Shift

Sustainable Horizons in Future Transport

Sustainable Horizons in Future Transport - with a Nordic focus

Project summary 2015-2019

Nordic Energy Research

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Shift in short

Informing smarter Nordic transport and energy policy

Transforming transport is a key energy challenge in the Nordic region to achieve the ambitious climate targets set by the Nordic governments. To capture the opportunities and overcome potential barriers, all Nordic stakeholders need a better understanding of how transport and energy systems interact with each other, and with broader economic, innovation, social and political systems.

By developing and applying tools that integrate fuel options, modal shifts, business models and consumer behaviour into scenario modelling and in-depth analysis covering urban passenger transport, long-haul freight and city logistics the Shift project informs smarter Nordic transport and energy policy.

Besides strengthening Nordic energy systems modelling and providing updated scenario analysis for the Nordic transport sector, Shift examines linkages between technological and organisational innovations that can decarbonise the road transport system. In addition, Shift assesses drivers, barriers and effects of transport modal shifts and analyses effective design of transport related policy instruments. Shift includes assessments on the Nordic level as well as policy relevant local Nordic case studies highlighting opportunities and challenges for the transition of the transport sector.

The Shift project is supported by Nordic Energy Research, for which we are very grateful. The opinions expressed in this report do not represent Nordic Energy Research's official positions but are entirely attributable to the authors.

This report summarises the assessments made in Shift including main findings. The policy briefs produced within the project are also included.

More information regarding the Shift project can be found at www.nordicenergy.org/flagship/project-shift/ or by contacting project manager Julia Hansson at julia.hansson@ivl.se

Shift Key Findings

- **It is possible to drastically reduce transport GHG emissions and reach carbon neutrality in the Nordic region by 2040-2050 but strong and immediate actions are required.** The Nordic region can very well become a frontrunner in solving the climate challenge in the transport sector but the deployment rate of low-carbon technologies and fuels as well as shift and avoid measures must accelerate.

- **A combination of transport mitigation measures is the most cost-effective scenario for decarbonizing the Nordic transport sector.** Modal shifts, innovative technologies, changes in travel behaviour and new business models are all needed. A considerable electrification and a shift towards low energy intense modes seem cost-effective for passenger and freight road transport. Biofuels are needed too, not least in shipping and aviation.

- **A cost-effective fuel and technology mix in the Nordic transport sector depend on several key factors.** These include the development of carbon capture and storage (CCS), expansion of low-carbon electricity generation, availability of sustainable biofuels and cost development of electrified options. Bio-CCS enabling negative emissions should be carefully assessed in the Nordic region, as this may facilitate for the transport sector.

- **Improved policy measures are needed to decarbonize freight transport in the Nordic region.** Policies must be designed to rapidly increase the use of low carbon vehicles for long-haul and urban freight transport, reduce transport demand, improve efficiency of transport modes and stimulate modal shifts. Policy measures aimed at modal shifts may benefit from a coordinated Nordic approach and should consider the effect on other emissions.

- **Commercialize and deploy a broad set of key transport innovations in the Nordic region.** The Nordic countries have explored several innovations and are currently regarded as international pioneers within areas such as electric vehicles, electrified roads and Mobility-as-a-Service (Maas). Attention should now be given to ways in which key innovations can be commercialized and deployed in the short to medium term in all Nordic countries.

- **Increase the understanding for the role of business model innovation for transport innovations.** It is critical that policymakers understand and promote the role of business model innovation as a mechanism that can: commercialize novel technologies that reduces transport emissions; harness synergies between different types of transport innovations and bring about significant changes in the ways in which transportation is produced and used.

- **Transport policies and programmes should be designed to create socially inclusive solutions.** The shift towards low-carbon transport, smart cities and smart mobilities needs to address both technical and social dimensions. Policies should target building cities catering to walking, bicycling, public transport and sharing solutions. Infrastructure design and provision should be guided by needs-based assessments and target a low-carbon transport society.

- **Improve the design and implementation of urban and transport plans by mapping the systematic benefits of proposed mobility solutions.** This would highlight the potential gains in energy use and emissions reduction. Emerging concepts like Mobility-as-a-service (Maas), car/bike sharing, transit-oriented development, integrated urban logistics hubs etc. needs to be linked with accessibility mapping exercises to plot the expected cut in emissions and energy use.

- **Green shift must include low-carbon and efficient Nordic city logistics.** Comprehensive urban freight strategies need to be formed by regional authorities and municipalities in due consultation with the urban freight stakeholders. Data collection and management is integral to frame and assess policy measures for reducing CO_2 emissions.

- **National policy instruments must be better coordinated to prevent effects from overlapping which may reduce their effectiveness.** Even when instruments partly overlap in their effects, the losses in effectiveness can be substantial. To prevent ineffectiveness, the effects from each policy instrument need to be understood and isolated already during development of new policy instruments, and in the evaluation of existing ones.

- **Climate policies for transport must be reformed to meet and incentivize electrification and to consider target conflicts.** Overall, the current climate policy instruments for zero emissions vehicles tend to undermine fuel taxation as a regulatory instrument for traffic volume. Electrification of transport generates a target conflict between greenhouse gas reduction, regulating traffic volume and tax revenue to fund public infrastructure and social costs of traffic. The target conflict calls for reassessing the taxation for road transports in Nordic countries.

- **Charge vehicles on a per kilometre basis according to the marginal external costs of their driving.** To maintain a long-term road infrastructure in the future for an expanded electric vehicle fleet and to match the social costs of traffic, the lost tax revenue from fuel taxes will need to be covered by a new tax base. The charge on a per kilometre basis will also restore the socially efficient balance between road capacity and traffic volume.

Scenarios for the Nordic energy and transport systems

Challenge

Achieving the ambitious climate change mitigation targets set by Nordic governments for the transport sector requires a systems approach to reducing the sector's share of final energy use and CO_2 emissions within the Nordic region. Transforming transport systems will have substantial impacts on the larger energy system. It is important to increase the understanding of the synergies – and potential conflicts – between the two systems.

Transition of the Nordic transport sector (Figure 1) towards carbon neutrality means that gasoline, diesel, kerosene and heavy fuel oil must be replaced by biofuels, hydrogen, electrofuels (produced from CO_2 and water using electricity) or green electricity. This concerns both passenger transport dominated by cars and freight transport that is almost equally divided between trucks and ships.

There are basically three ways of reducing environmental impacts from transport:

Avoid

These measures aim at reducing activity (measured in passenger-kilometres or tonne-kilometres). Such measures enable people to satisfy their daily needs while avoiding taking a trip or limiting its distance and ensuring that goods are delivered while minimizing their overall distance. Urban design is an important driver of transport activity. Compact cities or neighbourhoods that include both residential dwellings and commercial or business activities enable shorter trips.

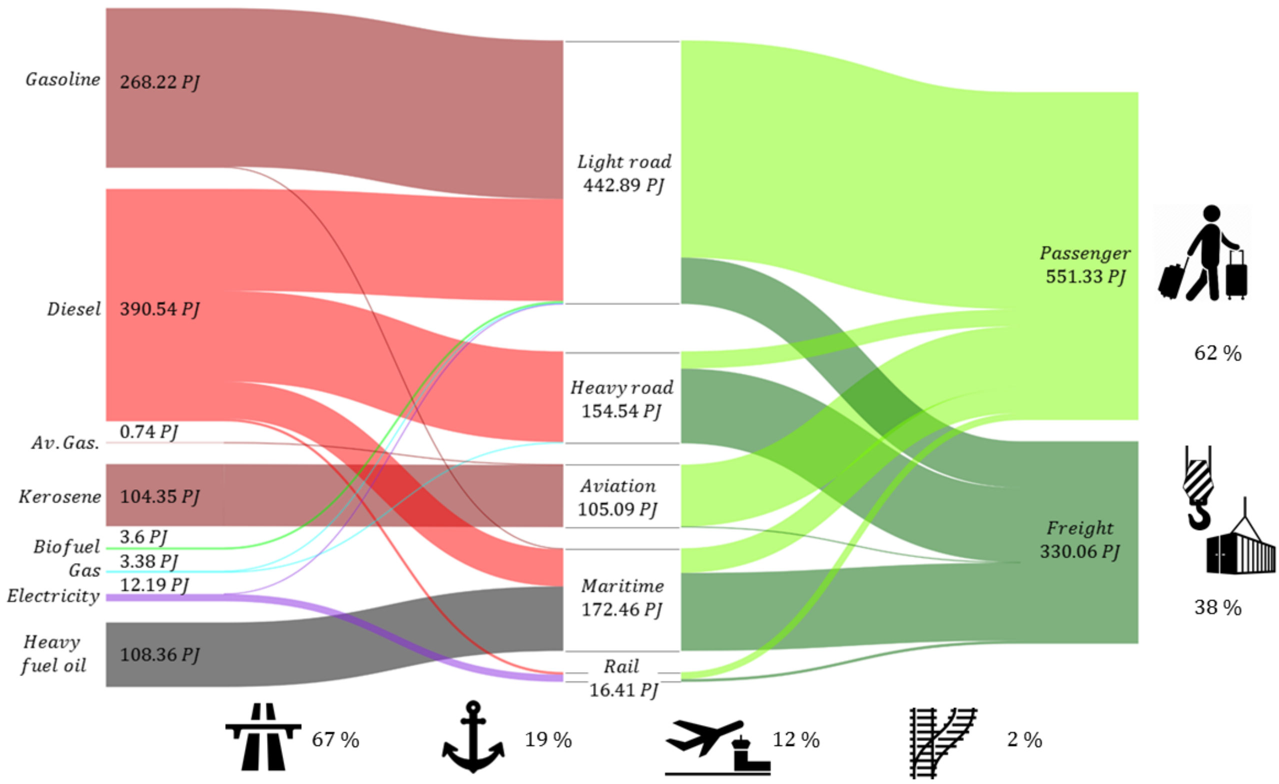

Figure 1. Final energy use and energy flows in the Scandinavian transport sector in 2010. Including international aviation and shipping. Source: (Salvucci, 2019a).

Shift

These actions seek to replace carbon-intense modes of transport with low-carbon ones. Figure 2 illustrates the rationale behind shift measures: rail has the lowest energy intensity in the passenger transport sector and the second lowest (after shipping) in freight transport. Therefore, shifting transport activity from private modes of transport or aviation to public transport enables energy demand to be limited significantly.

So far, shift policies have mainly been limited to urban areas, as reflected by the several targets on the modal share of public transport of several countries (ITF, 2017). However, shift policy measures generally do not target as much freight and intercity passenger transport.

Increased integration of the transport sector with the overall urban environment can foster the utilization of active modes of transport such as 'bike and walk' and increase public transport ridership. Transit-oriented development should be the urban paradigm for fast-growing cities, facilitating access to public transport and shorter trips.

Improve

The measures intend to accelerate deployment of low- and zero-emissions vehicles and the replacing of carbon-intense fuels with low-carbon fuels. The size of the global electric vehicles fleet is increasing rapidly. Sales of electric cars were about 2 million in 2018 and the stock of electric cars at the end of 2018 reached 5.1 million globally (IEA, 2019b), 45% were located in China (see Figure 3).

While China leads the electric mobility sector in absolute numbers, Norway and Iceland have the highest sales shares, reaching 46% and 11% respectively in 2018.

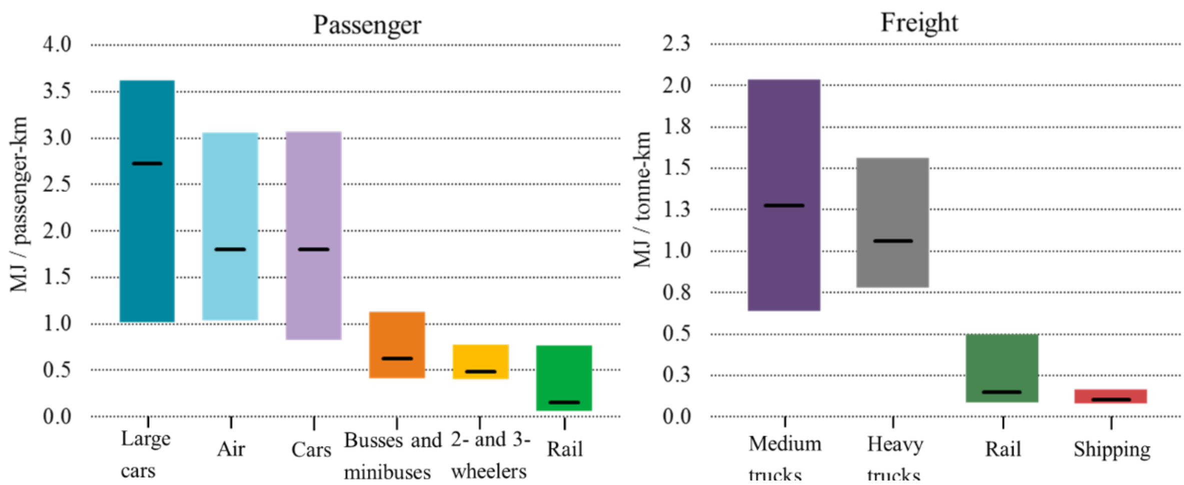

Figure 2. Comparison of the energy intensities of different transport modes (passenger and freight). The boxes indicate the range of average energy intensity in various countries, while the horizontal black lines represent the world averages. Source: (IEA, 2019a).

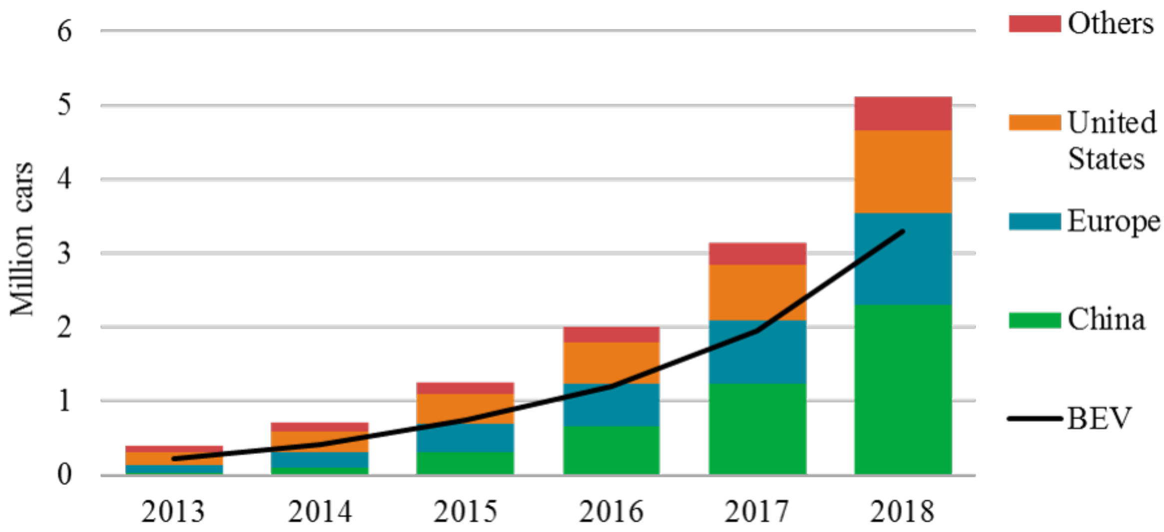

Figure 3. Passenger electric car stock in main markets, 2013-2018, Source: (IEA, 2019b).

Global biofuel production is also increasing, and is expected to continue to grow. In the Nordics, Sweden represent the largest user of biofuels.

While an increasing portfolio of low-carbon technologies is becoming available for short-distance inland transport, the shipping and aviation sectors are still facing a slow uptake of clean technologies and are proving to be the most difficult to decarbonize. The low energy density of batteries constitutes the main hurdle to the electrification of aviation, long-distance road transport and shipping. Currently, biofuels, synthetic fuels or hydrogen seem more attractive low-carbon solutions for these sub-sectors, as long as their production chains follow sustainability criteria.

The low-carbon transition of the aviation sector is being encouraged through the Carbon Offsetting and Reducing Scheme for International Aviation (CORSIA), the regulatory framework that aims to stabilize GHG emissions from the aviation sector by 2020 (ICAO, 2019).

For the shipping sector, in 2018 the International Maritime Organization approved the target of reducing its GHG emissions by 50% by 2050 with respect to 2008 levels (IMO, 2018).

However, the policy measures needed to reach this target have not yet been identified. The main binding regulatory framework is the EEDI, a fuel-efficiency standard mandating a minimum improvement of energy efficiency for new ships (IMO, 2019a) and a policy imposing a cap of 0.5% on the sulphur content of maritime fuels (IMO, 2019b). Several different fuels are being looked at for their potential to serve as low-carbon fuels in the shipping sector.

Our contribution

The overall aim of this work is to increase the Nordic capacity for energy systems analysis and to define the role of transportation in the transformation of the overall Nordic energy system towards carbon neutrality.

More specifically, we aim to
- assess how the future Nordic energy system may evolve, and how the transport sector will fit into and interact with it,
- assess how modal shift and consumer behaviour can be integrated into transport sector modelling to adequately reflect the full range of tight interconnections with the energy system,
- characterise mixes of technology and organisational innovations that will be most effective in the transition towards an energy-efficient and low-carbon transport system in different scenarios.

The long-term scenarios generated, based on quantitative energy systems analysis captures the Nordic energy system (excluding Finland) as well as the situation in the individual Nordic countries (Denmark, Norway and Sweden) (Salvucci et al., 2019a, 2019b; Tattini et al., 2018). The Nordic region will also benefit from our ambition to make research results, data, and assumptions available freely.

To answer the questions above a state-of-the-art energy system model of the Nordic energy system has been developed Fig. 4. The model covers Norway, Sweden and Denmark (can be expanded to include more countries) and is based on the TIMES modelling framework. The model, called TIMES-Nordic, covers all sectors and is open access (contact the project leader for more information).

TIMES-Nordic

TIMES-Nordic belongs to the TIMES models family (IEA, 2018). TIMES-Nordic covers the full energy system of the included countries. Each country is modelled individually and is geographically aggregated into different regions (Figure 4). Regions are interconnected through the representation of transmission lines, allowing electricity trade. The modelling structure of each national energy system is inspired by the architecture of TIMES-DK, the TIMES model representing the Danish energy system (Balyk et al, 2019).

The national energy system is divided into five sectors: supply, power and heat, industry, residential and transport. TIMES-Nordic has techno-economic projections until 2050. The whole-time horizon is composed of periods of various length, usually between one and ten years. Moreover, every year is sub-divided into 32 consequential time slices representing seasonal (four seasons), weekly (work-ing/non-working days) and daily variations.

A special focus has been on representing the transport sector at a detailed level and a new method to model transport behaviour including switch between transport modes have been developed and included in TIMES-Nordic (see next section).

More information on TIMES-Nordic can be found at the official webpage (http://shift.tokni.com, to be launched end-November 2019), where the user can consult most recent results, check scenario analysis descriptions and information about how to download the model.

Figure 4. Geographic area and representation of the energy system in TIMES-Nordic. For Denmark and Sweden model regions correspond to the Nord Pool power regions, while for Norway power regions are aggregated into two macro-regions.

Transport sector in TIMES-Nordic

Each national transport sector comprises all passenger and freight transportation, both characterised in terms of mobility demands and end-use transport technologies. Fuels can either be traded in the international market or produced by Nordic refineries, bio-refineries or other production technologies (such as electrolysers and electrofuel facilities).

Each sector is divided into inland, aviation and navigation. Inland passenger transportation comprises ten modes: car, bus, coach, rail (metro, train, light rail), two-wheelers (motorcycle and moped) and non-motorized modes (bike and walk), while the inland freight sector comprises three modes: van, truck and rail. Aviation and navigation comprise only one mode each, namely aircraft and ship.

The mobility service demands are defined exogenously for each mode for the entire time horizon in the form of passenger-kilometres (pkm) and tonne-kilometres (tkm). The mobility demands are mainly based on the national transport statistics that are projected up to 2050 based on trends assumed in the Carbon Neutral Scenario CNS in the Nordic Energy Technology Perspectives (IEA & NER, 2016).

In addition, modal demands are split further into distance range classes. For the inland passenger, these are extra short (XS, <5 km), short (S, 5–25 km), medium (M, 25–50 km) and long (L, >50 km). For passenger navigation and aviation modal demands are split into National and International. Freight modal demand are split into national short (NS, <50 km), national long (NL, >50 km) and international (I) with the exception of rail and ship where national demand segments are not split and freight aviation that only comprises the international demand.

The transport sector structure is presented in Figure 5.

Each transport mode is characterised by a defined travel pattern, representing the percentages travelled in the different distance classes. In the case of passenger transport, travel patterns reflect population travel habits, while for freight they represent typical modal adoption with respect to distance. Travel patterns are country-specific quantities, which can also vary across regions.

For each mode, a set of existing and future technologies is defined. These technologies differ in terms of fuel use, efficiencies and costs. The model satisfies the defined modal demands for the entire time horizon by deploying the technology mix with the lowest levelised costs while fulfilling the ulterior constraints implemented (such as environmental goals).

Moreover, an elasticity of substitution is defined for each distance category, allowing the model to adjust the modal demands defined in each category based on changes in their shadow price stimulated by the environmental goal under study. This later mechanism is a novel contribution of this project to the representation of transport behaviour in energy system models. In particular, it enables the representation of modal shift, and its potential contribution to decarbonise the transport sector when investigating specific policies triggering it.

The inclusion of elastic modal shift in TIMES-Nordic enables modes to compete among each other. The optimal solution is identified as a co-optimization of modal shares and technology shares considering the environmental policies in force and the rest of assumptions adopted, considering the elasticities values.

More information about TIMES-Nordic structure can be found in (Salvucci, 2019a) while a full description of how the elastic modal shift works in (Salvucci et al, 2018).

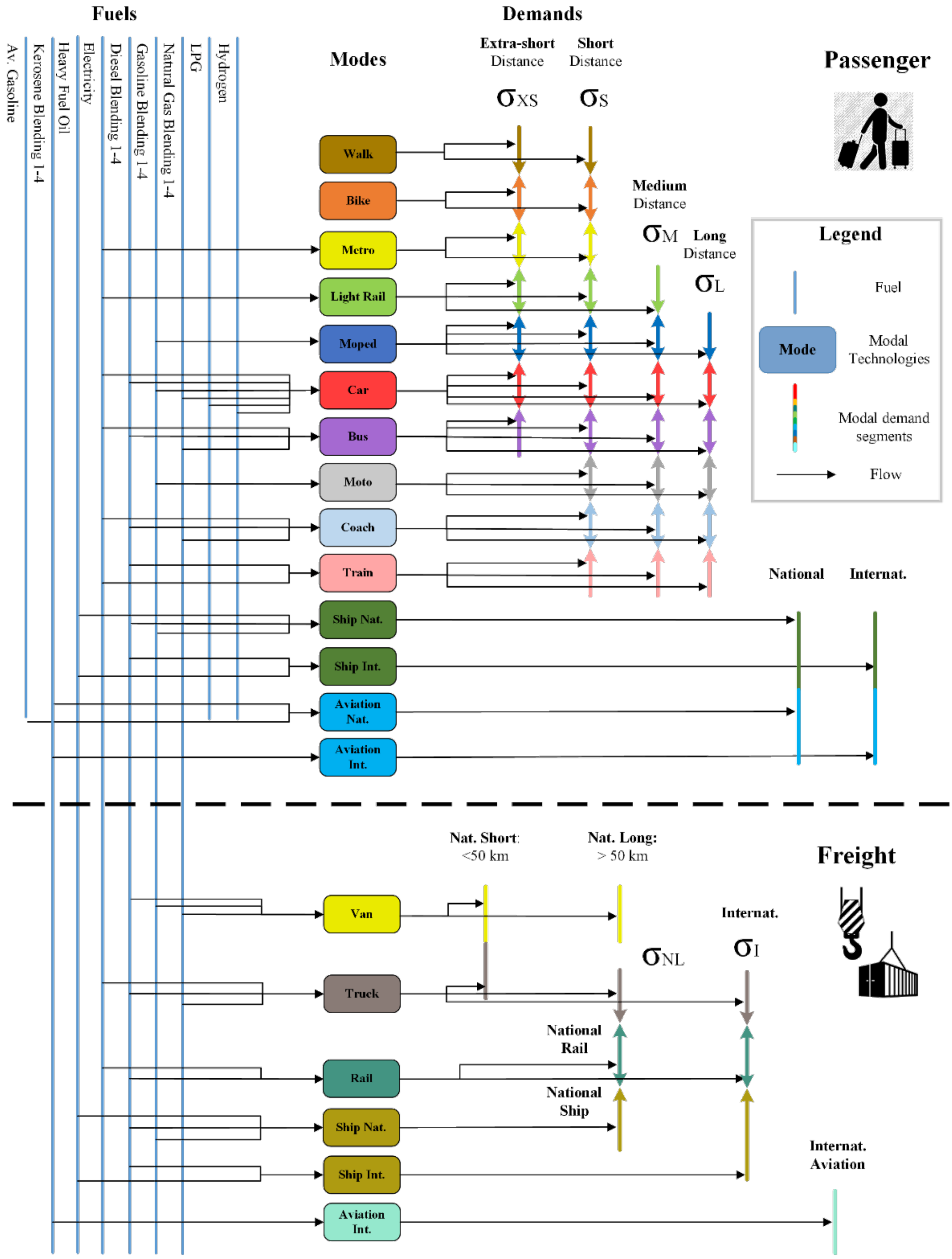

Figure 5. Transport sector structure in TIMES-Nordic. Elastic substitution across modal demands within distance categories is represented through arrow segments, while σ_($_{XS,S}$,..) are the elasticities adopted for each category. Source: (Salvucci, 2019a).

Result interface

Figure 6 exemplifies the result from TIMES-Nordic by showing the future fuel use in the Nordic transport sector and total energy system cost for different scenario conditions. To present the results from TIMES-Nordic publicly we have developed an interactive web-interface (see Figure 7) where scenarios from the model can be inspected and compared. It also includes background material such as assumptions and scenario description. The user can compare different scenarios and switch central assumptions to study the impact from this. The web-interface will be launched by end of November 2019.

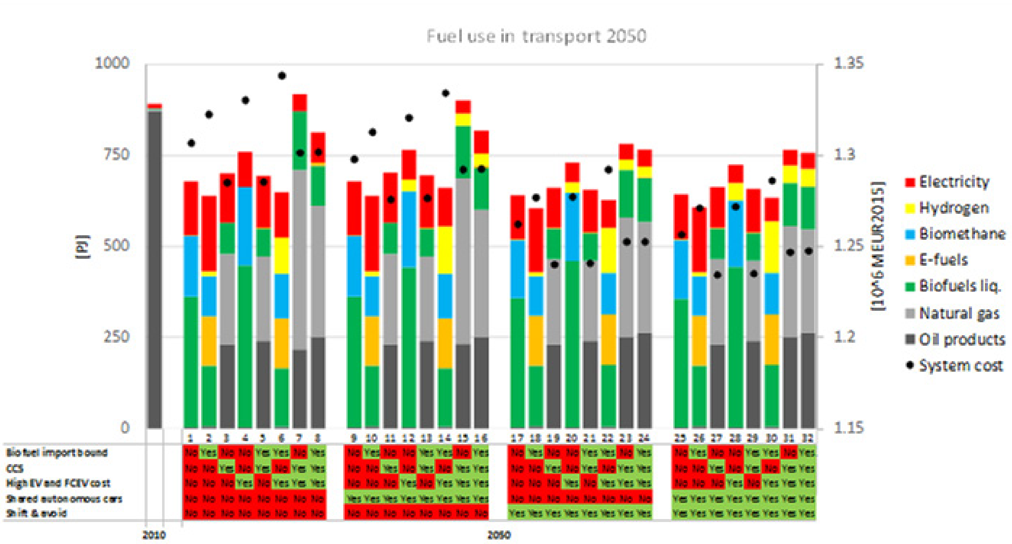

Figure 6. Fuel use in 2050 in the Scandinavian transport sector and linked discounted total energy system cost (for 2010-2050) for 32 different model cases with different combinations of scenario conditions assessed with TIMES-Nordic. Shift & Avoid assumes an alternative transport demand development with, e.g., lower car traffic levels. EV: Electric vehicle, FCEV: Fuel Cell Electric Vehicle, CCS: carbon capture and storage.

Figure 7. Illustration of the interactive Web-interface showing scenario results from TIMES-Nordic.

Findings in short including policy recommendations

- A state-of-the-art energy system model of the Nordic energy system, covering Norway, Sweden and Denmark, TIMES-Nordic, has been developed. The model architecture is structured to fill research and modelling gaps identified in previous studies by (Salvucci et al, 2019a). For interactive and detailed scenario results the reader is referred to https://shift.tokni.com/ (to be launched end of November 2019).

- A novel approach for considering modal shift in TIMES energy system modelling using substitution elasticities has been applied. We find that this approach can be used to emulate transport modal shift for both the passenger and the freight sub-sectors (Salvucci et al, 2018). This method reflects the complicated behaviour when it comes to modal shift but require a relatively limited amount of data and modelling efforts. The resulting modal shift potentials obtained for the Scandinavian region through the use of substitution elasticities is comparable with the ones identified by different studies, highlighting the methodology solidity (Salvucci et al, 2019b).

- It is possible to drastically reduce Nordic transport GHG emissions to 2040-2050 but strong and immediate actions are required. Thus, the Nordics can become frontrunners in solving the climate challenge in the transport sector, but the deployment rate of low-carbon technologies and fuels as well as shift and avoid measures need to be accelerated. A firm coordination among Nordic countries and a common technological strategy is pivotal.

- A combination of several transport mitigation measures are needed for decarbonizing the Nordic transport sector. Transport modal shifts, innovative transport technology options, changes in travel behaviour and new business models are all needed.

- A considerable increase in uptake of electric vehicles and a concurrent modal shift towards low energy intense modes seem cost-effective to decarbonize the Scandinavian transport sector for passenger and freight road transport (Salvucci et al, 2019b). However, biofuels are also needed, not least in shipping and aviation.

- In particular, a shift from trucks to more energy efficient modes such as rail and ships results to be cost-effective mitigation measures when decarbonizing the Scandinavian transport sector (Salvucci et al, 2019b). However, reducing transport demand, improving the efficiency of transport modes and stimulating modal shifts in the freight sector may only contribute to relatively limited emission reductions. Measures that increase the take-up of low- and zero-emission vehicles and fuels both in long-haul freight and in urban freight traffic is needed.

- Decarbonizing Nordic freight transport will require large amount of low-carbon fuels and electricity. In the mid-term for on-road freight mainly in the form of biofuels while in the long-term also through electrified options and/or hydrogen. All these options need policy support.

- Shared and autonomous electric vehicles can have large impacts on the development of the Nordic transport system and represents an attractive option from an energy system perspective.

- The cost-effective fuel and technology mix in the future Nordic transport sector depends on several key factors. These include the development of carbon capture and storage (CCS), expansion of low-carbon electricity generation, availability of sustainable biofuels and cost development of electrified options. Bio-CCS enabling negative emissions can reduce the need for the most expensive solutions for CO_2 reduction in the transport sector and its deployment should be carefully assessed in the Nordic region.

- The Nordic countries can become net CO_2 negative by 2040, but we need to speed up and collaborate. The CO_2 net negative target needs to be translated into realistic policies for each sector and the importance of CCS (carbon capture and storage) acknowledged.

- There is a considerable potential for electro-fuels in the Nordic region. However, renewable electricity and production costs, rather than CO_2 supply, limit the potential for electro-fuels production in the Nordics (Hansson et al., 2017).

- Measures supporting technological transformation and fossil-free freight transport must be implemented across the Nordic region. A better understanding of stakeholder preferences may improve the design and implementation of such policies and measures (Hansson et al., 2019).

Can the Nordic countries become carbon negative in a near future?

the Shift project initiated a common analysis across the three flagship projects (Shift, Flex4RES focusing on future energy markets and Negative CO_2 developing a carbon capture technology) assessing if the Nordic countries can become net negative CO_2 emitter by 2040.

The analysis was done in the TIMES-Nordic model, linked to the Flex4RES Balmorel model covering the power system in North Europe including the Baltic countries. The Balmorel model provided the boundary conditions for power trade and expansion of power transmission lines to TIMES-Nordic which were expanded with carbon capture technologies, CO_2 transport option and CO_2 storage facilities.

The TIMES-Nordic model was constrained to stay within a carbon budget fulfilling the Paris Agreement. The model may reduce emissions very fast with no carbon capture and storage (CCS) or slower with CCS (Figure A). For some sectors as heavy land-based transport, ships, aviation and heavy industries it is difficult or expensive to phase out all use of fossil fuels. If CCS is introduced, then some delay in reductions can be counter balanced by CCS linked to biomass plants.

Critical points and conclusions

The study shows that the Nordic countries can become CO_2 negative before 2050. However, action needs to be taken now. There is a need for very fast going from research to full scale solutions. Both technologies, the energy system and regulations need to be ready.

Some points are critical if the Nordic countries should become net negative CO_2 emitters:
- The integration of the different sectors is a key.
- Is there enough sustainable biomass available to the Nordic energy system?
- Carbon capture and storage (CCS) seems needed and there is a need to test such solutions especially linked to biomass fuelled plants to potentially allow for net negative emissions.
- The greening of the transport sector must speed up dramatically
- There is a need for disruptive technology development
- A lot of effective policies is needed.

The results from this analysis can be seen at https://timesnordic.tokni.com/

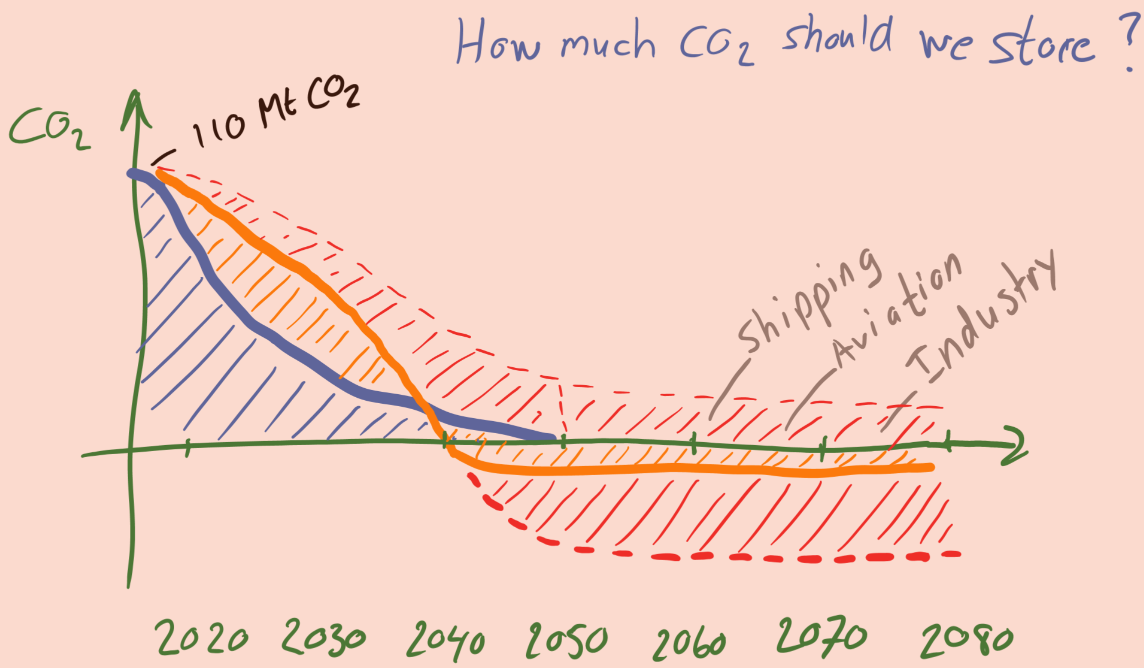

Figure A. CO_2 emission profiles with the linked need for CO_2 storage.

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Stimulating the transition towards a low-carbon, energy efficient transport system

Challenge

Achieving the ambitious climate change mitigation targets set by Nordic governments for the transport sector is a substantial challenge that requires an integrated innovation systems approach to reduce the transport related CO_2 emissions in the Nordic region. In doing so, strategies need to be aligned on an innovation systems level. Novel business models need to be considered alongside new developments in propulsion technologies. Specific attention must be taken to the systemic nature of transition. Finally, within the Nordic region as well as globally, several promising innovations ranging from technologies to business models interact in complex ways making the task of deciding a clear path forward difficult.

Our contribution

The aim of this work is to increase knowledge on current innovation systems challenges pertaining to the reduction of transport related CO_2 emissions in the Nordic region. More specifically, we have focused on the following areas of inquiry:

- Conceptual framework for examining transitions and innovations for a low-carbon Nordic transport system (Sarasini and Linder, 2018).
- Current barriers and possibilities for a number of key innovations (for passenger and long-haul freight) within the Nordic region (Langeland et al., 2019; Söderholm et al., 2019).
- The role of business models in transformation of the Nordic transport system, analysing ongoing developments in Mobility as a Service (MaaS) as a case.
- The relation between technology and business model innovations in systemic transformations in the Nordic transport sector using e.g., electric roads and MaaS as cases.
- How transformative transport related innovations interrelate, either competing or synergizing.

The insights gained in analysing case studies, a Nordic expert survey and panels will help inform Nordic policy makers on viable paths combining innovations to achieve CO_2 emission reduction in the transport sector.

Findings in short including policy recommendations

- In an overview of progress in several key innovation areas in the Nordic region, real market formation can only be traced for electric vehicles (EVs) and biofuels. There is no commercial market for electric road systems (ERS) or for hydrogen cars. ERS is still in a test phase and hydrogen still suffers from technological barriers and lack of infrastructure. Autonomous vehicles are in an early test stage and MaaS is still in a stage of pilot testing.

- If public transport agencies should move towards becoming a MaaS operator, existing regulation and policies must change and be clarified:

  - In both Sweden and Finland, there is an uncertainty regarding how subsidies for public transport can be used in MaaS services including private actors. This becomes problematic when the MaaS operator is private since it makes public transport non subsidized and hence not viable.
  - Car pool services probably plays an important role for MaaS development in the Nordic region. In Sweden the lack of legal definitions of car pools hinders growth. In particular, peer-to-peer services in rural settings find it hard to expand.
  - Differences in VAT levels for various mobility services create unequal market terms for Maas actors (6% for public transport and taxi, but 25% for carpools)
  - Public transport is viewed as the cornerstone actor in a Maas ecosystem, yet public transport actors have been reluctant to allow third party ticket sales.
  - Mobility service actors are wary of losing direct contact with customers and in the long run the control of their brands.

- The roles of network management changes at the interface between various phases of the technological development process, which is illustrated with the case of advanced biorefinery technology development in Sweden. Inefficient actor role-taking, the emergence of small, ineffective and competing actor networks in similar technological fields, and a shortage of interpretative knowledge are potential negative consequences of ignoring network management strategies in the innovation policy mix (Söderholm et al., 2019).

- Electric roads are still in pilot, demonstration and deployment projects and as of yet not commercially diffused. However, these activities have prepared ERS for potential takeoff (Tongur, 2018). While there are rationales for adopting ERS coupled to "greening" legitimization and cost reductions for e.g. haulers and operators, currently there are no established business models for delivering that potential value sustainably.

- New policies such as an upcoming deployment project that is being planned through the Swedish government national plan for infrastructure investment (Swedish Government, 2018) and the Transports administrations roadmap for ERS will be crucial for stimulating regions, suppliers, and users to deploy ERS. This will enable functioning business models to develop, that support a market diffusion of ERS to first niche markets and subsequently into mass markets, see Figure 8 (Tongur 2018).

- Our research has demonstrated that business models can play a critical role in sustainability transitions, as both a source of inertia and a source of change. That is, existing business models among incumbents can serve as a barrier to sociotechnical change, as they are intertwined with existing technologies and infrastructures, embedded within industry networks, and they reinforce existing user practices. As a source of change, however, business models can play a key role in commercialising carbon free technologies, and in some cases business model innovations can encompass radical innovations that revolutionise the way in which we produce and consume transportation. We have also shown that business models play different roles according to the characteristics of the transition in question. (Sarasini and Linder 2018, Sarasini and Langeland 2019).

- The implications of these findings are that policymakers, particularly those involved in R&I policy formulation, together with public and private organisations deeply involved in transition processes, must give sufficient attention to the role of business models and particularly business model innovation when trying to orchestrate sustainable transitions. This may be reflected in, for example, R&I programmes that provide support for experimentation with new business models in real-world settings, and activities that seek to evaluate and assess the potential for new business models to reduce CO_2. (Tongur 2018, Langeland et al. 2018, Sarasini and Linder 2018).

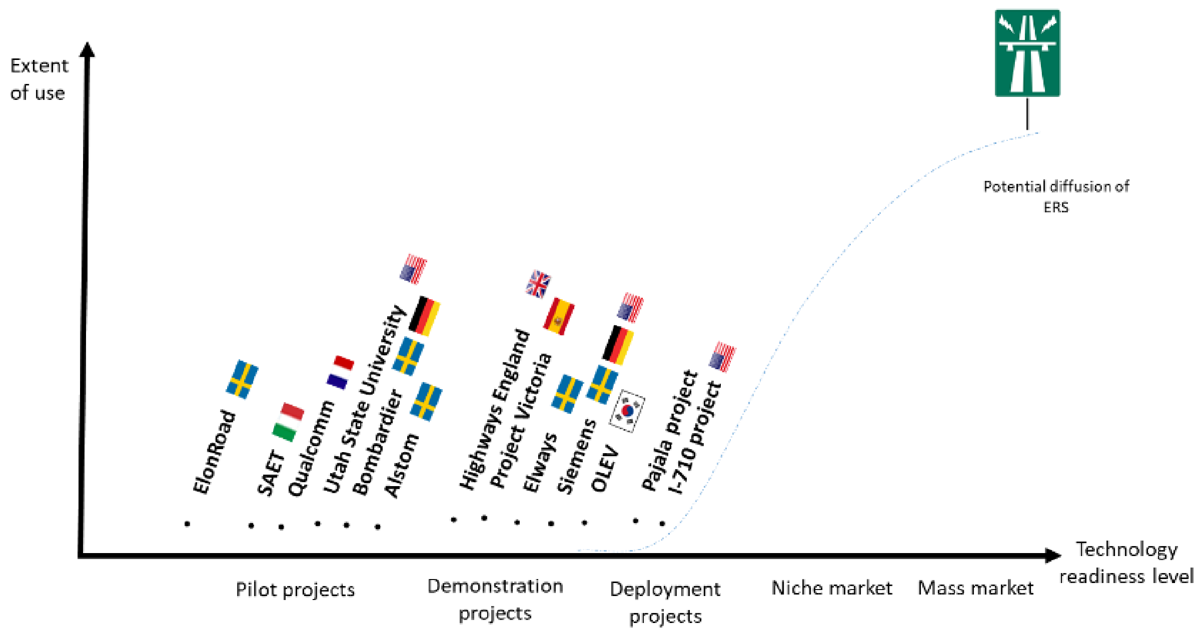

Figure 8. Electric road systems (ERS) activities preparing for commercial take-off (Tongur, 2018).

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Drivers, barriers and effects of transport modal shifts and efficient mobility solutions

Challenges

The social implications of transport technologies and infrastructure is poorly understood and remains unaddressed. Technological and engineering domain continues to dominate the transport sector. Efficiency gains and optimization approaches, embedded in the technical domain, is making progress in addressing the climate change mitigation targets set by Nordic governments for the transport sector. But modalities like behavioural change, integrated land-use planning, constraints on road capacity expansion, modal shift, uptake of smart solutions for passenger and freight transport etc. have received considerably less attention.

Further, the challenge of streamlining institutional approaches at the national, regional and local levels towards modal shifts and efficient mobility and urban planning solutions remain. The interlocking of modifying travel behaviour, solutions for low carbon public transport and freight transport, air quality, social inclusion, equity and post carbon/post car society is yet to be addressed in a robust framework.

A country level analysis reveals that in Denmark the focus is to make the country independent of fossil fuels by 2050 pointing towards a mix of adopting technical solutions and organizing the mobility sector differently than before. At the national level, Sweden has for example drafted a policy which targets modal shift and efficient mobility operation with the primary aim of achieving fifty per cent public transport by 2020. The Norwegian solution, however, has been to adopt a target of zero growth (measured in vehicle kilometres) in personal car transport in the 11 largest cities by 2030. In order to achieve this, a new tool called Urban Growth Agreements has been introduced where the government institutions across all levels have to cooperate and commit to reach this common goal.

Analysing the current plans and strategies highlight that issues like modifying travel behaviour, promoting modal shift and low carbon transport etc. get partly addressed at the different institutional levels based on the responsibilities of the different institutions. But it is a complex issue and specific programs which focus on better integration of land-use, public transport, walking and cycling, are often not taken forward in the grand scheme of things. The Scandinavian capital cities have prioritized public transport and it is seen as an important part of the future transport system linked to a strong polycentric approach. Similar approaches are lacking in smaller urban areas.

Policy measures aimed at reducing CO_2 emissions have started to decrease emissions from passenger cars, but not to the same extent from freight transport. The demand for freight transport in the Nordic countries is expected to increase also in the future, particularly by road implying a challenge.

Our contribution

This work has concentrated on building a knowledge pool to promote the uptake of modal shifts and efficient mobility solutions. We have:

- Examined factors that will influence modal shifts in both urban passenger as well as urban and long-haul freight transport. Identified what drives or inhibits modal shifts and exploring the options and effects of modal shifts have been pivotal.
- Explored the key determinants for travel behaviour in passenger transport, and ways in which some modal choices can be promoted, and how existing barriers can be broken down. We have drafted a methodology to plot future scenarios for passenger transport and associated CO_2 emissions.
- Assessed the role of shared mobility in the Nordic region.
- Assessed the potential for and impact of existing and strengthened policy instruments for modal shift in the Nordic countries and the associated environmental effects (including greenhouse gases, nitrogen oxides and particles) by focusing on modal shares for import to Norway (and Nordic transit countries).

The aim has consistently been to build a stronger base of research on both freight and personal travel behaviour as a vital component for shifting to low-carbon transport. For passenger transport, we have developed a model called DEMOTRIPS which creatively combines population projections, inputs from travel behaviour surveys and projections for labour market evolution to chart both opportunities and barriers for uptake of different modes in the future.

Shared mobility was studied as it is increasingly being recognised as a way to break the incessant increase in automobility. With an aim to assess if shared mobility actually possesses the potential to redefine future passenger transport, we explored the existing and potential landscape of shared mobility. This included examining the characteristics of necessary future interventions, including how cities can plan for shared mobility networks, strategies to promote the adoption and retention of shared mobility and its effective deployment across diverse contexts. We have further linked the future modal split, land-use potential and demographics to derive the potential growth areas for promoting shared mobilities.

The energy and emissions implications of modal shifts – e.g. higher shares of shipping in freight transport and of public transport and/or shared mobility in passenger transport – were plotted to highlight future energy demand and emissions impacts in both freight and private transport (Pinchasik et al., 2019).

Findings in short including policy recommendations

- Urban freight or city logistics has not been given its due place in the planning decisions. Relevant policies for increasing efficiency and reducing energy use and emissions in the field of urban freight have been identified (Fossheim et. al. 2020).

- Car sharing, an upcoming mobility solution, depends on integrated land-use patterns and provision of good-quality and easily accessible public transport system. Car sharing needs to be further studied in terms of users and non-users' profile, adoption-retention strategies, and policies-program's needs.

Some pointers for this area (Priya Uteng et. al. 2019c):
- Significant differences exist between users of different car sharing schemes. For example, between the users of cooperative and peer-to-peer schemes[1].
- Life events or life stages linked to the users have markedly different influence on opting for a particular format of car sharing scheme.
- Having children in the household is strongly related to cooperative-based car sharing.
- Events related to relocations were more common for uptake of peer-to-peer car sharing scheme.
- Materiality–skills–meanings [2] associated with car sharing influences both adoption and retention mechanisms. For example, the materiality set consists of proximity to transit-stops, access to high-frequency public transport services, walking/cycling infrastructure and, parking facilities.
- Future spatial and transport policies need to be integrated to promote car sharing.

- Gender and age emerge as a primary differentiating factor dictating the uptake of emerging solutions like car sharing and bike sharing across Scandinavia (and the world at large). The usage and preference for new mobility solutions vary between men and women. Till date, majority of the customers using the so-called smart solutions, comprises Caucasian male with stable employment, relatively high income and education. Age is also an important factor as elderly population face challenges in using digital solutions (Priya Uteng et. al. 2019b, Priya Uteng and Farstad 2020a).

- In order to promote sharing solutions, we need to identify performance gaps and build community outreach initiatives targeting groups at different life-stages, women and elderly.

- Accessibility mapping in light of both current and future

[1] Cooperative scheme refers to an organized, co-operative based system of car sharing where shared cars are available at designated spots, while the peer-to-peer scheme operates on a one-to-one basis with private people lending out their cars for a specified time-period at a specified rate.

[2] In short, materiality refers to available infrastructure, urban space and design, while skills deal with the associated competencies. Meanings refer to the bundle of values and norms associated with the transport modes in this discussion, aspects related to mode choice and space use are influenced by a combination of materiality, skills and meanings associated with them.

land-use growth potentials can ensure that areas where it is possible to promote public transport, walking and bicycling get built (Priya Uteng et. al. 2019a). These mappings should then be analysed in light of gender and age.

- Analysing the current plans and strategies highlight that issues like modifying travel behaviour, low carbon transport, promoting Mobility-as-a Service (MaaS), ride-sourcing and automated vehicles etc. get partly addressed at different levels based on the responsibilities of the different institutions. It is a complex issue and needs further attention.

- Analysing regulation and economic properties of the unscheduled passenger transport markets with scenario analyses for examining how ride-sourcing and automated vehicles affect these markets revealed that the underlying economic mechanisms faced in markets dominated by ride-sourcing and automated vehicles have similarities with traditional markets. Hence, regardless of how the services will be offered, some need for regulation will remain. As the market segments will differ, the possible and suitable forms of regulation will change (Aarhaug and Olsen 2018).

- An easily measurable approach based on accessibility planning can facilitate the regional authorities and municipalities. The Scandinavian capital cities have prioritized public transport and it is seen as an important part of the future transport system linked to a strong polycentric approach (Knapskog and Priya Uteng 2020). Similar approaches are lacking in smaller urban areas.

- Support schemes such as the eco-bonuses for rail and sea should be designed such, that they are only paid out when the support results in a (new) modal shift away from road transport. If they are harmonized over the borders of the Nordic countries, they will have a higher impact on goods transferred (Pinchasik et al., 2019).

- Combined measures which stimulate sea and rail transport and reduce the profitability of truck transport will have a greater impact than measures only stimulating one mode of transport (Pinchasik et al., 2019).

- Policy makers aiming at inducing modal shift in order to reduce CO_2 emissions need to consider also other environmental impacts (for example particles and NOX emissions) (Pinchasik et al., 2019).

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Effective design of policy instruments in the Nordic region

Challenge

The transition towards sustainable and efficient Nordic transport sectors requires a reform of energy policy and collective international initiatives. High energy efficiency, low local pollutions and low greenhouse gas emissions make electric vehicles a key element in sustainable traffic. The high energy efficiency of electric vehicles further results in low operating costs to the user. The running cost for the owner of an electric vehicle is only about 25 percent compared to a conventional diesel or petrol vehicle.

The reasons are twofold - high energy efficiency of electric engines and tax exemptions to electric vehicles paying no fuel taxes and reduced vehicle taxes in the Nordic countries. At the same time, the current production cost of electric vehicles is still significantly higher than for conventional vehicles. Policies need to address the trade-off between high capital costs of ownership and low running cost of electric vehicles.

Reducing fossil dependence of the transport sector by promoting electric and plug-in hybrid cars is essential for achieving the targets of climate change policy. Various types of government-financed subsidy programs have therefore become commonplace in the Nordic countries (IEA, 2018). Overall, climate policy instruments for transports will tend to undermine fuel taxation as a general regulatory instrument for traffic volume. As drivers change their behaviour in line with these instruments, the effects on vehicle travelled distance of fuel taxes declines. Drivers of electric vehicles do not change their vehicle travel distance behaviour to changes in fuel taxes.

Electrification requires a new general tax system for regulating traffic volume as well as restoring a socially efficient balance between road capacity and traffic volume. To maintain a long-term road infrastructure in the future for an electric vehicle fleet, and to match the social costs of traffic, the lost tax revenue from fuel taxes will need to be covered by a new tax base.

Our contribution

Electrification calls for reassessing road policies as it generates a target conflict between greenhouse gas reduction, regulating traffic volume and tax revenue to fund public infrastructure and social external costs of traffic. We have used mathematical analysis to develop structural designs for reformed transport policy in the Nordic region based on the new conditions that follows from electrification of the vehicle fleet.

By using advanced econometrics and micro-level data, our focus has been to isolate the effects of single policy instruments including for example the introduction of public charging points, the super-green car premium in Sweden promoting cars with low GHG emissions, the bonus-malus system and a potential differentiated kilometre tax for cars.

A new kilometre tax may represent an important tax base. With advances in GPS-based metering technology, it is now possible to charge drivers on a per kilometre basis according to the marginal external costs of their driving and thereby restore socially efficient balance between road capacity and traffic volume.

The development in GPS technology makes it also possible to differentiate a kilometre tax between rural and urban areas and charge drivers on a per kilometre basis according to the marginal external costs of their driving. Setting socially efficient tax rates would imply about 50 - 70% reduction of the total cost per kilometre in rural areas compared to urban areas and compared to today. Thus, electrification together with a new tax reform will also realize social benefits from deterred vehicle driving that held back development in rural areas.

When two or more instruments overlap in effects, their effectiveness in terms of changing behaviour is reduced. Policymakers need to coordinate policy instruments to prevent that their effects overlap. Our results show that even when instruments partly overlap in their effects, the losses in effectiveness can be substantial. Because of the loss in effectiveness, cost efficiency is also impeded.

To prevent ineffectiveness, it is important to understand and isolate the effects from each policy instrument already in the analysis during development of new policy instruments, and in the evaluation of policy instruments while they are in use. Thus, our findings can be used by policymakers designing transport energy policies and collective strategies in the Nordic region.

Findings in short including policy recommendations

- An increased number of public charging points causally increase the adoption rate of electric vehicles, especially in urban municipalities. Differences in the expansion of public charging infrastructure across municipalities can explain why the adoption rate of electric vehicles was faster in some municipalities. Expansion of charging infrastructure is therefore indicated to be an effective instrument to increase the share of electric vehicles (Egnér and Trosvik, 2018). The effect of public charging infrastructure was also found to be larger in urban municipalities than in suburban and rural municipalities. Adjusting policy instruments to the specific characteristics of municipalities and making them visible to the public can increase the effectiveness of the instruments.

- Public charging points in rural municipalities are recommended to be placed mainly along roads with high traffic work in order to counteract range anxiety. In urban municipalities, public charging points should also be placed close to the home as the main urban barrier is limited charging possibilities at home.

- Public procurement in municipalities also increases the adoption rate of electric vehicles. The hypothesis is that municipalities that use electric vehicles in the municipality work create a positive externality in terms of experience spill-overs to other citizens. The effect is larger in rural municipalities than in urban (Egnér and Trosvik, 2018). This could be explained by that municipally owned electric vehicles are relatively more visible and receive more attention in smaller municipalities where smaller social networks contribute to more experience spill-over (Egnér and Trosvik, 2018).

- The super-green car premium in Sweden lies behind 1 out of 3 registered plug-in hybrid cars registered during the period 2012 – 2015. The results imply that 2 out of 3 plug-in hybrid cars that received the premium would have been purchased and registered even without the super green car premium.

- The super green car premium partly overlapped with several other policy instruments that were in use in Sweden at the same time also affecting the number of registered plug-in hybrid cars. This reduced the effectiveness of the super green car premium (Hennlock, 2019a).

• The bonus-malus system in Sweden needs to be strengthened. Our results call for an increase in the bonus and malus in the bonus-malus system in Sweden. All vehicles should receive either a bonus or a malus which clarifies and simplifies the system (Inkinen and Hennlock, 2019).

• We identify an adjustment rule for the bonus and malus that follows the development of the relative price index and the ratio of the market shares of zero emissions vehicles and plug-in hybrids. The rule improves policy predictivity by balancing bonus and malus payments over the period. It also guarantees that the bonus remains sufficiently high until the price of bonus vehicles falls on the market.

• The existing road tax exemption for driving electric vehicles plays an important role for incentivizing the transition towards electric vehicles in the Nordic countries. The optimal timing of the introduction a kilometre tax occurs when the sales of zero emissions vehicles and plug-in hybrids with an e-range of reaches 70 – 90 percent market share (Hennlock, 2019b).

• The development in GPS technology makes it possible to differentiate a kilometre tax between rural and urban areas and charge drivers on a per kilometre basis according to the marginal external costs of their driving. Setting socially efficient tax rates would imply about 60% reduction of the total cost per kilometre in rural areas compared to urban areas and compared to today.

• Reduction commitment is still important in Sweden. Even with the reformed tax system, the 70 percent reduction target on CO_2 emissions until 2030 still needs a reduction commitment of 50 percent for diesel while the levels for petrol are at the limit what is technically possible today.

• To improve social efficiency, the social efficient tax - to charge vehicles on a per kilometre basis according to the marginal external costs of their driving – can be differentiated as the vehicle fleet transforms to zero emissions vehicles. Setting socially efficient tax rates would imply about 60% reduction of the total cost per kilometre in rural areas compared to urban areas and compared to today. Thus, electrification together with a new tax reform could realize social benefits from deterred vehicle driving that held back sustainable development in rural areas (Hennlock, 2019b).

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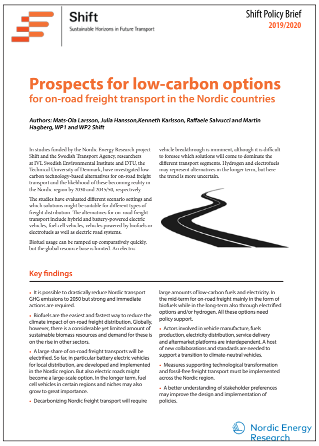
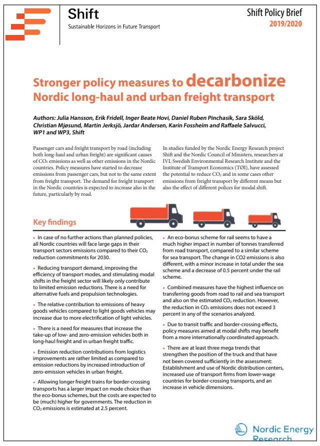
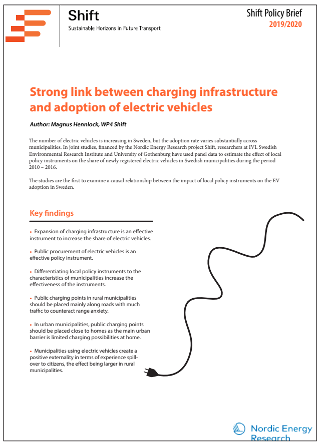
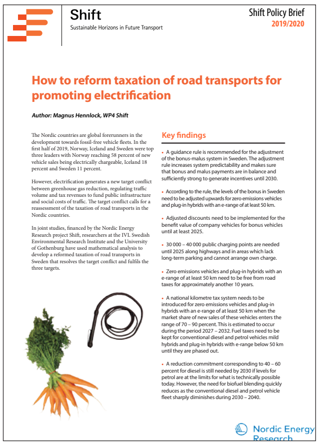
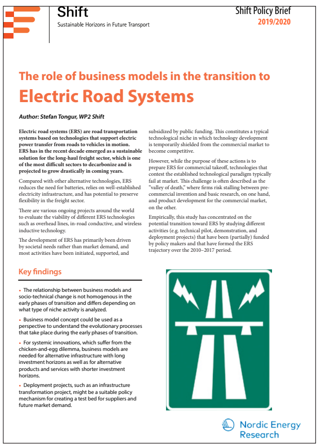
1. Prospects for low-carbon for on-road freight transport in the Nordic countries
2. Stronger policy measures to decarbonize Nordic long-haul and urban freight transport
3. Strong link between charging infrastructure and adoption of electric vehicles
4. How to reform taxation of road transports for promoting electrification
5. How to support the development of MaaS: Implications for public governance
6. Smart mobilities: a gendered perspective
7. The role of business models in the transition to electric road systems
8. Examining the nature of technological change
9. Supergreen car premium behind 1 out of 3 plug-in-hybrids in Sweden

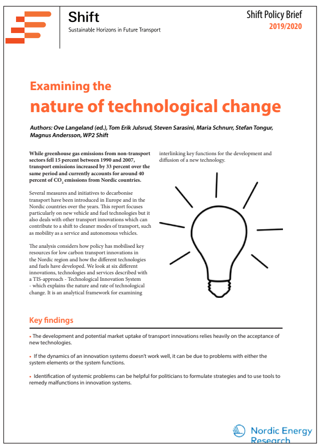












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Shift
Sustainable Horizons in Future Transport

Shift Policy Brief
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Prospects for low-carbon options
for on-road freight transport in the Nordic countries

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In studies funded by the Nordic Energy Research project Shift and the Swedish Transport Agency, researchers at IVL Swedish Environmental Institute and DTU, the Technical University of Denmark, have investigated low-carbon technology-based alternatives for on-road freight transport and the likelihood of these becoming reality in the Nordic region by 2030 and 2045/50, respectively.

The studies have evaluated different scenario settings and which solutions might be suitable for different types of freight distribution. The alternatives for on-road freight transport include hybrid and battery-powered electric vehicles, fuel cell vehicles, vehicles powered by biofuels or electrofuels as well as electric road systems.

Biofuel usage can be ramped up comparatively quickly, but the global resource base is limited. An electric vehicle breakthrough is imminent, although it is difficult to foresee which solutions will come to dominate the different transport segments. Hydrogen and electrofuels may represent alternatives in the longer term, but here the trend is more uncertain.

Key findings

- It is possible to drastically reduce Nordic transport GHG emissions to 2050 but strong and immediate actions are required.
- Biofuels are the easiest and fastest way to reduce the climate impact of on-road freight distribution. Globally, however, there is a considerable yet limited amount of sustainable biomass resources and demand for these is on the rise in other sectors.
- A large share of on-road freight transports will be electrified. So far, in particular battery electric vehicles for local distribution, are developed and implemented in the Nordic region. But also electric roads might become a large-scale option. In the longer term, fuel cell vehicles in certain regions and niches may also grow to great importance.
- Decarbonizing Nordic freight transport will require large amounts of low-carbon fuels and electricity. In the mid-term for on-road freight mainly in the form of biofuels while in the long-term also through electrified options and/or hydrogen. All these options need policy support.
- Actors involved in vehicle manufacture, fuels production, electricity distribution, service delivery and aftermarket platforms are interdependent. A host of new collaborations and standards are needed to support a transition to climate-neutral vehicles.
- Measures supporting technological transformation and fossil-free freight transport must be implemented across the Nordic region.
- A better understanding of stakeholder preferences may improve the design and implementation of policies.

Nordic Energy Research

Technology and politics determines the future

When it comes to goods transportation by road, there is a considerable discrepancy in all Nordic countries between carbon dioxide emissions and the commitments made to reduce them. Both technological innovation and low-emission fuels must be encouraged.

Which factors will be crucial when different climate-smart alternatives compete for market shares? This will be determined by the interaction between political decision making, technological development, availability, potential for scale-up and the strategies of vehicle and engine manufacturers and the fuel industry. Vehicle buyer's perception of the advantages and disadvantages of various options may also play a significant role. Our studies are based on a wide range of criteria and cost optimization and have analysed a wide selection of aspects and actors, which has enabled us to identify some of the most important factors.

Options and scenarios:
Low-carbon on-road freight transport

Climate neutral fuels

Biofuels are the easiest way of reducing the climate impact of road transport. Large-scale production of renewable fuels to replace fossil diesel in conventional and modified engines has already taken off and may increase comparatively quickly. In Europe the commercially important fuels are biodiesel (HVO and RME) and ethanol. In Sweden, biogas plays a role in certain niches. If usage is to increase, new instruments and expanded production capacity are needed. Some of today's biofuels are climate-efficient, others not. Stricter requirements must be imposed to improve climate performance.

But in a global perspective, bio raw materials cannot be sustainably harvested in sufficient quantities to satisfy all needs. The amount of bio-resources that can be used for fuel internationally is uncertain. Only a small portion of global fuel usage can be replaced by biofuel alternatives if these are to be produced sustainably. At national levels, however, there may be more resources available. Demand for biofuels may decrease as the combustion engine is challenged by electrical solutions. An increased demand for biomass is expected by the chemical, construction and energy sectors and as well as shipping and aviation.

Electrofuels are chemically identical to biofuels. They can be produced from renewable electricity and a climate-neutral carbon source, such as flue gases from bio power plants. Due to the current limited production, it is difficult to assess if electrofuels will be competitive for road transport. Also, the shipping sector is interested in electric solutions and electrofuels.

Battery-powered electric vehicles

Battery electric vehicles are few when it comes to heavy trucks, but the supply of models is growing. They have many advantages, such as lower noise level at moderate speeds, but primarily the potential to be cheaper than combustion engines due to high energy efficiency. The limitations are in the batteries: expensive (but prices are falling), with short range and long charging time (can be improved in the long run). The market for light distribution vehicles powered by electricity is developing rapidly. However, it is largely smaller vehicles for regional freight distribution that have reached a commercially viable level. But electric technology for heavier trucks and long haul is advancing rapidly, and battery prices are falling.

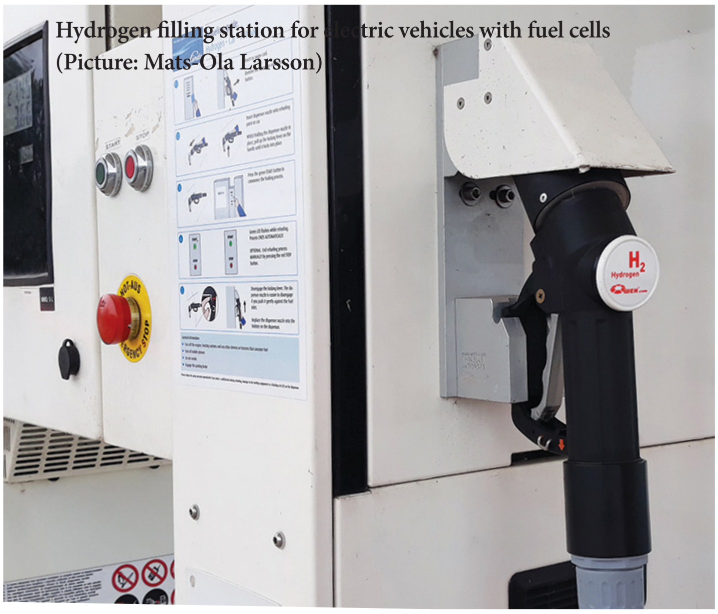
Electric vehicles can also be fitted with overhead lines or rails enabling them to run on electric roads, with fuel cells driven with liquid hydrogen, or in combination with an internal combustion engine. Battery powered electric vehicles in combination with range extenders are more expensive but much more flexible.

The development will benefit from the vehicle industry promoting new business models to finance the expansion of the charging infrastructure for trucks and also to press battery costs. Public actors may be needed to support expansion of the charging infrastructure. The manufacture and recycling of batteries will become increasingly important. Access to rare materials, inefficient battery production or poor recycling could slow development.

Electric vehicles with fuel cells

A fuel cell vehicle converts a fuel (usually liquid hydrogen) into electricity. The tank requires a similar refuelling time as a diesel engine vehicle and delivers approximately the same distance range. The fuel cell may also function as a range extender, complementing a battery. Fuel cells

Truck from Volvo driven by liquified biogas. (Picture: Volvo)



Hydrogen filling station for electric vehicles with fuel cells (Picture: Mats-Ola Larsson)

have better energy efficiency than combustion engines, but not as good as batteries and electric roads.

The best outlook for commercial breakthrough is probably to be found in local and regional freight distribution. Hydrogen distribution can be developed in the market without requiring large-scale expansion.

Although fuel cell technology is advancing rapidly, it has not yet got a commercial breakthrough. It is not clear what role it will play in the future. Fuel cells driven with hydrogen can in the long run become an increasingly realistic complement or alternative to batteries.

Many interdependent actors need to scale up to a commercially viable level at roughly the same rate. The interaction includes producers and distributors of hydrogen, fuel cell and vehicle manufacturers, and not least users.

Electric road systems

Electric roads supply electric power to vehicles. It can either be via overhead lines (as railroads), in-road conduction from rails or wireless electromagnetical induction embedded under the road surface.

All electrical road technologies have great potential as they reduce the need to store electricity on board. There are no commercial electric roads today, but some countries are preparing on a pilot scale. The specific technical solutions are uncertain, but electric roads will probably be of importance within a decade as yet another way of mitigating climate impact, provided that electricity and raw materials are sourced in a climate-neutral way.

Electric road with overhead lines. Scania's and Siemens' project outside Gävle, Sweden. (Picture: Scania)

The biggest challenge is funding. The build-up phase is costly, while a large number of users are needed to provide profitability at later stages. Decisions to expand the first networks with electric road systems need to be made before investors are able to assess the interest of the automotive industry and buyers.

It is likely that public actors will need to co-finance or procure the infrastructure. New business models may also be required for purchasing and owning vehicles, and for paying for electricity and infrastructural costs.

Possible scenario for on-road freight transport technologies 2030 and 2045/2050.
Prerequisites: National and international policies make an effort to change road transports to achieve fossil freedom as quickly as technology shifts allow, and all concerned parties act accordingly.

	Market in 2030			Market in 2045/2050		
Freight	Local	Regional	Long-distance	Local	Regional	Long-distance
Electric road systems			?			
Biofuels						
Battery vehicles						
Fuel cells	?	?		?	?	??

- Up to 10 per cent of transports may come to utilize this technology
- At least 10-20 percent of transports may come to utilize this technology
- ? Very uncertain prognosis
- ?? Extremely uncertain assessment

Nordic scenarios

The Nordic TIMES model, developed in the Shift project, covers all sectors of the national energy systems in Denmark, Norway and Sweden, including power and heat, industry, service, residential and transport as well as relevant connections and interactions. Scenarios to year 2050 is studied with a cost-optimization approach. Onroad freight transport is described by the selection of fuel and vehicle technology options described above, e.g. including biofuels, electricity and hydrogen as well as electric vehicles, hybrids and fuels cell vehicles.The possibility of modal shift is also included.

In scenarios with stringent CO_2 emission reductions reaching net zero emissions on the Nordic level by 2050, biofuels (mainly biodiesel) are the preferred low-carbon choice in the mid-term while electrified options and/or hydrogen increase considerably in the long-term. The development in other parts of the energy system influences the on-road freight sector. Key factors include biofuel import possibilities, availability of low-carbon electricity generation, and carbon capture and storage, which support the use of liquified natural gas (LNG).

For scenario results see https://shift.tokni.com/

Policy recommendations

- Switching goods distribution and long-haul transports to fossil-free fuels requires the adoption of many international courses of action. But individual nations, actors and companies also exert great influence on local markets.

Examples of such measures are that political actors demand that a gradually increasing proportion of new sales within the EU is made up of rechargeable or biofuel vehicles. Taxes on vehicles and fuels can steer more clearly towards climate-neutral solutions, also for the shipping sector. Quota or reduction systems can be used to leverage a gradually increasing proportion of renewable components in fuels. Standards and support can be designed to accelerate new technologies. Electric road systems, charging stations and other infrastructure may need to be procured or partially financed publicly.

- Transport buyers can demand a climate-smart approach to transport. Public actors can impose procurement requirements on new technologies. Vehicle manufacturers, fuel manufacturers, electricity distributors and financiers need to develop new products, develop new business arrangements and collaborate with new players.

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Shift

Sustainable Horizons in Future Transport

Shift Policy Brief

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Stronger policy measures to decarbonize Nordic long-haul and urban freight transport

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Passenger cars and freight transport by road (including both long-haul and urban freight) are significant causes of CO_2 emissions as well as other emissions in the Nordic countries. Policy measures have started to decrease emissions from passenger cars, but not to the same extent from freight transport. The demand for freight transport in the Nordic countries is expected to increase also in the future, particularly by road.

In studies funded by the Nordic Energy Research project Shift and the Nordic Council of Ministers, researchers at IVL Swedish Environmental Research Institute and the Institute of Transport Economics (TØI), have assessed the potential to reduce CO_2 and in some cases other emissions from freight transport by different means but also the effect of different polices for modal shift.

Key findings

- In case of no further actions than planned policies, all Nordic countries will face large gaps in their transport sectors emissions compared to their CO_2 reduction commitments for 2030.
- Reducing transport demand, improving the efficiency of transport modes, and stimulating modal shifts in the freight sector will likely only contribute to limited emission reductions. There is a need for alternative fuels and propulsion technologies.
- The relative contribution to emissions of heavy goods vehicles compared to light goods vehicles may increase due to more electrification of light vehicles.
- There is a need for measures that increase the take-up of low- and zero-emission vehicles both in long-haul freight and in urban freight traffic.
- Emission reduction contributions from logistics improvements are rather limited as compared to emission reductions by increased introduction of zero-emission vehicles in urban freight.
- Allowing longer freight trains for border-crossing transports has a larger impact on mode choice than the eco-bonus schemes, but the costs are expected to be (much) higher for governments. The reduction in CO_2 emissions is estimated at 2.5 percent.
- An eco-bonus scheme for rail seems to have a much higher impact in number of tonnes transferred from road transport, compared to a similar scheme for sea transport. The change in CO2 emissions is also different, with a minor increase in total under the sea scheme and a decrease of 0.5 percent under the rail scheme.
- Combined measures have the highest influence on transferring goods from road to rail and sea transport and also on the estimated CO_2 reduction. However, the reduction in CO_2 emissions does not exceed 3 percent in any of the scenarios analyzed.
- Due to transit traffic and border-crossing effects, policy measures aimed at modal shifts may benefit from a more internationally coordinated approach.
- There are at least three mega trends that strengthen the position of the truck and that have not been covered sufficiently in the assessment: Establishment and use of Nordic distribution centers, increased use of transport firms from lower-wage countries for border-crossing transports, and an increase in vehicle dimensions.

Nordic Energy Research

Background:

Policy measures in the Nordic countries to reduce emissions

The report *Reducing CO_2 emissions from freight* maps current initiatives to reduce CO_2-emissions from freight in the Nordic countries. In Norway, those emissions are expected to further increase towards 2030, while in Denmark they are expected to stay at the current level and reduce in Sweden and Finland.

Policy measures taken

The main means for reducing CO_2-emissions can be grouped into reducing transport demand, increasing transport mode efficiency, modal shift, switching to fuels with lower carbon content and moving towards lower-carbon vehicle technologies.

These policy measures to reduce transport demand are used in the Nordic countries:

- Toll/road pricing (NO, SE)
- CO_2/NO_X taxes on fuel (all)
- Road infrastructure fees on fuel (NO)
- Energy tax on fuel (SE, FIN, DK)
- Reduced taxes for biofuels (all)
- The Eurovignette (SE, DK)
- Environmental zones for reducing local pollution (SE, DK)

Other Nordic measures include relaxed restrictions on weight and length of heavy goods vehicles (FIN, SE) and extensions of the road network for 25.25-meter-long vehicles (NO, DK). Another way of reducing CO_2 emissions is through modal shifts, shifts to transport modes with lower CO_2 emissions per transported unit (mainly from road to rail and waterborne transport).

The main policy instruments include taxation, subsidies, and facilitating infrastructural measures. Nordic examples include eco-bonuses, schemes for waterborne transport (NO) and for rail (SE, NO). The mode of choice for border-crossing determines to some extent the modal choice also later in the transport chain. This influences the freight transport in transit countries, e.g. Sweden and Denmark.

All Nordic countries have biofuel blending requirements. The EU promotes more efficient conventional propulsion and development of alternative technologies, as binding targets for reduced CO_2 emissions in new heavy-duty vehicles. Policies promoting the uptake of lower carbon vehicle technologies for freight need to be strengthened in all Nordic countries. There are some demonstration projects (e.g. platooning and electric roads in Sweden). In Norway, a support scheme started in 2019 gives purchasers of electric vans a subsidy of 15 000 to 50 000 NOK, depending on the vehicle's engine power and also provides subsidies to energy and climate measures within land transport.

National policy focus

Most of the current Nordic policy measures are directed at the national markets, implying that they might result in unintended outcomes or a sub-optimal effectiveness due to spill-overs. When compared to the national CO_2 reduction commitments for 2030, it is concluded that current and planned policies will not lead to the required reductions. Measures aimed at reducing transport demand, improving the efficiency of transport modes, and stimulating modal shifts in the freight sector will likely only contribute to limited emission reductions. There is a need to further promote alternative fuels and propulsion technologies. However, incentives are needed, at least in an early phase, both for freight transfers through modal shifts, and for low-carbon fuels or alternative propulsion systems.

The modal shift potential

Assessments of domestic modal shift for freight (from road to rail and waterborne transport) might under-estimate the full modal shift potential. If more goods enter the Nordic countries by rail or sea, this can increase the likeliness of domestic transports by these modes.

A study by TØI and IVL assesses the impact of existing and strengthened policy instruments for modal shift in the Nordic countries for import to Norway (and Nordic transit countries) and their environmental effects.

The analysis of policy scenarios for 2030 indicates that a Norwegian eco-bonus scheme for sea transport replacing road transport might have a much larger impact in number of tonnes transferred from road transport, compared to a similar scheme for sea transport. Allowing longer freight trains between Norway and Sweden has a larger impact on mode choice than the eco-bonus schemes, but will likely require large government investments.

Significant increases in the Eurovignette rates will result in reduced road transport, but to a limited extent, mostly through shifts from road to rail transport. This policy measure can also affect route choice and reduce road transport related to Norwegian transit through Sweden, and result in increases in domestic road transport in Norway.

Allowing longer freight trains and better access to rail terminals in Europe will increase transport by rail in model simulations, but transports are mainly shifted from sea, than from road. New infrastructure connections, as the Fehmarnbelt-connection, give a weak increase in road transport, and an even smaller increase in rail transport, both at the expense of sea transport.

Scenarios where measures are combined yield the largest effects on transferring goods from road to rail and sea transport. Harmonizing policy instruments between the Nordic countries might lead to stronger effects.

Most scenarios reduce greenhouse gases, nitrogen oxides (NO_X) and particles, particularly with a combination of policies and considering the effect also outside of Norway. However, in several scenarios there are increased emissions, for example of NO_X and particles, due to increases of sea transport, where the emission limits are less strict.

The role of modal shift for 2050

The specific role of modal shift in decarbonizing the Scandinavian transport sector is assessed by Salvucci et al. (2019). The assessment is made by implementing long-term substitution elasticities for modal shift from the literature for passenger and freight transport in a model depicting the national energy systems of Denmark, Norway and Sweden.

This is the first time that passenger and freight modal shift are modelled in an energy model for a real case study. Modal shift is found to be cost-effective for decarbonizing the Scandinavian transport sector under an increasing CO_2 tax (one of several cost-effective measures). When rail and to some extent ship replaces trucks the total modal shift (including the passenger sector) results in a reduced fuel use in 2050, and 2.2 percent lower CO_2 emissions from transport.

Comparing alternative scenarios

TØI assessed, through case studies in the Oslo and Akershus region, how emissions from freight traffic in cities might develop to explore how the current policies supports significant emission reductions. The alternative scenarios included improved logistics efficiency and a significant introduction of zero-emission vehicles.

It was found that logistics improvements like better management to limit the overall traffic are important. A general advice is to improve the national guidance for urban freight planning. However, the introduction of zero-emissions vehicles is the game-changer. When compared to them, emission reductions from logistics improvements are rather limited. The relative contribution to carbon dioxide emissions from heavy vehicles can increase compared to light goods vehicles, due to increased electrification of the latter.

Policy recommendations

- The introduction of low-carbon fuels and propulsion technologies in the freight transport sector need to be supported in all Nordic countries, for both long-haul freight and urban freight transport. This will increase demand and give an incentive to companies to prioritize development of these technologies.
- Measures aimed at reducing transport demand, improving the efficiency of transport modes, and stimulating modal shifts in the long-haul freight sector need to be promoted further.
- Logistics improvements, for example better management of freight movements to limit the overall traffic and belonging negative impacts in metropolitan areas, are also important to promote.
- Support schemes such as the eco-bonuses for rail and sea should be designed such, that they are only paid out when the support results in a (new) modal shift away from road transport. If they are harmonized over the borders of the Nordic countries, they will have a higher impact on goods transferred.
- Allowing longer trains may have a higher impact on rail transport than certain subsidy scheme designs.
- Combined measures which stimulate sea and rail transport and reduce the profitability of truck transport will have a greater impact than measures only stimulating one mode of transport.
- While measures such as larger allowances for vehicle dimensions might improve the efficiency of road transport, they also make road transport more competitive versus rail and sea.
- Regulatory measures in urban areas (such as time access regulations, parking regulations, environmental restrictions e.g. low emissions zones, size/load access restrictions, freight-traffic flow management) should be designed in parallel to market-based measures (involve pricing, taxation and tax allowances) to systemize urban freight and control the externalities associated with it.
- For urban freight a combination of measures is needed. A comprehensive urban freight strategy in municipalities need to be drafted by the authorities, a common database mapping the types of urban freight activities and trips in the cities need to be created and there need to be increased coordination between urban freight stakeholders.
- Implemented policy measures should be evaluated and the findings shared between the Nordic countries as this may improve the design of new policies.
- Policy makers aiming at inducing modal shift in order to reduce CO_2 emissions need to consider also other environmental impacts (for example particles and NO_x emissions).

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Strong link between charging infrastructure and adoption of electric vehicles

Author: Magnus Hennlock, WP4 Shift

The number of electric vehicles is increasing in Sweden, but the adoption rate varies substantially across municipalities. In joint studies, financed by the Nordic Energy Research project Shift, researchers at IVL Swedish Environmental Research Institute and University of Gothenburg have used panel data to estimate the effect of local policy instruments on the share of newly registered electric vehicles in Swedish municipalities during the period 2010 – 2016.

The studies are the first to examine a causal relationship between the impact of local policy instruments on the EV adoption in Sweden.

Key findings

- Expansion of charging infrastructure is an effective instrument to increase the share of electric vehicles.

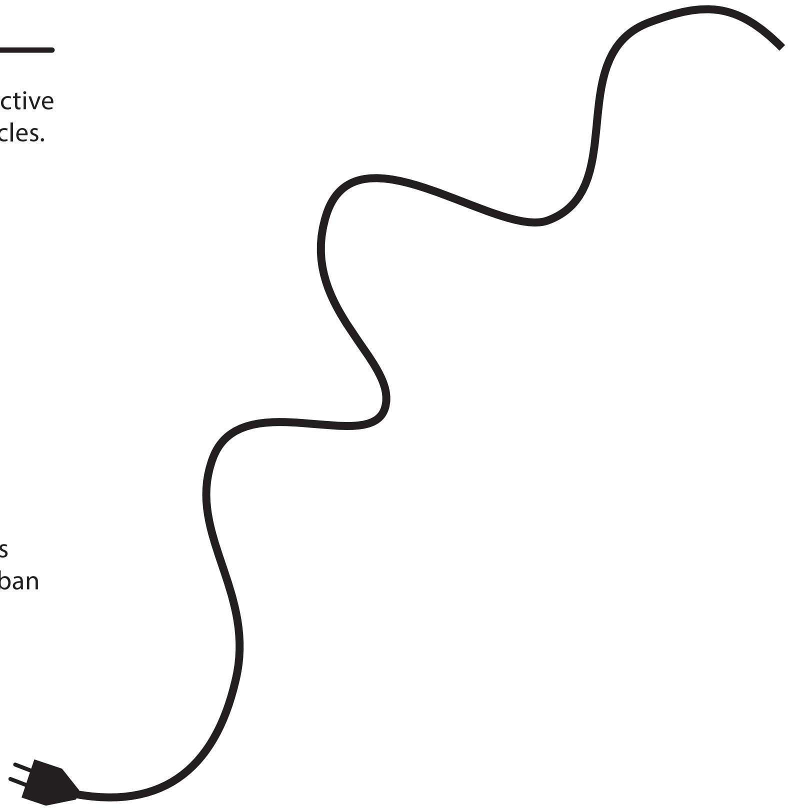
- Public procurement of electric vehicles is an effective policy instrument.

- Differentiating local policy instruments to the characteristics of municipalities increase the effectiveness of the instruments.

- Public charging points in rural municipalities should be placed mainly along roads with much traffic to counteract range anxiety.

- In urban municipalities, public charging points should be placed close to homes as the main urban barrier is limited charging possibilities at home.

- Municipalities using electric vehicles create a positive externality in terms of experience spill-over to citizens, the effect being larger in rural municipalities.



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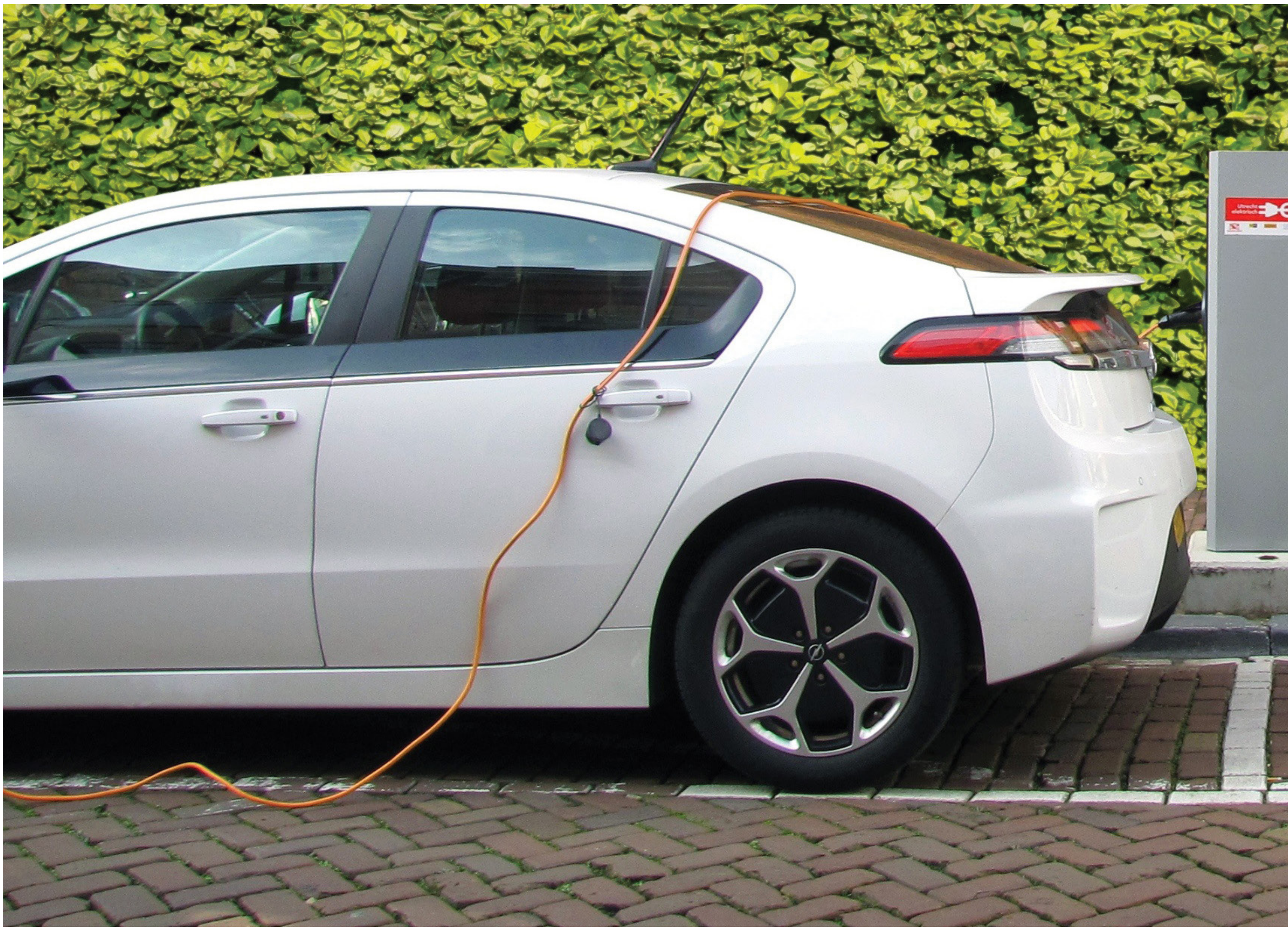

Background:

Understanding EV adoption by examining its determinants

The reduction of greenhouse gas emissions from the transport sector is essential for achieving the targets of climate change policy. To reduce these emissions, Sweden has set a target to achieve a fossil independent vehicle fleet by 2030. Depending on the source of electricity, a transition towards electric vehicles (EVs) has the potential to reduce greenhouse gas emissions and therefore Sweden has implemented several policy instruments to increase the adoption of electric vehicles.

Significant variations across municipalities

The aim of this study is to contribute to the understanding of electric vehicle adoption by empirically examining its determinants. The study specifically addresses the significant variation in the adoption rate of electric vehicles across municipalities, despite the fact that national financial incentives are the same across municipalities. The study focuses on battery electric vehicles (BEVs) and examine the impact of local policy instruments designed to promote the adoption at a municipal level.

The local policy instruments in Sweden include parking benefits and public charging infrastructure. In addition to these existing policy instruments, the study also investigates whether public procurement of BEVs at the municipality level has the potential to increase the BEV adoption.

EVs vs BEVs

Compared to other EV types, BEVs have the potential to lower greenhouse gas emissions during driving to a higher extent since they don't require any fossil fuel. The emissions instead depend on the power source and since over 90 percent of the electricity production in Sweden is generated from renewable or nuclear sources, the greenhouse gas emissions from BEVs are low. On a local level, BEVs also bring benefits such as air quality improvements and reduced noise. However, barriers such as high costs, limited battery capacity, and dependence on charging infrastructure are limiting the widespread diffusion of the EV technology. Studies further suggest that imperfect information and limited knowledge about EVs contribute to slow diffusion rates.

National instruments have been weak

Related literature has in several countries found both nationally implemented financial incentives and locally implemented policy instruments to have a positive impact on EV adoption. However, the effectiveness of the Swedish national financial instruments promoting EVs have so far been weak and the local policy instruments in Sweden have not previously been empirically examined with quantitative methods. The long-term effects of the bonus malus system introduced in Sweden in 2018 remain to be evaluated.

First study to look at the causality of local instruments

By taking advantage of the municipal variation in BEV adoption rates and local policy instruments in Sweden, this study is the first to causally investigate the impact of local policy instruments on the BEV adoption in Sweden by testing for so calles reverse causality between charging infrastructure on the BEV share in the regressions.

Key findings:

Public charging points increase the adoption of EVs

The results indicate that an increased number of public charging points causally increase the adoption rate of electric vehicles, especially in urban municipalities. Differences in the expansion of public charging infrastructure across municipalities could explain why the adoption rate of electric vehicles was faster in some municipalities. Expansion of charging infrastructure is therefore indicated to be an effective instrument to increase the share of electric vehicles.

Differentiated charging infrastructure

The effect of public charging infrastructure was also found to be larger in urban municipalities than in suburban and rural municipalities. Adjusting policy instruments to the specific characteristics of municipalities and making them visible to the public can increase the effectiveness of the instruments.

Public charging points in rural municipalities are recommended to be placed mainly along roads with high traffic work to counteract range anxiety. In urban municipalities, public charging points should also be placed close to the home as the main urban barrier is limited charging possibilities at home.

Positive externality and spill-over

The results also show that public procurement in municipalities also increases the adoption rate of electric vehicles. The hypothesis is that municipalities that use electric vehicles in the municipality work create a positive externality in terms of experience spill-overs to other citizens. Again, there is a difference in the size of effect between rural and urban municipalities with the effect being larger in rural municipalities.

The higher effect could be explained by that municipally owned electric vehicles are relatively more visible and receive more attention in smaller municipalities where smaller social networks contribute to more experience spill-over.

This result suggests that public procurement of electric vehicles is an effective policy instrument and that local policy instruments should be differentiated to the characteristics of municipalities to increase their effectiveness.

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Shift

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Shift Policy Brief

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How to support the development of MaaS: Implications for public governance

Author: Steven Sarasini, WP2 Shift

Mobility as a Service (MaaS), sometimes referred to as Combined Mobility, Mobility on Demand, and Integrated Mobility, is considered to have the potential to bring about sustainability gains within passenger transportation. Billed as an alternative to private car ownership and use, with public transport as a 'backbone', MaaS can promote more sustainable travel behaviour through, among other things, modal shifts towards shared and active modes.

In studies funded by the Nordic Energy Research project SHIFT and the Vinnova project IRIMS, researchers at RISE and several other Swedish research organisations have investigated the dynamics of MaaS developments in Sweden, Finland and other locations across Europe. These studies have examined a set of drivers and barriers to innovation as a means to derive implications for the governance of sustainable MaaS developments.

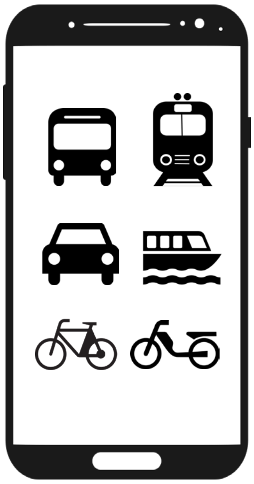
Key findings

- Support is needed to coordinate public and private organisations given the prevalence of barriers to collaboration in MaaS ecosystem. Publicly funded activities that provide support for business modelling and coaching should be given priority.

- If public transport is to act as a MaaS operator, existing laws and governing directives must be modified and clearly emphasise the possibility for public transport to be able to assume new roles in the future MaaS ecosystem. Alternatively, if MaaS is to develop along a more commercial path where private sector entrepreneurs act as MaaS operators, directives are needed to mandate third-party sales of public transport tickets.

- Ticketing systems within public transportation must be digitalised according to standardised protocols to enable MaaS operators to develop services that are attractive to travellers.

- It is critical that MaaS contributes to a sustainable reorientation of the transport system. Ongoing pilots must be assessed and evaluated according to their sustainability credentials. R&I funding should be a priority within the Nordic region given its international reputation as a pioneer of MaaS developments.



- Uncertainties linked to the market potential and willingness to pay for MaaS are a persistent barrier to investments in MaaS. National and Nordic visions should be coupled to existing transport policies and outline pathways and stepping stones for sustainable MaaS developments.

- In addition to issues related to tax legislation the use of existing instruments such as public procurement and subsidies for different transport services should be investigated and revised as a means to support sustainable MaaS developments within the Nordic region.

- Cities and municipalities should take a more active role in MaaS developments at the local level where they should both enable and ensure that MaaS developments are guided towards sustainability.

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Research findings

Drivers, barriers and uncertainties related to MaaS

At present there is significant interest in the Nordic region, within Europe and in other locations across the globe for intermodal mobility services that bundle and repackage existing transport modes into a single offer.

In what follows, we outline research outputs from studies that examine the dynamics of innovation vis-à-vis intermodal MaaS services.

Drivers of MaaS developments

- There are a number of societal trends driving MaaS developments, including digitalisation, servitisation, the sharing economy, urban densification and an increased focus on positive experiences in connection with different types of consumption.

- An increasing number of people prefer not to own a car and instead utilise different services. Cars are increasingly seen as an expensive and complicated burden. There is also a growing interest in sustainability and health through active modes among individual travellers.

- A high level of digital maturity means that many traveller segments can be considered 'ready' for MaaS services, especially in Nordic metropolitan areas.

- Sweden and Finland are considered pioneers of the MaaS concept. However, Finland has a stronger and more coherent vision for the transport system and MaaS in particular, which is anchored among a number of key organisations via individual 'MaaS champions' within public authorities, industrial associations and individual companies. By comparison, Sweden has been slower in creating a common MaaS vision and in building interorganisational networks.

- Finland launched a pilot programme at an early stage to test different types of MaaS in real-world settings. Sweden followed suit, launching a pilot programme of its own. Today, there are a number of start-ups in both Sweden and Finland, some of which have managed to attract significant amounts of venture capital.

- A more sustainable transport system and the goal of doubling the number of travellers using public transport are driving forces for MaaS in Sweden.

- Finland is in the process of deregulating the transport system and legislation is currently forcing transport providers, especially public transport, to allow third-party sales of services and tickets. This is crucial for commercial operators who want to develop MaaS services whereby public transport constitutes a 'backbone'. There is no corresponding change or legislative process in Sweden. Instead, the government has prioritised informal instruments and some public transport authorities have created directives for public transport operators to allow third-party ticket sales.

Uncertainties regarding existing regulative frameworks and taxation laws

• In both Sweden and Finland, national and EU legislation are interpreted to imply that public transport authorities and operators cannot adopt the role of MaaS operator. In Sweden, it has taken several years to clarify this interpretation, creating uncertainties and slowing investment. Ongoing disparities between countries within and beyond the Nordic region create uncertainties regarding the size of the international MaaS market within the private sector.

• There is uncertainty as to whether public procurement can support innovation within the MaaS field. Also, MaaS does not currently exist as a service category within procurement criteria in the public sector. Clarification of the rules related to public procurement and organisational learning are essential to the mobilisation of public funds as a support to MaaS developments via procurement activities, regardless of the role/s adopted by public transport organisations in the MaaS value chain.

• In both Sweden and Finland, there is uncertainty about and different perceptions regarding the way in which subsidies for public transport should be used or redistributed via MaaS services where commercial operators are key partners. This is important in cases where commercial operators assume the role of MaaS operator, as it can be difficult to create viable business models, even in cases where public transport tickets are subsidised within MaaS services.

• Car sharing is likely to play a crucial role for MaaS. In Sweden, there is currently no legal definition of car clubs, which makes it difficult for different types of car sharing services to grow. Other barriers to growth include administrative burdens when locating parking spaces and vehicle recharging within urban areas.

• There are differing levels of value added tax for different mobility services such as taxis, car clubs and public transport, creating an uneven playing field for individual mobility service providers.

Uncertainties regarding sustainability impacts

• There is a lack of knowledge regarding the sustainability of MaaS. Hence some key organisations, particularly within the public sector, are concerned that MaaS will lead to increased (rather than reduced) travel and that travellers will opt for less sustainable modes resulting in a net transfer from walking, bicycling and public transport to taxis, rental cars and car clubs.

Barriers to ecosystem collaboration and the renegotiation of roles

• The need for new and redistributed roles in the MaaS ecosystem is typically faced with reluctance from existing customer-facing organisations who must be repositioned further upstream in the value chain. Such organisations typically perceive three types of associated risks: damage to existing brands, the loss of customer relationships, and the risk of cannibalisation within the MaaS ecosystem. Uncertainties regarding the type of actors who take on integrator/operator roles serve to compound these risks.

• Swedish public transport sees its own role as decisive for the sustainable development of the transport system and is carefully considering its role in MaaS developments. Public transport has the opportunity to significantly inhibit developments as MaaS operators are dependent on public transport to create commercially viable services.

Uncertainties regarding the MaaS business case and the business model

• There are currently no well-documented cases of viable business models for MaaS, or of commercially viable MaaS services.

• Many commercial MaaS players perceive public transport as inertial and lethargic organisations who are inflexible and unclear in terms of their role and mandate. This slows MaaS developments and is an obstacle for the entrepreneurial firms that aim to develop MaaS services in an agile fashion, and inhibits private sector investment.

• Even in cases where pilot projects demonstrate significant potential, the lack of a licence to operate inhibits MaaS developments vis-à-vis the deployment of new business models within entrepreneurial firms.

Uncertainties regarding the role and engagement of city administrations and municipalities

• Cities and municipalities have hitherto not been strongly engaged in formal discussions and debates about MaaS developments, neither in Sweden nor in Finland. There is a general lack of knowledge and awareness of the MaaS concept within these types of public organisations. Greater involvement from cities and municipalities is required to ensure that MaaS contributes to urban development, improved accessibility and access to transport, more attractive cities, more efficient land use, etc.

Uncertainties related to market demand and willingness to pay

• There is a lack of knowledge regarding what motivates travellers to trial or purchase MaaS services, willingness to pay and what influences sustainable travel behaviour.

• There is a similar lack of knowledge about how travellers' needs and preferences vary between segments and different geographical areas, such as cities, suburbs and sparsely populated areas.

• These uncertainties create difficulties in mapping out a pathway for MaaS developments, and in creating socially inclusive services.

Uncertainties regarding the need for regulatory and legislative changes

• There is a lack of knowledge about what regulatory and legislative changes are required to support the diffusion of MaaS among different customer and user segments, and on the types of policy instruments that are needed to encourage sustainable travel behaviour. Existing regulatory frameworks and policies require careful investigation given the existence of policy interactions and the tendency towards regulatory lock-ins.

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Shift
Sustainable Horizons in Future Transport

Shift Policy Brief
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Smart Mobilities:
A Gendered Perspective

Author: Tanu Priya Uteng, WP3 Shift

Both energy usage and emissions associated with the transport sector can be tackled better if we focus on creating infrastructure design and systems that are in sync with the gendered mobility patterns.

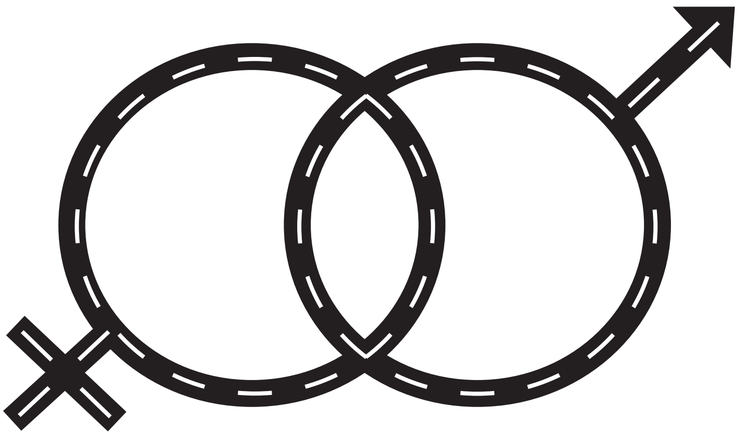
Gender equality and sustainable development are two deeply embedded and central priorities in the Sustainable Development Goals. Simultaneously, the urban and transport planning fields are confronted with demanding challenges in the field of connecting transport, sustainability, and mobility for all.

The intersection of these two fields - sustainable and gender-fair spatial (vis-à-vis mobility) development has so far been neglected and downplayed in research and policy making at all levels. Rooted in the idea of smart, green and integrated transport, this study urges for new conceptualizations on smart cities, transport, mobility and gender equality. Issues regarding safety, affordability, accessibility, availability, acceptability and accommodation are vital and need to be taken into transport design and planning. We need to build transport systems that take these gender specificities into account.

This brief presents some potentials and limitations of upcoming 'smart' solutions in terms of gender equality. The intention is to highlight how smart solutions can be designed to retain inclusivity at its core.

Key messages

- Prioritise public transport over providing for cars.
- Prioritize areas for future growth which support walking and bicycling.
- Encourage and engage women in the transport field.
- Insert inclusive settlements in smart cities and smart mobility solutions.
- Put safe and secure spaces on the agenda in spatial and transport projects.
- Link policies of other social development sectors with the transport sector.
- Include innovative solutions like bike sharing, car sharing and shuttle buses in transport planning discussions at all levels - national, regional and local.



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An introduction

Women and transport vis-à-vis gender and transport

While the Nordic countries are classic examples of equality between the sexes, even here there are evident examples of differences between men and women on a variety of issues related to both structural conditions and preferences. The sector which underpins all the development agendas, namely energy and transport, have been traditionally operating in strict engineering domains and the societal and gendered ramifications of under-delivery of these services have been not understood and thus remain unaddressed.

Daily mobilities for women hinges on accessibility to local services and sectors where there is a heavy concentration of female employment, trips accompanying elderlies and children and a higher use of public transport, walking and cycling.

The issue of both safety and security remains a highly gendered topic and does not affect the daily mobilities of men to the same extent as women. And even though women are relatively secure in the Nordic countries, the level of perceived physical safety varies.

Women travel shorter distances and their trip duration is also limited as compared to men. This is evident in their commuting or work-related trip patterns but holds true for other trip purposes as well. In comparison to men, long-distance commuting remains restricted for women.

A further layering to the discussion is provided by the 'smart' city agendas and smart mobilities. This policy brief structures its arguments with due regards to the digitalization and smart agendas currently under discussion.

Smart cities and smart mobilities

Smart cities is the buzz word in the world of urban planning today. And while the term 'smart' remains contested, a few things are quite apparent:

- The term smart remains fuzzy and it appears that smart is primarily being interpreted in terms of digitalization and is increasingly being shaped to include 'automation' as well.

- Corporations developing these digital solutions, get a strong foothold in the urban planning world. Their ideal module is to develop systems which can have a standard design solution and can be integrated at a global level.

- Smart mobilities is being developed in a framework where solutions like GPS fitted buses, real-time tracking etc. are being promoted as the smart solutions.
In this sense, smart mobility concerns itself primarily with innovative technological or consumer-centric solutions rather than adopting a social sustainability lens to the entire mobility agenda.

Our analysis of approximately 7 million trips taken on Oslo's shared bikes for the year 2017-2018, also revealed a highly gendered narrative. (Priya Uteng et. al. 2020b)

We see a strong correlation between the zones with high concentration of female employment sectors and the dominant female biking routes. There seems to be a high usage of city bikes by women for access-egress purposes (first-last mile) but also for other trip purposes. However, there exists a dissociation between the peripheral location of female-dominant employment sectors (for example, hospitals) and the heavy central concentration (which also coincides with male-dominated employment sectors) of the docking stations of Oslo's city bikes.

Since the bike-sharing scheme of Oslo is an expanding mission, this mapping exercise should be taken into consideration while planning new docking stations. Sewing in gendered considerations can ensure that the uptake of bike sharing by women is further maintained and bolstered in future.

Before embarking on implementing the upcoming smart solutions, it would be prudent to reflect on the following consistent findings:

- Women's travels are often multi-purpose, complex and resource-constrained (vs the male norm)
- Women undertake a greater share of trips made on sustainable travel modes.
- Even the new 'smart' modes are showing a gender bias in their use patterns.
- Smart mobilities and smart cities do not automatically help the agenda of creating inclusive cities.
- A continuous mapping exercise of needs and preferences, at the macro, meso and micro levels, is needed to design truly inclusive smart solutions.

Conclusions and recommendations

Include both routinised and innovative public transport systems in the national transport plans through specific programs like revising the tax structure for public transport.

Prioritise public transport over providing for cars. Include innovative solutions like bike sharing, car sharing, feeder bus service options like shuttle bus etc. in the different hierarchies of transport planning – from national, regional to local transport plans.

Linking landuse and accessibility planning is an absolute essential. Conduct accessibility mapping for different transport modes and prioritize areas for future growth which support walking and bicycling. In areas which are already built, create infrastructure which allows for safe walking and bicycling. Priya Uteng et. al. (2019c) provides an example of accessibility mapping exercise for E-bikes in the four largest Norwegian cities.

Link policies of other social development sectors with the transport sector. Welfare and social protection programmes can be built around the issue of access to promote access to education, health and employment.

Both personal security and safety in traffic are major concerns for women. Spatial and transport projects need to prioritise creating safe and secure spaces.

Women are poorly represented at all levels of the transport domain. Actively encouraging and engaging women in the transport field, through targeted programs, can have major impact on the future of this field.

Smart cities and smart mobility solutions are emerging fast but they remain locked in a corporate driven agenda. It is important that the element of inclusive settlements is inserted in this development.

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Shift
Sustainable Horizons in Future Transport

Shift Policy Brief
2019/2020

The role of business models in the transition to Electric Road Systems

Author: Stefan Tongur, WP2 Shift

Electric road systems (ERS) are road transportation systems based on technologies that support electric power transfer from roads to vehicles in motion. ERS has in the recent decade emerged as a sustainable solution for the long-haul freight sector, which is one of the most difficult sectors to decarbonize and is projected to grow drastically in coming years.

Compared with other alternative technologies, ERS reduces the need for batteries, relies on well-established electricity infrastructure, and has potential to preserve flexibility in the freight sector.

There are various ongoing projects around the world to evaluate the viability of different ERS technologies such as overhead lines, in-road conductive, and wireless inductive technology.

The development of ERS has primarily been driven by societal needs rather than market demand, and most activities have been initiated, supported, and subsidized by public funding. This constitutes a typical technological niche in which technology development is temporarily shielded from the commercial market to become competitive.

However, while the purpose of these actions is to prepare ERS for commercial takeoff, technologies that contest the established technological paradigm typically fail at market. This challenge is often described as the ”valley of death,” where firms risk stalling between pre-commercial invention and basic research, on one hand, and product development for the commercial market, on the other.

Empirically, this study has concentrated on the potential transition toward ERS by studying different activities (e.g. technical pilot, demonstration, and deployment projects) that have been (partially) funded by policy makers and that have formed the ERS trajectory over the 2010–2017 period.

Key findings

- The relationship between business models and socio-technical change is not homogenous in the early phases of transition and differs depending on what type of niche activity is analyzed.
- Business model concept could be used as a perspective to understand the evolutionary processes that take place during the early phases of transition.
- For systemic innovations, which suffer from the chicken-and-egg dilemma, business models are needed for alternative infrastructure with long investment horizons as well as for alternative products and services with shorter investment horizons.
- Deployment projects, such as an infrastructure transformation project, might be a suitable policy mechanism for creating a test bed for suppliers and future market demand.

Nordic Energy Research

Background

Will electric road systems take off?

Policy makers, practitioners and scholars have argued that sustainable technologies are insufficient in themselves to bridge the valley of death. It is often said that new business models are needed to realize their potential on the mass market.

New business models could translate the beneficial qualities of new products to end users, thereby creating user acceptance, firm profitability and facilitating the transition. Several studies have identified and analyzed new types of business models that firms deploy for sustainable technologies. However, these studies have not taken into consideration that many of these technologies require socio-technical change e.g. regarding infrastructure, user practices, institutions, actor network etc. Business models are analyzed from a product or service perspective and treated as static models that transforms a focal firm's strategy.

This study addresses this research gap by analyzing the relationship between business models and socio-technical change in the early phases of a potential transition.

Few studies have focused on the processes during the early phases of transition. This study contributes to more nuanced views of how technological niches are shaped, the interactions between actors in different contexts, the strategies that firms use to manage potential technology shifts, and different empowerment strategies used by niche advocates to commercialize sustainable technologies in different contexts.

Findings

Business models in the early phases of potential transition

The first finding is that the relationship between business models and socio-technical change is not homogenous in the early phases of transition and differs depending on what type of niche activity is analyzed.

In the studied pilot projects, development of new business models was not part of the technological niche, as the focus was on developing radical innovations without any interactions with potential users. These projects illustrated how the new technology did not fit with incumbent business models.

In the demonstration projects, which focused on developing a socio-technical experiment that involved interaction with users, new business models were developed for commercializing the new technology. However, they were neither implemented or tested in these projects (or on the market).

In the deployment projects, which focused on evaluating wider socio-technical change, business models were tested by evaluating the economic feasibility of different types of technological niches and the willingness to pay for and use the new infrastructure. Figure 1 summarizes this finding and illustrates the relationship between business models and socio-technical change in the early phases of transition.

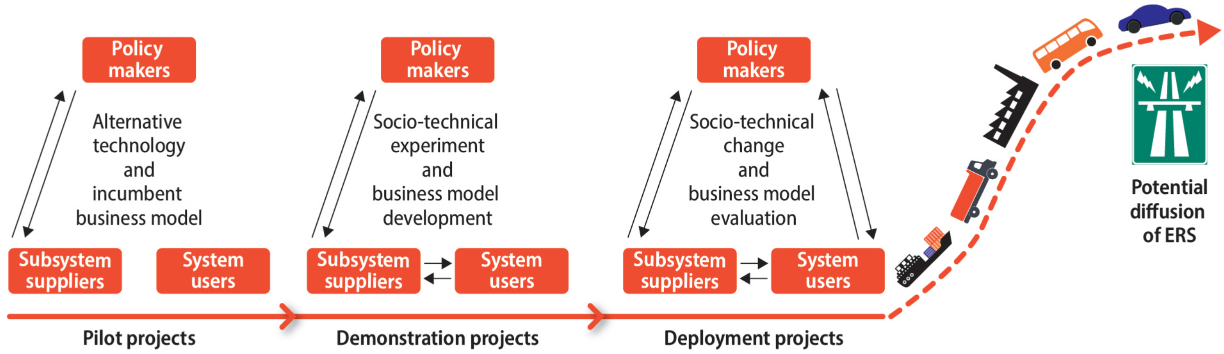

Figure 1. The relationship between business models and socio-technical change in pilot, demonstration and deployment projects. (Tongur, 2018.)

Pilot projects with different ERS technologies.
① Overhead lines. Scania's and Siemens' project outside Gävle, Sweden. (Picture: Scania)

② In-road conduction. Volvo's and Alstom's project in Hällered, Sweden. (Picture: Volvo)

③ Wireless induction. Electreon's test in Israel. (Picture: Electreon)

The second finding is that the business model concept could be used as a perspective from which to understand the evolutionary processes during the early phases of transition. When it comes to niche activities, the right business model solutions are apparent only after the innovation has taken off and reoriented the existing socio-technical system. By adopting a business model perspective to understand processes of socio-technical change, attention is concentrated on the value added by the new technology from multiple actor perspectives, rather than only from the perspective of the firm – user relationship. In this way, the business model perspective is useful, as it integrates both environmental and sustainable value for policy makers, subsystem suppliers, and users.

A third finding is that the challenges of commercializing and deploying systemic innovations, such as ERS, are complex. Most studies focus on the potential benefits or drawbacks of new sustainable technologies but tend to neglect the fact that the commercialization of them is dependent on investments in alternative infrastructure.

For systemic innovations, which suffer from the chicken-and-egg dilemma, business models are needed for alternative infrastructure with long investment horizons as well as for alternative products and services with shorter investment horizons. The various actors must find their roles and ensure that they complement one another to produce a functioning business model that allows investments in both sustainable transportation infrastructure and the related vehicles.

Deployment projects, such as an infrastructure transformation project, might be a suitable mechanism for facilitating a window of opportunity for such systemic innovation. It creates a test bed for suppliers and future market demand, attracting support from policy makers for necessary infrastructure investments.

Practical implications:
Are the electric road systems to be or not to be?

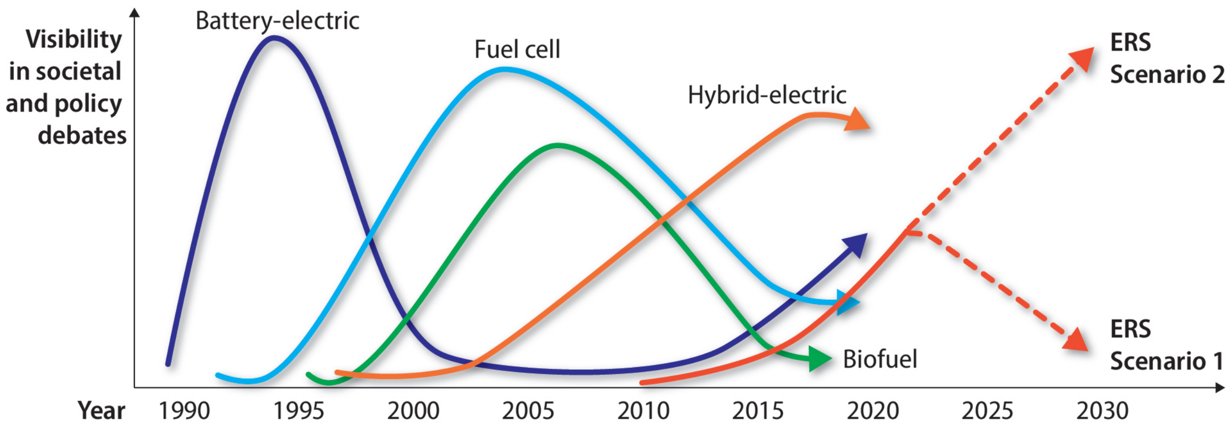

Figure 2. The cycles of hype and disappointment of different technologies. (Tongur, 2018, based on Geel, 2016.)

ERS is competing with other solutions such as battery-electric, fuel cell, natural-gas, and biofuel technologies. Figure 2 illustrates the cycles of hype and disappointment of several technologies in recent years.

So, will ERS will take off or not? To answer that question, we are assuming two future scenarios for heavy trucks in 2028. For each scenario, the technical, political, and economic conditions are discussed, using Sweden as a point of departure.

Why ERS will not takeoff

- **Technical perspective:** Solutions were promoted that where closer to the existing system interfaces.
- **Economic perspective:** Uncertainties deterred potential users and investors from committing to ERS.
- **Political perspective:** The costs of transition failure was not high enough.

Why ERS will takeoff

- **Technical perspective:** ERS new dominant design with other technologies as complements.
- **Economic perspective:** Relative low capital cost, new public-private arrangement, and ERS as competitive advantage for users.
- **Political perspective:** All solutions were needed due to urgency, open standards made ERS procurable, and Sweden was positioned as the global ERS knowledge and export hub.

Policy recommendations

- Policy has an important role in development of new business models – laying down the conditions of business models and transitions.
- Engage with business model development early on, not only technology development.
- Stimulate cooperation between different types of actors that can build the future together.
- Standardization between interfaces to allow for competition and business model innovation.

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Shift
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Shift Policy Brief
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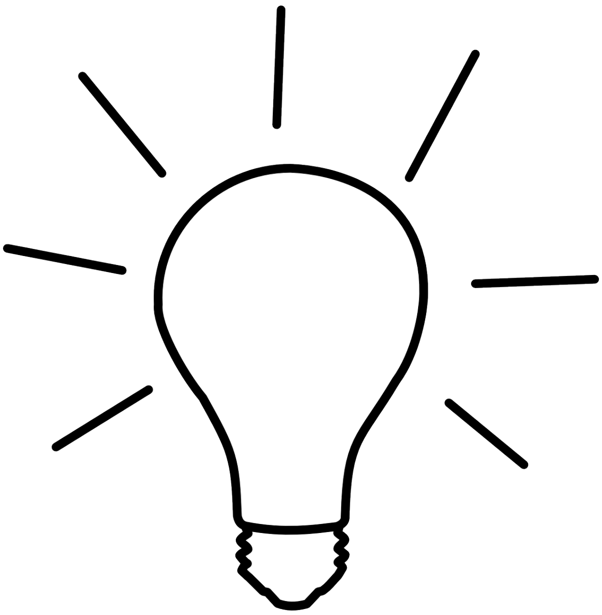
Examining the nature of technological change

Authors: Ove Langeland (ed.), Tom Erik Julsrud, Steven Sarasini, Maria Schnurr, Stefan Tongur, Magnus Andersson, WP2 Shift

While greenhouse gas emissions from non-transport sectors fell 15 percent between 1990 and 2007, transport emissions increased by 33 percent over the same period and currently accounts for around 40 percent of CO_2 emissions from Nordic countries.

Several measures and initiatives to decarbonise transport have been introduced in Europe and in the Nordic countries over the years. This report focuses particularly on new vehicle and fuel technologies but it also deals with other transport innovations which can contribute to a shift to cleaner modes of transport, such as mobility as a service and autonomous vehicles.

The analysis considers how policy has mobilised key resources for low carbon transport innovations in the Nordic region and how the different technologies and fuels have developed. We look at six different innovations, technologies and services described with a TIS-approach - Technological Innovation System - which explains the nature and rate of technological change. It is an analytical framework for examining interlinking key functions for the development and diffusion of a new technology.



Key findings

- The development and potential market uptake of transport innovations relies heavily on the acceptance of new technologies.
- If the dynamics of an innovation systems doesn't work well, it can be due to problems with either the system elements or the system functions.
- Identification of systemic problems can be helpful for politicians to formulate strategies and to use tools to remedy malfunctions in innovation systems.

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Background:
The systemic setting around new technlogies

The Technological Innovation System concept was developed to explain the nature and rate of technological change. A TIS analysis focuses on system elements and system functions.

There are four types of system elements:
Actors: individuals, organizations, networks, NGO's, companies, governments, research institutions.
Institutions: habits, rules, norms and strategies.
Interactions: networks and individual contacts.
Infrastructure: physical, knowledge and financial.

The functions in innovation systems refer to a set of activities that are key to the development and diffusion of a given technology. If the dynamics of an innovation systems doesn't work well, it can be due to problems with either the system elements or the system functions.

Thus, identification of systemic problems can be helpful for politicians to formulate strategies and to use tools to remedy malfunctions in innovation systems. The TIS-approach can also be used to analyze if and how technologies are related and interact - how synergies and conflicts can arise between technological systems.

The development of a new technology can be slow or fail because important actors are absent or due to lack of competence or, because specific institutions are not in place or not able to support the new technology. It can also be due to lack of interactive learning, trust etc, or to lack of resources.

Technologies may compete in markets and for resources, they may complement one another or be neutral to one another. A new technology may also benefit from the existence of an older technology, sometimes at the expense of the older technology. Finally a new technology can be locked out via the existence of an older technology.

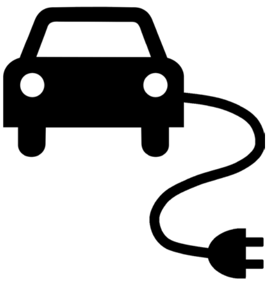
Since the innovations studied in this analysis are in different development states - some are still in its testbeds while others are already on the market - not all functions are relevant to analyse for all technologies, fuels and services.

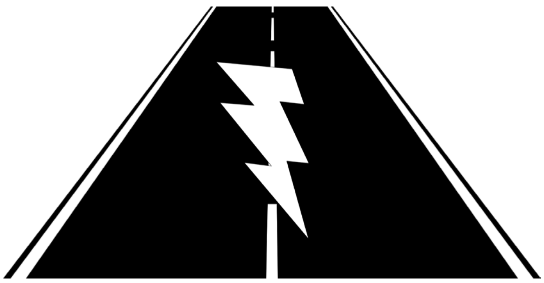
The analysis includes the following transport technologies and innovations:

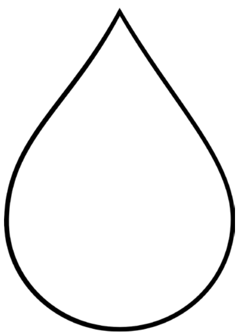
- **Electric vehicles**
- **Electric road systems**
- **Hydrogen vehicles**
- **Biofuels**
- **Autonomous vehicles**
- **Mobility as a service**

The analysis of all functions in the innovation systems are carried out only for three of the transport innovations - electric vehicles, electric road systems and biofuels. These represent either partly developed technologies and/or they are already introduced on the market.

This is particularly so for electric vehicles and biofuel, whereas electric road systems are still in their infancy and subject to pilots and tests. For hydrogen vehicles, autonomous driving and Mobility as a service there are still not much sign of market formation or any substantial mobilization of resources.







Findings and conclusions

Sufficient resources are necessary for transport innovations to develop and be commercialised. Most innovations are depending on support from public funding and efforts from relevant industries. All transport innovations and research projects mentioned in this study rely on public funding. The international car industry is also heavily involved in the development, particularly in the testing of autonomous driving.

The development of the technologies and fuels mentioned in this study are all influenced by national and international policy regulations. All Nordic countries have also established climate targets and introduced fiscal incentives which promote the electrification of cars or cars which use hydrogen or biofuel.

The development and potential market uptake of transport innovations relies heavily on the acceptance of new technologies. Electric vehicles seems to have climbed high on the legitimation ladder together with biofuel, although the last one still suffers from the food vs fuel controversy. Main technological barriers related to vehicle electrification is on-board energy storage, range, battery technology and charging infrastructure. Other barriers are related to price, energy sources and raw materials for batteries.

Both electric road systems and autonomous vehicles have still to prove its functionality and operability, whereas hydrogen must overcome technological barriers particularly related to the infrastructure.

Real market formation can so far only be traced for electric vehicles and biofuel. There is no commercial market for electric road systems or for hydrogen cars. Autonomous vehicles are in an early test stage and Mobility as a service are at the present being primarily ideas rather than realities, though interesting experimentation is taking place.

Autonomous vehicles and Mobility as a service are however regarded as innovations that will radically transform the transport system. The Swedish car industry currently carries out several pilots for the development of electric vehicles and electric road systems, in cooperation with Nordic research institutions. Likewise, pilots also take place for autonomous vehicles and mobility services where both private companies and public transport operators are involved.

Entrepreneurial experimentation takes place via tests and demonstration projects for all transport innovations. As of now, this study finds there are several possible pathways to a more sustainable transport system in the Nordics countries related to innovations in technologies and fuels and to new mobility services.

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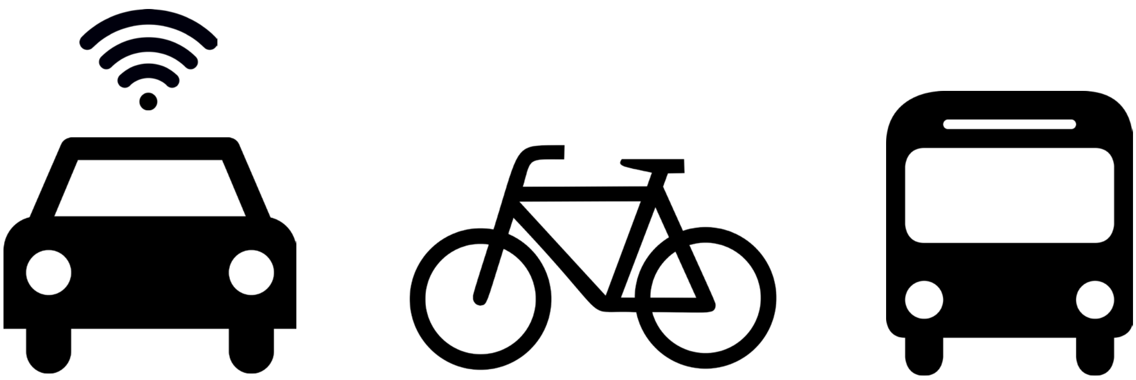

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Super-green car premium behind 1 out of 3 plug-in hybrid cars in Sweden

Author: Magnus Hennlock, WP4 Shift

In order to reduce fossil dependence of the transport sector and to promote the development and distribution of electric and hybrid cars, various types of government-financed subsidy programs have become commonplace in the Nordic countries.

Researchers at IVL Swedish Environmental Research Institute and University of Gothenburg have managed to isolate the effects of the super green car premium, introduced in Sweden in 2012, from the effects of other policy instruments in use at the same time.

The study finds that the super-green car premium lies behind 1 out of 3 registered plug-in hybrid cars registered during the period 2012 – 2015. The remaining 2 out of 3 plug-in hybrid cars that received the premium during the period 2012 - 2015 cannot be explained by the premium.

The results bring new light on the effects of subsidies for promoting new transport technologies and provide insight to effective future designs of policy instruments such as the new bonus-malus system in Sweden.

Key findings

- The super green car premium caused the purchase and registration of 1 out of 3 plug-in hybrid cars with emissions below 50 grams CO_2/km.
- 2 out of 3 plug-in hybrid cars that received the premium would have been purchased and registered even without the super green car premium.
- Most of the cars that received the premium were company cars.
- The super green car premium partly overlapped with several other policy instruments that were in use in Sweden at the same time also affecting the number of registered plug-in hybrid cars. This reduced the effectiveness of the super green car premium.
- To prevent ineffectiveness, it is important to fully understand the effects from each policy instrument also during its development.

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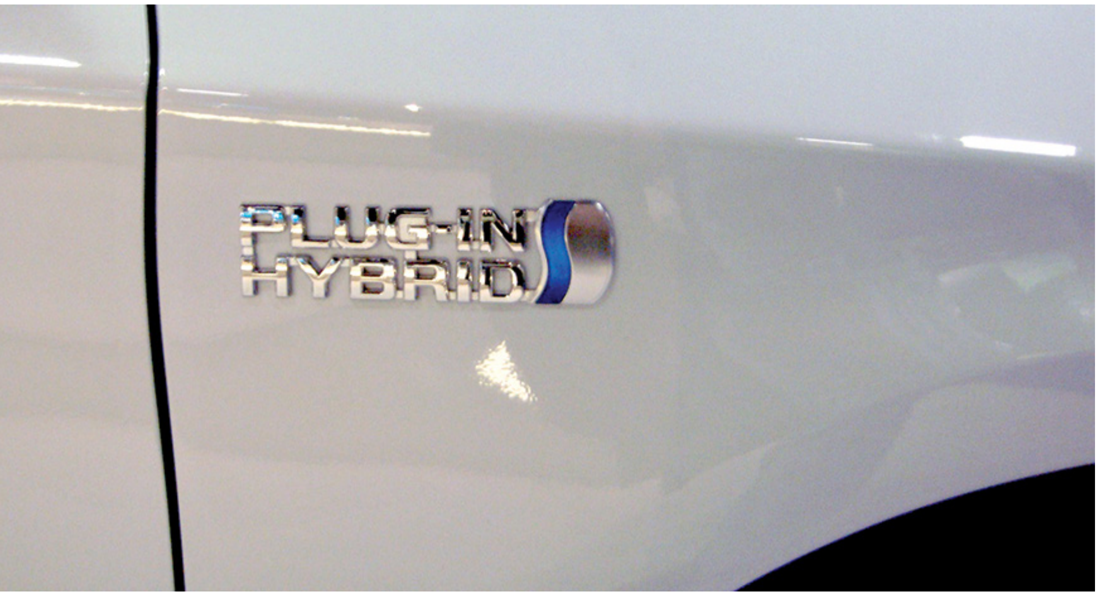

About the study

Isolating the effects of policies

Reducing fossil dependence of the transport sector by promoting electric and plug-in hybrid cars is essential for achieving the targets of climate change policy. Various types of government-financed subsidy programs have therefore become commonplace in the Nordic countries.

In Sweden, such a subsidy was offered for the first time during the period 2007-2009 to newly registered cars with emissions of a maximum of 120 grams of carbon dioxide (CO_2) per kilometre.

In 2012, a subsidy program, the so-called super green car premium, was introduced, with higher premium amounts by targeting cars with emissions of a maximum of 50 grams CO_2/km, which in practice were only electric cars and plug-in hybrid cars. The super green car premium was in operation until 2018 when it was replaced by the bonus-malus system.

Researchers at IVL Swedish Environmental Research Institute and University of Gothenburg have for the first time managed to isolate the effects of the super green car premium from the effects of several other instruments operating during the same period.

The results bring new light on the effects of subsidies for promoting new transport technologies and provide insight to effective future designs of policy instruments such as the new bonus-malus system in Sweden.

Several policy instruments were in use in Sweden during the period 2012–2015 that, intendedly or unintendedly, affected the number of registered plug-in hybrid cars with emissions below 50 grams CO_2/ km.

When several policy instruments are contributing to the same target it becomes even more important to isolate the effects from each policy instrument in the evaluation of policy instruments. By using advanced econometrics and micro-level data, our focus has been to isolate the effects of the super green car premium from the effects of other policy instruments on registered plug-in hybrids in Sweden during the period 2012-2015.

Our methodological approach addresses this problem by formulating the following hypothesis: If the super green premium had a stimulation effect in the car market, a “disturbance” should take place in the statistical distribution of registered cars from 2012 and on. Specifically, from 2012 and on there should be a discontinuity in the distribution of registered vehicles with emissions just below 50 grams CO_2/km and comparable vehicles with emissions just above 50 grams CO_2/km. If this proves to be the outcome, and such a discontinuity also proves to be statistically significant, we have found evidence of a local causal effect of the super green car premium on the number of registered super green cars.

On the other hand, if the super green car premium did not have a stimulation effect on the registered super green cars, there should be no “disturbance” in the distribution - the distribution of registered vehicles with emissions just below 50 grams CO_2/km and the distribution of comparable registered vehicles with emissions just above 50 grams CO_2/km should not statistically differ.

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Findings and conclusions

A reminder to policy makers to coordinate instruments

Our results show that a significant discontinuity in the distribution of plug-in hybrid cars took place corresponding to 2 760 plug-in hybrids cars out of 8 139 plug-in hybrids cars registered during the period 2012 – 2015 and that were still registered in the vehicle registry in January 2018. This means that the super-green car premium lies behind 1 out of 3 registered plug-in hybrid cars registered during the period 2012 – 2015.

The results imply that 2 out of 3 plug-in hybrid cars that received the premium would have been purchased and registered even without the super green car premium. That corresponds to premiums paid to the value of almost SEK 0.25 billion during the period 2012 - 2015 for which we cannot show any effect on the registration of plug-in hybrid cars. Most of the cars that received the premium were company cars. The reduced effectiveness also undermined the instrument's cost efficiency since the number of registered super green cars explained by the premium was reduced while the public expenditure for the premiums was the same.

The introduction of super green car premium implied the introduction of a new label - "super green cars" - on the market which could have had an informational effect on buyers' decisions. We could hypothesize that the introduction of the label "super green cars" would increase the overall emissions awareness also among buyers of cars other than super green cars. For instance, a buyer that was imagining buying a car with emissions 120 grams CO_2/km could buy a car with somewhat lower emissions as a result of an overall increased emissions awareness following the introduction of the concept of "super green cars" on the market.

If that is the case, we should expect to find differences also in the statistical distributions of registered cars around emissions levels other than the limit 50 grams CO_2/km. While there are downward movements of the means of the distributions across the entire scale of emissions levels during the period as a result of several policy instruments in use, none of these changes in the distributions can be statistically connected to the super green car premium. Hence, we find no evidence that the super green car premium did have a global information effect reducing the overall emission levels of car fleet. We conclude that its effect on plug-in hybrid cars was local around the limit 50 grams CO_2/km and explaining 1 out of 3 registered plug-in hybrid cars with emissions below 50 grams CO_2/km during the period 2012 – 2015.

When two or more instruments overlap in effects, their effectiveness in terms of changing behaviour is reduced. The results in this study remind policy makers about the importance of coordinating policy instruments to prevent that their effects overlap. Overlapping effects reduce the effectiveness of instruments in terms of their effects on actors' decisions. The results show that even when instruments partly overlap in their effects, the losses in effectiveness can be substantial. Because of the loss in effectiveness, cost efficiency is also impeded. To prevent ineffectiveness, it is important to understand and isolate the effects from each policy instrument already in the analysis during development of new policy instruments, and in the evaluation of policy instruments while they are in use.

The analysis is corrected for the electric car procurement that was in use at the time. However, there were likely overlaps with other instruments that were in operation during the same period and that reduced the efficiency of the super green car premium. For instance, the changes in the rules for reducing the benefit value for environmental cars, which favoured electric cars and plug-in hybrid cars compared to other cars. Another example is the super credits in EU legislation 443/2009 which from 2012 provided incentives for car manufacturers to market cars with emissions less than 50 grams CO_2/km to buyers in the EU market. To identify and isolate the effects also of these instruments are left for future research.

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