the consortium had to cut the planned funding from Nordic Energy Research with 23 per cent. The funding of the PhD was reduced and some research tasks were taken out of our plan, such as the research on the role of demonstration projects for the transition pathways. Our partner at the Faculty of Engineering at Lund University hosted the PhD candidate and organised other project funding for the PhD student. Among others, the PhD candidate worked on a 2-years project on Scandinavian demonstration projects, which was funded by the Research Council of Norway after this topic had been taken out of the TOP-NEST project. We agreed without further delays on a collaboration agreement and the PhD candidate Alexandra Nikoleris could start her work in autumn 2011 at Lund University. Her supervisors are Lars Nilsson (main supervisor) and Lars Coenen (co-supervisor). Her PhD is still ongoing and we expect her to conclude her PhD in 2016. Project work on different other projects have somehow prolonged her PhD period.

The steering of the project was achieved through pro-active project leadership and the continuous involvement of the steering group. The steering group comprised the group leaders from the different Nordic research organisations: Antje Klitkou from NIFU, Lars Coenen from CIRCLE, Lars Nilsson from LTH, Simon Bolwig (earlier Birte Holst-Jørgensen), and Nina Wessberg from VTT. We used Skype meetings, meetings back to back with workshops and the annual seminars as arenas to discuss the progress of our project. The project established from a very early stage a well-functioning website, were we published reports and reported about scientific articles and conference papers.[1]

Every autumn we organised annual seminars in different locations: we met in 2011 in Oslo, in 2012 in Espoo, in 2013 in Lund, in 2014 in Roskilde and in 2015 in Oslo again. At the annual seminars we discussed research results. There we involved members of the Scientific experts advisory group to

[1] www.topnest.no

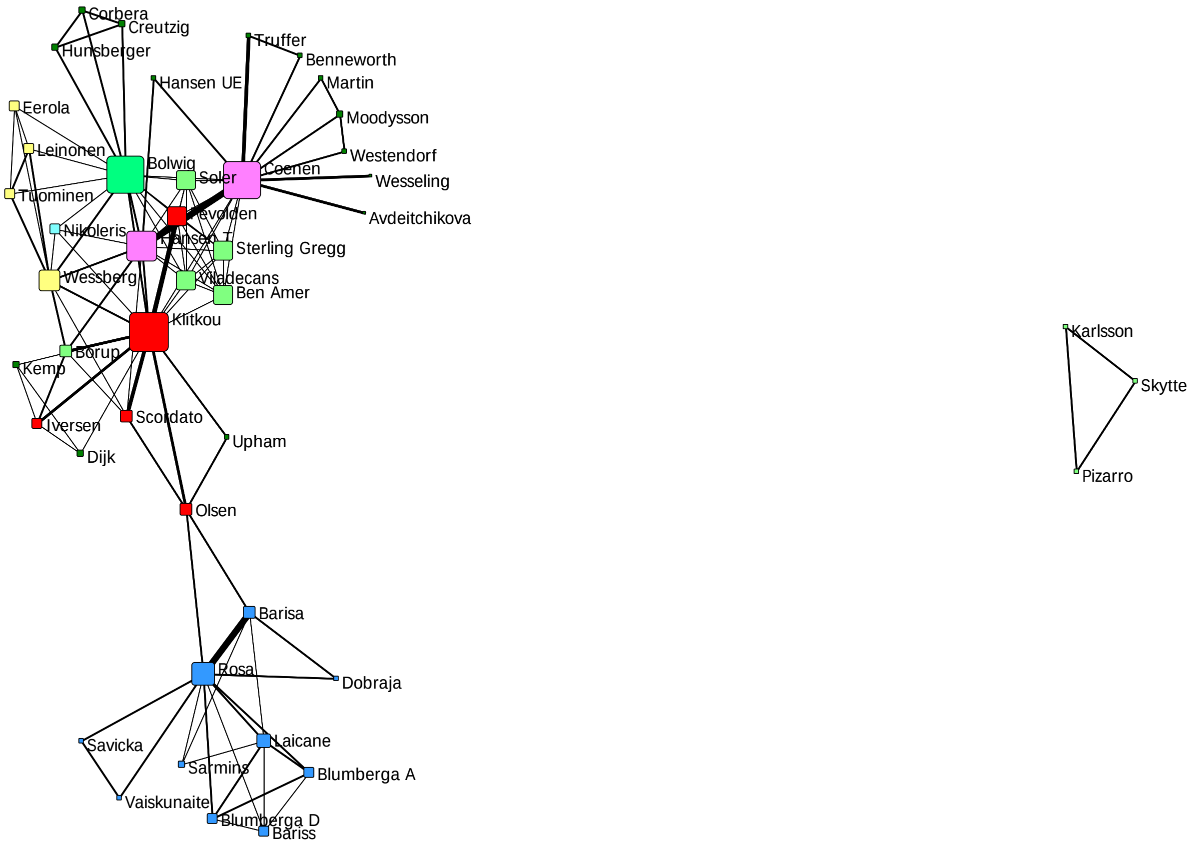
receive comments. To each seminar we invited at least one or two of the external experts. The seminars were also used to discuss the next steps in our research project.

Half a year after we had started the project, Nordic Energy Research offered additional resources through the introduction of Baltic researchers with earmarked funding of PostDocs in our project. We received several applications and decided that the proposal written by Marika Rošā, Associated professor at Riga Technical University in Latvia, Faculty of Electrical Engineering and Power, Institute of Energy Systems and Environment was best aligned with our proposal. Therefore, we decided to include her in the project. With this extra funding, Marika Rošā has financed with this extra funding her own PostDoc, but also some work of the work of a PhD student (one fourth of the earmarked funding from NER). She and her research group has managed to publish a number of research results. In parts of the project, there has also been cooperation between her and other researchers of the TOP-NEST project. However, the integration into our project was rather limited. We suggest therefore, that in future projects Baltic researchers should be integrated into the research proposals from the very start in order to achieve a better integration and collaboration.

The chapter about the scientific output of the project demonstrates that we have produced many more scientific articles than planned in our proposal. These research results could be achieved by collaboration across the whole project, but there are also many examples of more national collaborations resulting in research publications, which are closely related to the context of our project. This demonstrates that we had a good balance of national and international collaboration in our project. Several of the researchers have also involved researchers outside the project for comparing or further developing certain perspectives. We have welcomed this.

A social network analysis of co-authorship for our scientific articles and conference papers shows a high degree of collaboration between the project participants, but also involvement of international researchers outside the project. Conference papers plaid an important role for exploring new collaboration possibilities.

Figure 1: Co-authorship for all TOP-NEST articles (N=19) and TOP-NEST conference papers (N=19), based on degree centrality.



Notes: Graph created with Borgatti, S.P. 2002. NetDraw: Graph: Visualization Software. Harvard: Analytic Technologies
Colours represent the different organisational affiliations: red: NIFU, purple: CIRCLE, light green: DTU, yellow: VTT, dark blue: RTU, light blue: LTH, dark green: external researchers

The involvement of the Industry advisory group concentrated on the first phase of the project and on the last stage, when we discussed the policy implications of the project with stakeholders. We assess that this role and function could be improved in future projects to improve the impact of our research.

How well has the TOP-NEST project functioned in the SES2050 Programme? Over the years, we received positive feedback from Nordic Energy Research, but the interaction with other projects in the programme turned out to be much more limited than we envisioned. We realise that the projects worked rather independently from each other. The communication with Nordic Energy Research was based on interaction with project officers – both personal, by email or on telephone. NER was also present at our annual seminars. We have experienced a shift of goals from the funder: while we had the understanding that this was a research project, in the last year NER urged us to look more into stakeholder contacts and outreach to the industry.

Beside the already mentioned issues, the project had to address a number of personnel challenges. This is rather normal since researchers retire, are mobile or have to prioritise other tasks. Even though the project was relatively well funded, the resources had to be spread across the different organisations and then across a large number of researchers in some of the organisations. Seen in retrospective, a concentration of resources on fewer researchers could have allowed more continuity and focus, but this is difficult to assess. It was certainly difficult to keep the whole project team focussed on the project until the very end of the project. Researchers have to apply for new funding and have to start new projects in parallel with the old one. University researchers have also teaching obligations in parallel to their research tasks. This makes it sometimes cumbersome to get all tasks realised as planned.

The collaboration in the project has contributed to additionality:

- A research project on the role of demonstration projects in innovation and the transition to sustainable energy and transport was funded for two years (2013-2014) by the Research Council of Norway and was based on the collaboration between the Scandinavian partners in the TOP-NEST project.
- A research project on sustainable path creation for innovative value chains for organic waste products (SusValueWaste) and lead by NIFU is funded for four years (2015-2018) by the Research Council of Norway and is based on the collaboration between the Scandinavian partners in the TOP-NEST project (Lund University and DTU) in addition to a number of Norwegian partners.
- A research project on flexibility for variable renewable energy integration (Flex4RES) and lead by DTU is funded four years (2015-2019) by Nordic Energy Research and is partially based on the project network in TOP-NEST.

4 Policy brief

This policy brief highlights issues and possibilities relevant for the governance of the transition to sustainable road transport in the Nordic countries based on analysis of three technology platforms: battery electric vehicles (BEVs), fuel cell electric vehicles (FCEVs) and hydrogen, and advanced biofuels. The conclusions are based on research performed by the TOP-NEST project (2011-15) supported by a grant from Nordic Energy Research. Further information is available at www.topnest.no.

4.1 Key messages

- Path creation processes are key processes for the transition to more sustainable fuels and vehicles for road transport.
- Transition policy should consider specific local, regional or national resources, infrastructure and institutional conditions for transitions and not just copy policy.
- There is a need for better policy coordination between different policy domains, between different policy instruments, and between the Nordic countries.
- Development of the three technology platforms are significantly conditioned by EU policies. The advancement of sustainable road transport in the Nordic region would benefit if the Nordic countries aligned their positions on this topic at the European level, despite internal differences.
- It is critically important to design sustainable road transport policies in light of a future low-carbon energy system. Across the Nordic region, more battery electric vehicles (BEVs) can reduce the total system cost slightly, compared to a baseline of mixed technologies, whereas the reverse is true for more fuel cell electric vehicles (FCEVs). Both BEVs and FCEVs can contribute to grid integration of variable renewable electricity, especially for FCEVs, by creating a higher but more flexible electricity demand.
- Governments have a choice between strategic long-term policy and weak political leadership within the area of sustainable road transport. The first choice involves developing ambitious targets for the deployment of new technologies and reinforcing these targets with strong and sequential policy packages. In contrast, weak political leadership is a situation where a government establishes targets without underpinning them with broad policy strategies, and thus targets are unlikely to be reached.

4.2 Technology platforms

Three technology platforms for sustainable road transport were analysed during the project: battery electric vehicles (BEVs), fuel cell electric vehicles (FCEVs) and hydrogen, and advanced biofuels. TOP-NEST looked at recent developments in the Nordic countries, path-dependencies, current policy frameworks, industrial strategies, and path creation processes. The project analysed how actors are involved in and handle technology research, development and demonstration (RD&D) and innovation activities. It also analysed the - current and future - value chains and emerging businesses related to these platforms. The project relied mainly on a combination of social science, technology assessment and energy modelling approaches.

Battery electric vehicles

Interviews with European BEV industry actors showed that collaborations in research projects and specialised organisations were important to keep up to date with technology developments and to learn from other experts. The interviews also revealed a preference for more homogeneous regulations across countries in Europe. So far, the lack of a favourable business case for BEVs has hindered technology learning effects in most of the Nordic countries. Norway is an exception due to its broad public support measures for e-mobility and a wide deployment of BEVs. Nordic consumers generally support BEVs according to several surveys (reported in Klitkou et al, 2015), but they have limited experience with or knowledge of them. The lacking consumer experiences in the other Nordic countries can be partly overcome by deploying electric buses and BEVs in car sharing arrangements. Policies that benefit or favour BEV users in their daily lives, such as free parking and the use of bus lanes, can also promote BEV uptake, shown by experience from Norway. Electric vehicle deployment involves the energy and transport sectors and these two policy domains have to be coordinated in concert with climate policy. A continued decarbonisation of electricity supply in the Nordic countries favours the deployment of BEVs.

A case study in Denmark showed failures and successes related to BEVs that have contributed to learning processes (Klitkou et al., 2015). Charging infrastructure has spread rather rapidly thanks to Denmark being a rather small and densely populated country. Charging stations are often owned and operated by major power producers. Current electricity production capacity in Denmark is estimated to be sufficient to handle many more BEVs through intelligent charging during night time; in fact, it is considered necessary to stimulate further and flexible electricity demand in order to allow a continuing expansion of wind energy production. This however requires stronger incentives for consumers such as differentiated electricity tariffs. Exemptions from registration and road taxes are currently in place and deemed crucial for the future of electric vehicles in Denmark by key stakeholders. However, changes in short-term legislation create uncertainty and the recent political decision to phase in registration and road taxes for BEVs over the next 5 years from 2016 is likely to have created further disincentives for BEV investments.

Fuel cell electric vehicles and hydrogen

The sustainability of a pathway towards hydrogen and fuel cell electrical vehicles (FCEVs) depends on the availability of a high share of electricity from renewable resources and affordable electricity prices. Among the Nordic countries, it is only in Denmark and Norway that there are significant R&D initiatives and policy debates on how to exploit excess renewable electricity for the production of hydrogen – in Denmark from wind turbines and in Norway from hydropower. This is despite the fact that these renewable sources are available to all Nordic countries through the common electricity market and that Sweden produces also significant amounts of hydropower. Norway has a long tradition of exploiting its natural endowments for producing hydropower and can thus exploit excessive hydropower for the production of hydrogen via decentralised electrolysers. Political framework conditions have contributed to more favourable conditions for FCEVs in Norway compared to other countries. FCEVs and BEVs are treated equally in Norway regarding taxes, parking, road tolls, free ferry use, use of bus lanes, etc. and so enjoy rather favourable conditions compared to internal combustion engine vehicles. Regional authorities are drivers for the deployment of H2/FC technologies.

The major barriers to new path creation are:

- Difficult market conditions for new entrants producing elements for the hydrogen system and FCEVs with larger chicken-and-egg problems than for BEV and biofuels.

- In Norway, strong industrial actors engaged in fuel cell and hydrogen technology that can back-up public R&D on this technology have only recently emerged. In Denmark, such actors have been present for a longer time even in the absence of significant FCEV infrastructure investments.
- Weak political commitment at the highest political level to ensure the necessary infrastructure for the deployment of hydrogen as an important energy carrier.
- The existing lock-in on oil and gas (Hansen et al., 2015).

Advanced biofuels

The further development and adoption of advanced biofuels in the Nordic countries depends on a range of factors. These include a guaranteed and stable support level, containing features such as stable and adjusted fuel prices and fossil fuel taxes as well as tax exemptions. Specific standards for advanced biofuels, increased mandatory turnover of advanced biofuels, and pilot- and demonstration programmes would also make the development and production of advanced biofuels more profitable and so incentivise investments in this technology platform. Such a supportive policy mix requires strong political commitment however (Fevolden and Klitkou, 2016).

A lock-in into first generation biofuels has become a barrier for the commercialisation of advanced biofuel technology. This has been the case for Sweden, which was a frontrunner for the deployment of first generation biofuels, but which lacks now long-term policies in support for advanced biofuels. Due to the lack of policy support for advanced biofuels, bio-refineries are increasingly focusing on products other than biofuels (Hansen et al., 2015). Finland on the other hand has stated the most ambitious target in the EU for renewable energy share in the transport system, with a goal of 20% by 2020. This goal will be achieved mainly by blending biofuels into petroleum fuels such as diesel and gasoline (at least three companies are developing and producing biofuels in Finland - Neste, St1 and UPM). However, there is an ongoing discussion as to whether it would not be wiser to produce low-volume high-value products, e.g. cosmetics, as opposed to high-volume low-value products, e.g. biofuels. The transition to the circular bioeconomy might involve using scarce bio-resources for more valuable products.

A study of the pulp and paper industry in Sweden and Finland showed limited investments in biorefineries even though these could provide a new opportunity for the industry (Hansen and Coenen, 2016). Decision making processes within companies should be highlighted in order to understand the limited diffusion of biorefineries. Organisational innovations and new value chain relations were found to be central to biorefinery commercialisation.

4.3 Energy system interactions

Pathway analyses of fuel use in the Nordic transport sectors by the means of an energy system model showed the advantages and the drawbacks of more focus on BEVs, FCEVs or biofuel-powered vehicles compared to the shares included in the Carbon Neutral Scenarios from the Nordic Energy Technology Perspectives (Skytte et al., 2015). Cross-country conclusions are that more BEVs can reduce the total system cost slightly whereas the reverse is true for more FCEVs. Both BEVs and FCEVs can contribute to grid integration of variable renewable electricity, especially for FCEVs, by creating a higher but more flexible electricity demand. A Swedish scenario with more biofuel-vehicles could be less costly than a scenario with more BEVs (and FCEVs). Excess heat from biorefineries can be used for district heating, thus affecting the total energy mix. Conclusions regarding costs obviously depend on price and performance developments for batteries and for infrastructure for hydrogen and biofuel production. For example, low efficiency of electrolysers results in higher capital investments in wind power to cover increased electricity demand.

4.4 Sustainability challenges

Environmental sustainability is mostly driven by the possibility to reduce greenhouse gas emissions, but also to lower air pollution with the help of BEVs and FCEVs, assuming future cleaner power systems. Land use changes related to biofuels are important to consider. This project has focused on more advanced biofuels such as waste-based and lignocellulosic ethanol where land use change should be a minor issue, although these technologies still involve competition over biomass resources between transport fuels and other uses such as animal feed and electricity production (Gregg et al. in prep.). Other environmental factors such as biodiversity and soil quality could also be impacted by advanced technologies depending on local conditions, biomass resource, and agronomic techniques.

Social sustainability can mostly be impacted by biofuel production in Nordic rural areas by creating a variety of job opportunities close to where biomass resources are harvested (Coenen et al., 2015). Conversely, the (continued) reliance on imported first generation biofuels from countries with weak environmental and social governance systems entails high risks of jeopardizing local livelihoods and exacerbating inequity. While sustainability standards exist that involve strict social criteria, these standards are often voluntary and are rarely used by the industry (Hunsberger et al., 2014).

The economic sustainability of the three technology platforms depends at a general level on the competiveness of new technologies versus incumbent fossil fuel technologies. It has to be considered how well the Nordic countries can build on existing knowledge, develop it further, and capture export opportunities.

4.5 Cross cutting issues

Path Creation and technological advantage

Studies of path creation highlight that engaged and entrepreneurial actors are central to technological and societal change and help overcome technological lock-ins and existing path dependencies. A core type of activity in path creation is actors' attempts to make smaller or larger mindful deviations from the existing structures and mobilize a collective support for the deviations despite resistance and inertia from the existing system. Path creation processes are therefore key processes for the transition to sustainable road transport.

Initial conditions such as energy production systems and infrastructures are important for which path creating processes are established and can favour certain technologies over others (Hansen and Coenen, 2016). A case in point is the high share of fluctuating wind energy in Denmark that favours e-mobility and hydrogen, which can help balance the energy system. The selection of the new path creation processes has to be done in awareness of technological, economic and environmental uncertainties regarding long-term dynamics and systemic effects and of the need to ensure learning from mistakes. It is important to avoid the domination of sub-optimal solutions from a sustainability perspective. Otherwise, this could lead to early inflexibility. Such inflexibility can be avoided by developing and applying a portfolio of solutions rather than selecting just one option (Hansen et al, 2015).

Technological paths can be strengthened also through policy or commercial decisions that significantly alter enabling infrastructures or systems. For example, Denmark and Norway both have relatively well-developed EV charging infrastructures thus adding to the relative advantage of e-mobility provided by respectively wind power and hydropower. Likewise, ambitious biofuels policies in Finland have strengthened the deployment of advanced biofuels.

Spatial perspective on transition

TOP-NEST research underlines that transition policy should consider specific local conditions for transitions in terms of a regional/national industry's position in (global) value chains, the territoryspecific institutions, and local competencies. Therefore, learning processes often are of a localized nature, be it regional or national (Coenen et al., 2012; Hansen and Coenen, 2014).

Regional innovation programmes have a significant impact on the innovation activities of their target industries and contribute to creation of novelty. However, important constraints to industrial and, thus, regional renewal remain due to path-reinforcing tendencies beyond the regional scale that are largely out of reach for such policy initiatives (Coenen and Hansen, 2016).

Policy coordination, policy mixes and institutional learning

TOP-NEST research highlights three spheres of policy coordination needed for successful transition processes: (1) policy coordination between different policy domains, (2) policy coordination between different policy instruments, and (3) policy coordination between the Nordic countries. By policy coordination we do not mean policy duplication or harmonization but rather the interactive design of different policies that together enhances the development and adoption of transition technologies.

1. Policy coordination between different policy domains such as energy and transportation can contribute to institutional learning effects despite the inertia of (existing) institutions regulating car use. Such policy coordination is developed to varying extents in the four countries (Klitkou et al., 2015). The involvement of local and regional authorities can reinforce such policy initiatives and local authorities can initiate such policy in the absence of national policy coordination. Joint projects of public and private actors can have a positive effect on institutional learning (ibid.).
2. Policy coordination also involves coordination between different types of policy instruments: policy support for research, innovation and entrepreneurship, demand-side policy instruments, such as different types of taxes and tax reductions, infrastructure-related policy, public procurement, supply-side policy instruments, and vehicle emission regulations (Iversen et al., 2015).
3. Differences between the Nordic countries require greater policy coordination between the countries. Road transport infrastructures for sustainable transport niches, such as recharging infrastructure and filling stations for advanced biofuels or hydrogen, must be aligned across borders to attract new actors and customers to engage with these solutions (Hansen et al., 2015). At the same time, policies need to consider place-specific conditions in terms of particular positions of industry in value chains, local knowledge and competences as well as territorial institutions, as previously noted.

European and Nordic development

TOP-NEST analysed not just the national policies of the four Nordic countries, but also policy at the European level. Stakeholders forming the European transport research and technology network highlighted the following issues to be solved: (1) the development of a stable long-term regulatory framework, including standardization and cross-country regulation; (2) better funding both at national and European level (Rosa and Bariga, 2014).

TOP-NEST research also showed that the development of the three technology platforms – BEVs, FCEVs and Advanced biofuels – are significantly conditioned by EU policies. It therefore seems likely that the advancement of sustainable road transport in the Nordic region would benefit if the Nordic countries aligned their positions on this topic at the European level, despite their differences in technological emphasis/choices. While sustainable road transport is a significant political objective across the Nordic region, this is not necessarily the case in the rest of EU.

Transition strategies and infrastructure systems

Transition strategies need to take into consideration the structure of the existing infrastructure system and the different modes of interplay in response to changes. Long-term strategies have to be adaptive to future generations’ demand and flexible in accommodating secondary uses of infrastructure. Institutional changes such as deregulation or privatisation of infrastructure systems lead to changes of the systems and therefore require careful planning (Hansen et al., 2015).

The TOP-NEST project performed foresight exercises through which future value chains related to the three renewable energy platforms were outlined. This work demonstrated that in a future sustainable road transport system, transport and energy systems must be closer integrated than today. It also showed that the potential for new businesses will lie especially in the intersections of the current transport and energy systems. The prospective value network process helps various system actors to consider landscape-level constraints, such as changes in values and global trends, as well as the needs, which guide the society to change the existing regime towards a higher use of renewable energy (Tuominen et al., 2015).

Political targets and regulations favouring collective solutions

Governments can develop ambitious targets for the deployment of new technologies and can reinforce these targets with regulations favouring collective solutions, such as the procurement of public transport vehicles and the establishment of charging and hydrogen infrastructure for collective transport solutions, thereby implementing sustainable solutions. However, governments can also simply establish renewable technology targets without underpinning them with regulations thus showing weak political leadership (Klitkou et al., 2015). In this regard, TOP-NEST has documented several examples of national regulations favouring fossil solutions or less sustainable solutions, such as first generations of biofuels, despite of high targets for sustainable energy and transport. In other cases, the unpredictability and lack of continuity of government regulations relevant for new technologies created barriers for the diffusion and deployment of advanced technologies (Fevolden and Klitkou, 2016).

Identification of value networks and future value chains is also important for reaching political targets since they help concretise the actions and actors required for renewable energy production and use in the future. In TOP-NEST, we created a procedure for the identification of future value chains, the so-called participatory prospective value network approach (Tuominen et al., 2015). This method allows direct knowledge diffusion to the decision makers and so can support strategic planning for public and private stakeholders. The approach widens the scope of system actors from a linear value chain thinking to a transition-oriented network approach. It creates a transition arena for stakeholders to develop and share the same image of the future’s transport system and so it can be a tool to increase the knowledge of different actors in making decisions towards low-carbon futures.

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