Nordic strengths in green transport

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Content

1. Introduction and background

The Nordic Council of Ministers has commissioned us (Lauritzen Consulting and Oxford Research) to perform a study on Nordic strongholds in green transport – and on how to further sharpen identified strongholds and encourage a still better cooperation between the Nordic countries.

We see the purpose of the Nordics' efforts in this area as threefold:

- The Nordic countries have achieved a lot in the efforts to make our societies greener, i.e. with lower emission of greenhouse gasses (CHG-emissions). Transportation is the "black sheep" of the green-transition family; reducing CHG-emissions has thus far proven more difficult here than in other sectors. So, to deliver on national objectives and on commitments to contribute significantly to EU-objectives and internationally agreed objectives, especially in the COP-agreements, more effective initiatives should be taken in transportation.
- Secondly, by acting smart, a role as green frontrunner can be achieved without compromising the competitiveness of traditional industries. On the contrary, a large number of new, high-value green jobs may be created contributing to a sustainable economic growth allowing us to sustain strong welfare societies
- Finally, if we succeed in setting a good example for effective policies in this area and thereby inspiring others, a further contribution to reducing global CHG-emissions can be made.

To be more concrete we have in this study mapped the Nordic countries' strengths within green transition of the transport sector to help public and private Nordic stakeholders to identify interesting opportunities for co-operation. The rationale behind the study is that by working together on green transport, the Nordic countries can complement each other, improve our knowledge in areas where the Nordic countries have comparative advantages, upscale good practices, and export these. Consequently, Nordic co-operation can contribute to climate efforts as well as sharpen Nordic competitiveness. Such an overview can underpin the Nordic Region's voice internationally. As the Nordic countries have different priorities and strengths in the development of new transport technologies and solutions, the task is to map the specific strengths and specialisations that each country has within green transport.

Identifying new future collaborations/partnerships between the Nordic countries is thus an important element of the study considering areas with a potential for 1) complementarity of competences in green transport and/or 2) reaching a larger critical mass and mutually strengthen the Nordic countries.

The study focuses on three parts:

1. **Systems:** Investments in new infrastructure and new transportation systems enable the use of greener transport (walking, biking, public transport, charging stations enabling the use of electrical vehicles, intermodality etc.
2. **Technologies**: New technological solutions are crucial for the green transition of the transport sector. Among these solutions are electric vehicles, hydrogen cars, hybrid buses as well as biofuels. New technologies also cover technological processes such as consultancy/knowledge services.

3. **Framework conditions and business environment:** How policy measures and strategies influence the development of the green transition in the Nordics, e.g. levies on electrical cars.

1.1. METHODOLOGY

The study is based on five country studies in Denmark, Finland, Iceland, Norway and Sweden. In each country, the analysis is based on a combination of desk research and interviews.

The desk research includes:

- Reports, analyses and academic studies mapping and describing the strengths, specialisations, growth potentials, comparative competitive advantages and relevant competences within green transport both qualitatively and quantitatively seen from 1) a business perspective and 2) a R&D perspective.
- Policy documents, strategy papers and websites describing the national strategy and policy objectives as well as significant national initiatives and programmes addressing the issue of a green transition of the transport sector.

The interviews have been held with key actors, stakeholders and experts from cluster organisations, professional organisations, universities, research and technology organisations and public authorities. In total, we have conducted 8 interviews in each country (in Iceland 5 interviews):

- 3-4 interviews with relevant cluster organisations, trade/professional organisations within green transport
- 2-3 interviews with relevant universities, research and technology organisations etc. holding an expertise in green transport
- 1-2 interviews with relevant public authorities within transportation

The selection of interviewees for the country study cover 1) transportation of goods and personnel, 2) road, railway, water and air transport, 3) systems and technologies.

2. Potential for development of the Nordic strengths and further collaboration on green transport

In our desk research, interviews and analyses throughout the Nordic countries we have met a number of skilled and energetic participants in the green "turnaround" that all Nordic countries are participating in. We have concluded that much has been achieved, but we see a potential for better results and more intense Nordic cooperation.

All Nordic countries are eager to comply with international demands to decrease CHG-emissions in line with, or at a speedier pace than EU, and to encourage other countries to more binding and effective commitments in the international COP-rounds. Most remedies that are used in this turnaround may incur costs to consumers and enterprises that have to bear the burden of higher energy prices and to have their competitiveness challenged due to higher production costs. Taxpayers also have to finance public subsidies to green technologies that still cannot survive on pure market conditions, in part because fossil fuels in many circumstances are not taxed according to their negative environmental effects. These costs are accepted by a large majority of the populations and electorates in the Nordic countries.

At the same time, much emphasis is put, in all Nordic countries, on paving the way for new green jobs in industries delivering solutions, products and services which are part of the upcoming, greener economy. The green transition of our economies has therefore to date not been an impediment to macroeconomic efforts to sustain economic growth, secure high employment and uphold competitiveness and sound financial balances.

The ambition is, naturally, to continue this successful transition in the coming years. This may not be easy. Many observers believe that we have actually until now only reaped the low-hanging fruit, the next reductions in CHG-emissions may be more demanding. If this is true it will be one more reason to increase Nordic cooperation in this area.

2.1 HOW TO TRANSFORM TO GREENER TRANSPORT

There are a number of available technologies and solutions that can contribute to greener transport. Basically, four different kinds of contributions exist:

- A number of solutions may contribute to decrease the overall transport demand, both for personal transport and for freight. This category includes dense urban population, increased homework, policies to encourage people not to commute too long distances, etc. It may also include methods to decrease freight. In this category can also be placed methods to increase the utilization of existing capacity, i.e. to ensure that cars, trains, busses and airplanes are filled. Other examples can be new infrastructure allowing routes to be shortened, like the coming Danish-German Fehmarn tunnel.
- A second contribution is to change transport modes - from individual car transport to collective transportation (trains, metros and busses) or even to biking or walking. Or to exchange freight by truck with rail or sea transport, or to exchange aviation with other transport modes.

- A third method is to replace existing technologies with new, different technologies, substituting the use of fossil fuels with renewables. This is first of all done through electrification and use of electrical engines to replace the combustion engine. It can also be done with biofuels substituting fossil fuels.
- A fourth method is marginal improvements in the energy efficiency of individual transport units - like developing cars that can go longer per liter of gasoline, or airplanes with better design.

In this study the last category - marginal improvements in energy efficiency - is disregarded. Not because it´s without effect, or even because it can´t be influenced by regulation, but rather because its contribution to the greening of transport patterns is insufficient to change the policy agenda in the area of green transport.

The first three categories include a number of possibilities and solutions that differ a lot. This applies especially to the third category *new technologies*. This category can again be subdivided into three or four categories:

The first of these is *electrification through use of batteries*. Battery-driven electrical personal cars have achieved a substantial market share in some countries, where they have been subsidized. In the Nordic countries, this is first and foremost the case in Norway and Iceland, but also to some extent in other countries. An important technology driver is that batteries have become cheaper and better in the latest years (" better" means especially higher capacity). Some sources claim that batteries have improved by 10 per cent annually in the last decade[1], and that the driving range on a full battery has increased from 100 to 300 km for the best new electrical cars[2] - and 500 km for the Tesla. Some observers argue that electrical cars can be sold without subsidies (or that fossil-fuel cars can be prohibited without much protest) in not-so-many years from now, especially when taking into account that electrical cars are simpler, have fewer parts and therefore lower maintenance costs than cars using gasoline or diesel.

Electrical cars with batteries may be battery-driven, hybrid or plug-in-hybrids. The sustainability of the two latter categories depends on how they are used in practice, but especially plug-in-hybrids can be sustainable while securing the driver a long driving range if necessary.

Heavy transport (lorries and busses) is a different matter. They have lower maintenance costs than their often diesel-driven counterparts, but are still much more expensive, and this extra cost may take more years to get rid of. Heavy electrified vehicles are already used in many cities, but mostly due to initiatives taken by public authorities or institutions that can afford this even though it´s more expensive in the short run. Privately owned lorries have until now only been electrified to a very little degree.

Ferry transport is also a different matter, being more expensive than traditional fuel-driven shipping, and where it is difficult to say how rapid technology and competition will reduce or remove the extra cost.

Secondly, *biofuels* may contribute to greener transport – and are already doing so. EU requires biofuels to constitute 10 per cent of gasoline and diesel used for land transport by 2020, and in many countries 5-6 per cent of these fuels are already biofuels. Sustainable biofuel (2.-generation biofuel) is counted double and constitutes today in some countries 0,9 per cent. Biofuels are, however disputed. Biofuels lead to CO_2-emissions

[1] https://ing.dk/artikel/elbiler-driver-ekstrem-udvikling-batterier-190094
[2] http://www.fdm.dk/biler/test-teknik/biler-paa-vej/renault-zoe-elbilen-der-koerer-ganske-langt

when used, but this is counterbalanced through a similar CO_2-absorbtion through photosynthesis when plants grow. If the biofuel is produced from crops replacing crops that could be used as human food or animal feed, this is not considered sustainable. Instead, the use of second-generation biofuel produced from waste, straw etc. is encouraged. Others argue that the global capacity to produce biofuel is limited - especially second-generation biofuel, since the most sustainable solution is to decrease the amount of waste in the first place. Consensus seems to be that biofuels have a role in the future, sustainable energy system, but only in special uses like heavy transport or aviation.

Thirdly, the use of *hydrogen* is also disputed. Hydrogen is really only a way to store (renewable) electricity, like batteries. Hydrogen and batteries are not only competing on costs. Batteries are not effective in long-term energy storage, and hydrogen cars can have longer mileage on a tank. Hydrogen, on the other hand, is not easy to store - it either requires very tight containers or to be frozen to liquid form, which in itself is energy demanding. The hydrogen is produced through electrolysis of water and subsequently the opposite chemical process, "burning" hydrogen with oxygen in a fuel cell to produce electricity with water as the only residue. The process, in other words, is clean. It is, however, also costly, and in spite of research efforts operating costs have not been reduced on a scale similar to the reduction in battery costs.

Until now, most hydrogen used in cars has been manufactured from natural gas. This is of course not a sustainable solution. Hydrogen can contribute to greener transport when the hydrogen is produced through electrolysis and with renewable electricity as a source.

The combined physical process of electrolysis and the fuel cell has a maximum energy efficiency of approx. 45 per cent – 70 per cent in the electrolysis multiplied with 60 per cent in the fuel cell[3]. The optimal energy efficiency of a modern lithium battery can be higher, approx. 80 per cent. In practice, however, the level of energy efficiency of batteries is lower. The efficiency of a battery is e.g. lower if the battery is charged rapidly. The battery will also slowly loose energy if it´s charged and not used. Hydrogen, on the other hand, can be stored for long periods, even smoothing out seasonal variations in energy demand. And if production is scaled the "residual energy" (the difference between 100 per cent and the efficiency rates mentioned above) may be used to district heating and to heat the car in cold periods.

The most important advantage for hydrogen is when total costs are taken into account. Even bigger batteries cost much more to produce per unit of energy it can store – today approx. 200 USD per kWh – than the cost of a hydrogen pressure tank, which may be as low as 10 USD´s per kWh for smaller facilities and down to 1 USD per kWh for large-scale facilities. In Denmark where almost all regions are covered by the existing Natural Gas Grid this grid can also be used to store hydrogen. Experiments show that hydrogen may be inserted and mixed with natural gas. Another way to store hydrogen is to "upgrade" it by e.g. producing methane.

The most important disadvantage for hydrogen cars, trucks and buses today is that they enjoy limited economies of scale compared to battery-driven vehicles, not to mention conventional vehicles[4]. Even though hydrogen is in practice tariff-free as opposed to diesel and gasoline the total expenditure per km is assessed by

[3] The source of the following three sections is an interview with VP for technology Uffe Borup, Nel Hydrogen, Denmark

[4] It also makes hydrogen cars more expensive that in practice they have to be supplemented by a (small) battery to allow for a rapid start and to re-use energy when the brakes are activated.

some experts to be more than. 15 per cent higher today, including both operating and capital expenditure, than conventional vehicles, but increased scale of production may make this difference go away within 5-10 years[5]. Other sources are more skeptical and do not expect hydrogen vehicles to be able to compete with traditional vehicles before at least 15 years from now[6]. But production in China of hydrogen busses is assessed to reach 10.000 vehicles annually in a year or two, and European producers are also starting production.

It could be mentioned that there may be other technological possibilities. One of these is the "electrified highway", where trucks with a pantograph on the roofs can be supplied with electricity just as electrified trains. It is presently tried in Sweden, but it´s uncertain whether this solution is feasible on a larger scale.

2.2 KEY CHALLENGES

A number of international challenges to the green transition have appeared, and the international framework for the transition has changed.

The challenges are most imminent in transportation. The greening of our economies requires reduced energy use everywhere, and an increased use of renewables, in heating and cooling of the building mass and in industrial processes. The de-coupling of economic growth and energy use or greenhouse-gas emissions has until now been a much bigger success in these sectors than in transportation. In some countries insulation requirements in the Building Code have been tightened so much that new buildings only require a tiny proportion of the energy use per square meter in the present building mass - and the most energy-efficient new buildings can be zero-energy houses. Similarly, industrial processes require less energy per unit of value-added than before, while a growing part of our economies are services which are less energy-demanding than industrial products.

Transportation, on the other hand, is the "black sheep" of the "climate family". In the last decades, total transportation, including both passenger transport and freight, has consistently grown more than economic output (GDP) in most countries. And even though more efficient combustion engines and better vehicle design has improved vehicle performance these improvements have been counterbalanced by increased transportation. And while industrial processes have been more and more electrified the electrification of transportation has until now, been slower.

To be more precise, the Nordic countries have higher transport related CO_2-emissions as a share of total emissions from fuel combustion than most other European countries: 35%, of which 89% are related to road transport[7]. The fundamental reason for that may be explained by the energy mix in the Nordic area where hydro power, nuclear power and biomass as well as wind power have strong positions for non-transport purposes. It also indicates strong efforts of energy efficiency measures in other sectors. The heavy ratio of CO_2-emissions of transport indicates a significant potential for change.

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[5] This concept of "fossil fuel parity" is complicated, as is the concept of "same prices without subsidies", as it is not clear whether this includes different taxation due to different externalities, ie. CO_2-emissions.

[6] See eg. Dansk Energi 2015, Analyse nr. 23, Brint i fremtidens energisystem. "Being able to compete" means with the present tariff structure where hydrogen is free of tariffs and hydrogen cars are subject to a low, or no, registration tax.

[7] International Energy Agency (2014): CO_2-emissions from Fuel Combustion

Among the present challenges in the green transition, especially in transport, are:

- **Also, high green awareness in other regions.** Even though "green awareness" is high in the Nordic countries we are – luckily – not alone. Many developed countries take part in the green transition. Even though the US is presently dragging its feet in climate questions many states on both US coasts, first of all California, are leading markets for many green technologies, e.g. electrical cars. A number of Asian nations are also devoting huge resources into the development of green technologies and solutions, among those China, Japan, South Korea and Singapore. In Europe, green awareness is also high in countries such as Germany, the Netherlands, Austria and Switzerland.
- **Also, strong green research in other regions and research environments.** In many regions of the world universities and other research institutions investments and funding of "green" research has been high. Research articles and patents have also increased in many regions. This has increased both knowledge-sharing and competition in the areas of "green" research.
- **More intense international competition in the production of cars, trucks, ferries and airplanes.** All Nordic countries have competitive manufacturers producing vehicle parts or acting as sub-suppliers to the shipbuilding or even airplane industries. The Nordic countries still have a number of shipyards, mostly in specialized niches. And Sweden is still a strong car manufacturer, even though Volvo is Chinese, the remaining parts of Saab is owned by Nevs and Scania is owned by Volkswagen. Globally, the number of independent car producers has decreased. The same has happened with the production of trains and airplanes. At the same time, many car producers have reduced the number of sub-suppliers.
- **A fragile international commitment to binding agreements to reduce CHG-emissions.** Internationally, US had decided to withdraw from the Paris COP agreement. The consequences of this decision on the conduct of other countries are uncertain – it may lead to both a reduced interest from other countries to commit to reductions, or the opposite. In all circumstances, most observers believe that the existing commitments agreed upon and deposited with the UN are not sufficient to keep global warming under 2° Celsius. Many developing countries are not taxing the use of energy, or are only doing so very modestly, and many developed countries are not contributing to the financial schemes to support green investments that are part of the agreements.
- **Lack of European consensus on climate issues.** Also in Europe and within EU disagreements on climate policy are widespread. Many Eastern European countries, for example, have resisted measures proposed to make the present Emission Trade System – ETS – more effective. As a result, CO_2 emission quotas are very cheap. This is a serious barrier to the introduction of green technologies which in many instances for some years to come have to be supported by government subsidies in order to be used.
- **Low prices on fossil fuels.** On top of the above-mentioned challenges, international before-tax prices on fossil fuels are low. The two main reasons for this is a subdued demand and production in economies that still have not entirely abandoned the years of financial crises of 2008-10, and consequences of new technologies like the extraction of crack gas in Northern America. Also in Nordpool, the Nordic wholesale electricity market, prices are still low in spite of some increases in the latest year. The low energy prices make the introduction of green technologies more expensive and dependent on subsidies.
- **Driverless cars?** Many think that driverless, autonomous cars may be common to see in streets only a few years from now. Others think it may take longer time. We find it probable that driverless cars may change transport patterns dramatically, and possibly for the better, allowing existing roads to be much better utilized with considerably fewer car accidents than today. Also, it may be more common for the

average family not to own a car (or two) but to rent these, perhaps even trip by trip. On the other hand, this may lead transportation to be individualized, and to make total transport demand grow even more than we are used to. If this is true, the challenges to reduce CHG-emissions from transportation will only increase further and make the task of making the transport greener even more important.

2.3 POLICY PROPOSALS – WHAT CAN THE NORDIC COUNTRIES DO – INDIVIDUALLY AND TOGETHER?

Having taken note of international circumstances and barriers, there seem to be a lot of possibilities to strengthen initiatives to make transportation in our economies greener and to improve our cooperation to this end.

Our main proposals are:

- **A strengthening of Nordic cooperation** – especially in the transfer of knowledge from universities and other research institutions to enterprises and central and local authorities. We will point to a number of possibilities in the next section. First and foremost, we recommend a substantial increase in the transfer of resources to common Nordic Energy research and investment programs in the area of green transport. We agree with the thinking expressed in the recent report by Jorma Ollila: *Nordic Energy Co-operation: Strong today – stronger tomorrow*[8]. We especially endorse Proposal 7 in this report to create a 67 mill Euro Nordic energy research and demonstration program. We also find that it is important in such a program that funds are specifically allocated to projects focusing on green transport. There are Nordic participants in some Horizon 2020 projects, but in many national projects there is too little inter-Nordic cooperation, so such a program would clearly make a difference. We believe that such an initiative could secure a continued strong international position for Nordic research environments in the energy area, and that Nordic demonstration projects are also necessary to secure a strong position for Nordic enterprises.
- **Avoid silo thinking.** In all Nordic countries, green transport is a combined responsibility of ministries of transportation, energy, industry and innovation. Even in the Nordic Ministerial Council, initiatives may be discussed in MN-NER (the Ministerial Council for Industry, Energy and Regional Policies), that does not include the transport ministers. It is often a strength that more ministries are involved and have an interest in an area, as this raises the political capital and weight of the topic. However, there is a risk that the involvement of more ministries could become counterproductive due to lacking coordination between the ministries. Thus, we recommend that the national ministries responsible for the different aspects of green transport formulate common strategic goals and measures on how to reach these. This creates a clearer division of labour and minimizes the risk of duplication of policy initiatives. It´s important that one ministry takes lead and other ministries give the question full attention. In many instances, it´s also an advantage if the question of green transport is given priority by the minister for finance or the prime minister.
- **Avoid stop-go policies.** In some Nordic countries, stop-go policies have sent messy signals to universities and especially businesses. Denmark, for instance, has changed the taxation of electrical cars a number of times in the latest years, and presently the sale of new electrical cars is very low. In Iceland, dire eco-

[8] Nordic Council of Ministers, May 2017

nomic circumstances put an end to former successful experiments and initiatives in the use of hydrogen in the years after 2007-8. All governments can of course legitimately take new actions and change policies put in place by their predecessors, but broad and therefore more lasting political compromises can give much better incentives for stakeholders to undertake long-term investments in a greener economy.

- **Support the development of different technologies - with the aim of being technology-neutral when solutions are mature.** As described above all "green" transport technologies – electrical, biofuel and hydrogen as well as other technologies – are still more expensive than traditional, fuel based solutions and hence require subsidies in order to be taken into use. In the last years, the largest improvements in technologies have, as mentioned, been in the area of electrical cars, especially due to better and cheaper batteries. Nobody knows, however, where the next, important technological improvements will take place. It is therefore important that the Nordic countries will not be locked to technologies that may be outdated in the future. As a consequence, we recommend that green subsidies are technology-neutral when they have been developed - but that authorities on the other hand have an open mind when technologies have not yet been commercialized on a wider scale. In order to test different technologies some "division of work" between the Nordic countries may be a good idea.
- **Secure the use of common standards.** Even though subsidies should be technology-neutral, we have met a number of industrial standards or practices that differ, or are adopted differently, between the Nordic countries. This is a barrier to pan-Nordic projects. In most cases the Nordic countries follow EU or global standards, but in some areas, these have not been defined or adopted. In these cases, coordinated Nordic positions in the ISO (International Standard Organisation) may be a good idea.
- **Make use of Nordic institutions already in place** - e.g. the Nordic Energy Research and NICE. We see no need to establish new institutions, which will take time, discussions and resources. With Nordic Energy Research, there is an instrument to fund and facilitate Nordic cooperation in energy research and provide analytical input, and NICE specifically focuses on supporting sustainable growth in the Nordics.The above-mentioned Ollila-report recommends that the proposed new 67 million programme should be administered jointly by Nordic Energy Research, Nordforsk and Nordic Innovation. As we would especially emphasize the need for innovation projects rather than basic research, we could see Nordic Innovation as a possible lead partner in such a programme.
- **Encourage Nordic enterprises to more participation in Horizon 2020-projects**. It has been outside the scope of this analysis to map the participation of Nordic enterprises in Horizon 2020 project, but some of our interview persons have pointed to the possibility of an increased Nordic participation, especially on the enterprise level. Many enterprises, however, see this as onerous and bureaucratic. It could therefore be a good idea to let an increased Nordic participation be a specific task and objective for Nordic Innovation.
- **Increase efforts to promote the Nordic countries as a testbed for green solutions to strong and innovative enterprises from other countries**. All Nordic countries have consumers and business communities that are open to new green solutions and willing to experiment with new technologies. At the same time, regulation is often flexible, and public authorities are ready to engage in public-private partnerships. Many international enterprises already see the Nordic´s as a good testbed area for green solutions, and a combined effort to strengthen the branding of a "Nordic test-bed" could increase foreign direct investments that can strengthen innovation and growth.

2.4 INCREASED NORDIC COOPERATION IN SPECIFIC AREAS

The specific proposals to enhance Nordic cooperation differ between the different transport segments.

In the area of *battery-driven, electrical transportation,* we will point to the following opportunities to strengthen Nordic cooperation:

- Norway and Iceland are presently frontrunners in the expansion of the share of electrical, personal cars. In Norway, this is i.a. due to large subsidies – electrical cars are exempt of the registration tax as well as VAT, a route the other Nordic countries have found too expensive. But Norway, and especially the Oslo area, has also supported electrical cars in a number of other ways. They are not subject to the "toll tax" paid by other vehicles, they pay no or lower parking fees and have privileged access to parking lots, they may enjoy the privilege of free electrical charging, they may use taxi lanes, etc. Other cities can indeed learn from these examples.
- Whereas electrical, personal cars may be able to cope on market terms without subsidies in a few years – or whereas the purchase of new, fossil-fuel-driven cars may be prohibited without severe costs to consumers – the same balance seem to be longer away for trucks and other heavy vehicles like busses etc. Electrical trucks and busses are still often twice as expensive as traditional trucks and busses, because the necessary batteries weigh much more and still have a limited capacity. These problems have called for the development of different, but still expensive, technologies as fast charging systems, wireless charging systems etc. In these areas, much research, experiments and testing is still needed. An increased Nordic cooperation and knowledge-sharing in this area could reduce costs for the individual Nordic countries.
- A number of electrical – battery-driven – ferries have been introduced in the Nordic countries in the latest years. All of these have been installed on shorter routes. In some instances, the use of fast-charging methods is necessary. Also in these areas, solutions are still expensive, and development costs per country can be reduced if results and problems from present projects are spread freely.

In the area of *biofuels,* we point to the following possibilities to increase Nordic cooperation:

- Few people see the use of biofuels in personal cars as a part of the long-term green transport picture. As the capacity to produce biofuels, also in the long run, will be limited, the consensus view is that biofuels should be reserved for transportation where batteries do not fit in, or are unsafe – especially heavy transport and aviation.
- In the area of heavy vehicles, the main challenge does not seem to be the development of engines, but rather the development of technologies that can make the production of biofuels cheaper. In this area research in many different processes and technologies is carried out and it seems very difficult to forecast where the next, most important break-throughs will occur. In the biofuel area, therefore, both combined and coordinated Nordic research projects and knowledge-sharing of tests and practical project-results may be very fruitful.
- Not all Nordic countries have given the same priority to biofuels. Sweden and Finland are frontrunners. In Sweden, biofuels already constitute more than 15 per cent of gasoline and diesel used in land transport. In the other Nordic countries this share is lower. This is not a problem – some "division of work" between the Nordic countries may actually be a good idea.

- In the area of aviation, regulation and technology-development is decided in other countries. In this area, coordinated Nordic positions in international fora and in EU may be suitable.

In the area of *hydrogen*, the achievement of viable, non-subsidized solutions is also some years away. In all Nordic countries, the number of hydrogen-driven cars is still very limited (below a hundred in all countries). This in turn makes the infrastructure investments in supply chain, storage capacity and tanks expensive when measured per vehicle. Norway and Denmark have invested most in the hydrogen area, Denmark with 10 stations constituting the world's first country-wide hydrogen network, and Norway with more than 15 stations in Southern Norway. Iceland has three stations with plans to install more- – Iceland was a frontrunner 10 years ago, but stopped hydrogen projects under the financial crises. Sweden and Finland have invested less in the hydrogen area. But as described in the country reports some projects have been carried out, trying to establish a "green highway" between the Nordic capitals.

Again, the different priorities is not a problem – we actually see this as a fruitful "division of work".

- In the hydrogen area, experiments and projects can be carried out at a lower cost per country if common hydrogen-projects are carried out, involving interested partners from all Nordic countries, but not necessarily taking place in all countries at the same time. This could be done if the Nordic energy fund described above was established and decided to support hydrogen projects.

The area of *ICT solutions* differs in many ways from the above-mentioned areas. Many solutions may be cheap and may be developed by SMEs. They may often be developed and marketed without government subsidies. At the same time, city-wide solutions may be purchased from or developed through private-public partnerships calling for major investments from larger municipalities involved in such projects.

- In the area of ICT solutions, the need for basic research and combined Nordic projects seems less urgent than in other areas. What is needed here seems first and foremost to be the mutual inspiration that bigger cities can give each other, in the Nordic countries and globally. That being said, there may still be an important role for Nordic knowledge-sharing as the will to reduce the share of car transport in the total transport system seems more prevalent here that in most other parts of the world.

Finally, in the area of *transport planning and city planning*, the need for technological research and combined projects also seems limited. The area does not require subsidies but rather heavy public investments in modern infrastructure like metros, light rail, bike lanes etc. This area, therefore, may be the area where most public money will be spent.

- In the area of public investment in liveable cities with good, collective transport systems, and where people feel safe and comfortable to walk or bike, bigger Nordic cities may inspire each other a lot, like they can inspire cities in the rest of the world and be inspired by good examples in other countries.

3. The Nordic strengths and current Nordic collaboration on green transport

Based on 1) interviews with experts and stakeholders in the Nordic countries and 2) insights from different studies, reports, analyses, policy documents on transport in each of the Nordic countries, this study has identified the current strengths and emerging strengths in the Nordic countries concerning the transition to more sustainable and greener transport. Table 3.1. below presents our assessment of the key strengths, emerging strengths as well as the contextual factors in the Nordics in general as well as in each of the Nordic countries.

Table 3.1. Overview of key strengths and emerging strengths in the Nordics

Country	Strengths	Emerging strengths	Contextual factors/characteristics
Common Nordic characteristics	• Ambitious plans to reduce CO_2 emissions • Public awareness of environmental issues related to transport (NOx, particles, noise, congestion) • A high innovation performance, eg. as measured by EU´s Innovation Scoreboard	• Hydrogen-based solutions	• The public authorities' willingness to cooperate with industry and academia and their strive to work at the forefront of the green transition of the transport sector. • High availability of low-cost renewable energy - an important supporting factor in the green transition
Denmark	• City planning and infrastructure • Cycling	• Smart city solutions • Hydrogen-based solutions	• A limited vehicle manufacturing industry • A strong maritime sector • As a geographical small country, little emphasis is placed on rail freight
Finland	• Biofuels • Integration of ICT solutions in the transport sector	• Mobility services • Further development of green technologies within sea-based transport	• A tradition for large trucks • A strong ICT sector • A large forest industry contributing to biofuel possibilities
Iceland	• Use of electrical cars (including Hybrids), including establishing the necessary infrastructure • Energy-saving marine solutions • Use of methane- and methonal-driven cars	• Electrical ferries	• A renewed focus on green transport as most other energy use is sustainable due to geothermal resources and water power • Iceland is sparsely populated (especially outside Reykjavik) which is a challenge for electrical cars due to their limited range. It´s also a challenge for the provision of public transport and for establishing a cycling culture
Norway	• Electricity-based modes of transport for personal cars • Long and broad experience with green solutions in the marine sector (ferries and fisheries)	• Further spreading electricity-based solutions both in land-based transport and in sea-based transport of goods	• A strong maritime sector

Sweden	• Biofuels • Production and electrification of vehicles (Scania, Volvo, Bombardier etc.)	• Further development of electrification, mainly in electric buses, heavy vehicles and the accompanying infrastructure	• A major manufacturing industry producing vehicles and parts • A large forest industry contributing to biofuel possibilities

Regardless of the differences between the Nordic countries, we assess that there are distinctively Nordic strengths characterising the Nordic region as a whole:

- **Firstly, all the Nordic countries have set out ambitious long-term decarbonising targets** i.e. becoming carbon-neutral by 2050 at the latest. These ambitious plans are also a result of a high green public awareness and concern for environmental issues related to transport such as NOx, particles, noise and congestion. Some countries have also important milestones on the way; Sweden to decrease domestic transport-related CHG-emissions (excluding aviation) with 70 per cent from 2010 to 2030, Norway by demanding that all new personal cars should be zero-emission cars already in 2025, and Norway and Finland by setting ambitious reduction objectives also for road freight (a reduction of 50-75 per cent in CHG-emissions in 2030).
- **Secondly, with access to both "clean" electricity and biomass for biofuel**, the Nordics both in the energy and the transport sectors are already in a favourable position to create first mover advantages in the carbon-neutral transformation.
- **Thirdly, the Nordics generally perform well on innovation**, e.g. as measured by EU's Innovation Scoreboard. This is also reflected in the Nordics' strong global position within R&D and innovation in green transport technologies. Furthermore, the Nordics' long tradition of triple-helix collaboration enables innovative solutions and the uptake of green transport solutions for use in the public sector.

In the country studies (see appendix 1), we have described and analysed each of the Nordic countries in terms of their key strengths and emerging strengths. The following gives a short extract of the main findings in each country.

3.1.1. Denmark

The analysis shows that Denmark only holds a few comparative business strengths and specialisations concerning technologies within green transport. Among these are technologies used in hydrogen cars, i.e. electrolysis, where Haldor Topsøe is a strong player. The Danish approach is often described as a 'soft' approach to green transition of the transport sector, i.e. in Denmark the emphasis is to a lesser extent on technological innovations but more on changing the mind-set and approach to green transition. The Danish strengths are specifically within systems, such as city planning and infrastructure creating a potential for building a strength within smart city solutions with Copenhagen as a global frontrunner city. In addition to this, Denmark has a strong maritime sector and is an industrial leader on a global scale due to a strong tradition of shipping activities and maritime transport logistics. The global Danish company Danfoss develops hybrid solutions for the maritime industry.

3.1.2. Finland

Finland has built a strong biofuel sector with many large companies such as Neste, ST1, UPM. Neste is one of the world's leading companies in biofuels. Secondly, Finland has a strong ICT sector and experience with the integration of digital solutions in transport. Thus, Finland has an emerging strength within mobility services with the Maas system as a successful example combining different forms of transportation to one package so a combination of forms of transportation can be bought in one ticket. Furthermore, Finland has a strong presence in different kinds of utility vehicles and has developed both fully electric and hybrid solutions such as cranes (Konecranes, Cargotec) and mining vehicles (Sandvik). The maritime industry is another Finnish stronghold, and recently a test region for unmanned ships has been established.

3.1.3. Iceland

The analysis shows that Iceland has a potential within the green transition of the transport sector, as Iceland's ample resources of relatively cheap, renewable energy can be used much better than today in providing sustainable solutions for the future - especially in green transport. Iceland also hosts a few promising businesses in the area of green transport, e.g. the global company CRI - Carbon Recycling International, producing 5 mill litres of methanol annually. Another company is Marorka specialised in providing systems end technologies enabling ships to reduce energy consumption and CO_2- emissions significantly. In Iceland, a further, steep increase in the number of electrical cars, but also methonal-driven cars and hydrogen cars, is anticipated.

3.1.4. Norway

Norway is no. 1 in the world in the proportion of new, personal cars (16 per cent pure battery-driven and 13 per cent plug-in-hybrids in 2016[9]) being electrical. The availability of low-cost renewable energy is an important supporting factor in the green transition in the Norwegian transport sector. This manifests mainly through the use of electricity-based modes of propulsion for personal cars and ferries, but can potentially be harnessed in the production of hydrogen, too. Norway's maritime sector also has a potential and leads in the green transition compared to the maritime sector in other countries, i.e. Norway is very active in introducing electrical ferries.

3.1.5. Sweden

Sweden hosts a number of major transport actors such as Bombardier within railway, Saab and GKN Aerospace within air and Volvo and Scania within road transport. Sweden is leading in the number of personal cars and trucks using biofuels as and has a strength within the electrification of the road sector. Volvo Personvagnar and Scania, being global companies, are significant drivers towards new green technologies and innovations. For example, Scania has developed heavy trucks compatible with electric roads. Volvo is well on their way phasing out their fossil fuel cars, exchanging them with electric or hybrid solutions already in 2019. With world-leading actors in the road sector; railway, water and air transport easily get overshadowed. Railway transport has a big part to play in the green transition in the transport sector and investments are made to maintain and develop the Swedish railway system.

[9] https://elbil.no/elbilstatistikk/elbilsalg/

3.1.6. All Nordic countries

Each of the Nordic countries have built up strengths within different transport modes determining their ability to create new green solutions within the different modes of transport, e.g. Sweden has large global vehicle manufacturers (Volvo and Scania) that are significant drivers towards green technologies and innovation within road transport.

At the same time, the Nordic countries have different research and innovation capabilities within the different green technologies and transport systems. The combination of these results in a number of cross-Nordic strengths as well as a potential for further development, as illustrated in table 3.2. below.

Table 3.2. Matrix of the cross-Nordic strengths

	Road transport	Rail transport	Sea transport	Air transport
Electrification	Sweden has large global manufacturers of vehicles (Volvo, Scania). Both companies focus on electrification of vehicles. Norway is no. 1 in the world in the proportion of new, personal cars being electrical – followed by Iceland (approx. 5 per cent). Oslo is strong in experiences on how to promote the use of electrical cars.	In Finland, Norway and Sweden, most locomotives are electrified. In Denmark, diesel locomotives stand for a minority of rail transport and will be replaced by electrical locomotive in the next ten years. Iceland has no rail system.	Norway is very active in introducing electrical ferries, but all Nordic countries have installed some – an interesting example will be the ferry between Helsingør, Denmark, and Helsingborg, Sweden. Sweden is strong in producing electrical parts and batteries. Iceland is strong in energy-saving marine solutions.	-
Biofuels	Sweden is leading in the number of personal cars and trucks using biofuels as well as having manufacturers producing vehicles or parts. Denmark and Finland are strong in some of the processes used in biofuel production	-	-	All Nordic countries are active internationally, esp. in EU, to promote the use of biofuels
Hydrogen	All Nordic countries - mostly Norway and Denmark – are experimenting with hydrogen cars, mostly personal, and hydrogen stations	-	-	-
ICT-based transport solutions	Most Nordic capitals have ICT-systems in place or plans to introduce "green waves", app-based parking services, real-time infor-	-	-	-

	mation services			
Transport and city planning	Copenhagen has very ambitious plans to decrease the share of car transport, has a strong tradition for biking and is well-known for city planning. Other Nordic capital have similar strongholds	Norway and Sweden have ambitious plans to strengthen the rail system, to build high-speed-trains and to increase the share of rail freight	Norway has ambitious plans to increase the share of sea freight	-

3.2. CURRENT NORDIC COLLABORATION ON GREEN TRANSPORT

In the study, several 'good practice' cases of Nordic collaboration on green transport have been identified. At the same time, many interviewees representing different types of institutions (research, business and policy) emphasise the lack of overview that they have of the collaboration opportunities in the different countries. Consequently, we see a risk that potential benefits from a collective and coordinated Nordic effort are not used sufficiently which in turn can slow down the Nordic transition to a greener transport sector.

The cross-Nordic collaboration takes place on different levels. Some are commercial activities – one Nordic company places an order at another Nordic company, others are research and innovation projects, and lastly there are examples of cross-Nordic policy initiatives. Table 3.3. shows 'good practice' cases of cross-Nordic collaboration identified in the interviews with the Nordic stakeholders. It is not an exhaustive list of good practices, but an indication that collaboration between different Nordic actors on different levels is already taking place to a large extent.

Table 3.3. Examples of good practice cases of cross-Nordic collaboration within green transport

Case	Countries involved	Level (business, research, policy)	Description
Norwegian grocery logistics company ASKO ordered hydrogen lorries from Swedish Scania	Norway, Sweden	Business	The Norwegian grocery logistics company ASKO has stated the ambition to become climate neutral, in part by using renewable fuels and modes of propulsion in transport. Consequently, ASKO has ordered four hydrogen lorries from Swedish Scania for testing.
The Scandinavian Hydrogen Highway Partnership	Norway, Sweden, Denmark, Iceland	Business, research, policy	The Scandinavian Hydrogen Highway Partnership (SHHP) consists of regional clusters involving major and small industries, research institutions, and local, regional and national authorities. The national networking bodies – Norsk Hydrogenforum in Norway, Hydrogen Sweden in Sweden and Hydrogen Link in Denmark – act as SHHP coordinators. The purpose is to install refuelling stations for hydrogen, and thus create an infrastructure for hydrogen.
Upgrading and retrofitting batter-	Denmark, Sweden, Norway	Business	Norway-based Plan B Energy Storage (PBES) supply the batteries required for the hybrid fer-

ies on two ferries operated by Scandlines			ries[10]. PBES have specialised in batteries and industrial scale energy storage.
Finnish ferry operator FinFerries purchases plans to purchase Norwegian electrical ferry	Norway, Finland	Business	The Finnish ferry operator FinFerries is set to purchase an electrical ferry, based on the Norwegian Ampere-ferry. The Norwegian branch of Siemens are contracted to deliver steering systems[11].
Innovationer för hållbar kollektivtrafik i Skandinavien. Erfarenheter och utmaningar	Sweden, Denmark, Norway	Research	VTI has cooperated with its Norwegian counterpart TØI and Institut for planlægning at Aalborg University in a project aimed at explaining why some regions have more successful transportation systems. In the project, case studies (on Nordic regions where innovative solutions were used) were conducted and the project resulted in a report in 2013 called Innovations for sustainable public transport – Experiences and challenges in the Scandinavian countries12.
Sustainable city solutions	Sweden, Norway	Policy	The Norwegian Bymiljøavtalen (public funding for sustainable city solutions) was an inspiration for the Swedish equivalent Stadsmiljöavtalen.
The green highway	Sweden, Norway	Policy	A cooperation between the municipalities of Sundsvall, Östersund och Trondheim called the Green Highway, connecting the participating cities with charging and biofuel stations.
NISA (Nordic Initiative for Sustainable Aviation)	Denmark, Sweden, Norway, Finland, Iceland	Business, Policy	NISA is an active Nordic association working to promote and develop a more sustainable aviation industry, with a specific focus on alternative sustainable fuels for the aviation sector. Nordic stakeholders within the aviation sector have joined forces to form the association NISA, in order to realise the development of new sustainable aviation fuels. The associations are established to work with biofuels issues on behalf of the aviation sector in the Nordic region.
SHIFT project	Sweden, Denmark	Research	Shift is led by IVL Swedish Environmental Research Institute and researchers from DTU Technical University of Denmark, TOI Institute of Transport Economics and Viktoria Swedish ICT. Shift will develop and apply tools that integrate poorly understood factors – modal shifts, fuel options, new business models and consumer behaviour – into scenario modelling, and carry

[10] SCANDLINES HELSINGBORG-HELSINGØR - 89 tonn batterier i verdens største el-ferge, Teknisk ukeblad, 21.06.2016

[11] Siemens - Verdens første store batteriferge har gått i et år. Dette blir ferge nummer to, Teknisk ukeblad, 04.03.2016

[12] https://www.vti.se/sv/sysblocksroot/forskningsomraden/planerings--och-beslutsprocesser/nordisk-kollektivtrafik/workshop-2/innovations-for-public-transport.pdf

			out in-depth analysis of two key areas: long-haul freight and urban passenger transport.
GREAT project	Sweden, Denmark	Research, business, policy	Great hosts a combination of private companies and regional authorities. The lead partner in the project is Region Skåne that in turn is supported through Partnership Agreements by the Supporting Partners. These partners are E.ON Sverige AB, E.ON Denmark A/S, E.ON Biofor AB, Fordonsgas AB, Nissan Europe, Renault, DTU.
Nordic secretariat for e-mobility	Denmark, Norway, Sweden	Research, business, policy	The partners are Dansk Elbil Alliance (Denmark), Norsk Elbilforening (Norway), Power Circle (Sweden). The purpose is to assist municipalities and regions in setting up an infrastructure for electrical vehicles and to collect best practices across borders.

Appendix 1: The Nordic country studies

SWEDEN

In Sweden, the following interviews have been carried out.

Universities and research institutes:

- Statens väg och transportforskningsinstitut (VTI) – Mikael Johannesson, forskningschef område miljö
- Svenska miljöinstitutet (IVL) – Erik Fridell, professor på området transporter
- Linköping Universitet – Maria Huge-Brodin, professor på klimatsmarta transporter
- Swedish electromobility centre – Anders Grauers, elfordonsspecialist

Public authorities:

- Trafikverket – Sven Hunhammar, måldirektör för de transportpolitiska målen
- Vinnova – Joakim Tiséus, avdelningschef på avdelningen för Samhällsutveckling
- Energimyndigheten – Kristina Difs, forskningshandläggare och programansvarig för ett forskningsprogramme inom transportområdet

A brief overview of the main policy actors and key stakeholders within green transport

The Ministry of the Environment and Energy is the department responsible for the Government's energy and climate policy and **the Ministry of Enterprise and Innovation** oversees policy issues related to transport. The Government agencies that are most relevant regarding the transition to a green transport sector are the following:

Collectively, **VINNOVA** (Innovation Agency), **Energimyndigheten** (Energy Agency), **Naturvårdsverket** (Environmental Protection Agency) and **Trafikverket (**Transport Administration) are responsible for planning, building and maintaining national transport infrastructure. Energimyndigheten is the public authority commissioned to coordinate the transition to a fossil free transport sector. As the importance and interdisciplinary nature of transport is growing, so is the number of relevant public authorities:

- **Datainspektionen** (data protection authority) oversees an increasingly digitalised transport sector.
- The National Board of Housing, Building and Planning, **Boverket**, controls the growing need of sustainable cities.
- **Transportstyrelsen** (Transport Authority) regulates and supervises the transport sector and is of growing importance due to the development of demonstration facilities and the legal issues they cause.

Other important stakeholders:

- **Forum for Transport Innovation** brings together stakeholders with the purpose of promoting innovation for breaking the link between transport activities and emissions;
- **The Electromobility Centre** which is the national centre of excellence for research on electrical and hybrid vehicles and infrastructure.
- **The 2030 Secretariat** is a think-tank based advocacy organisation promoting fossil fuel independence. ¨

Interest organisations supporting different areas within green transport:

- **Vätgas Sverige** promotes the use of hydrogen as an energy carrier in Sweden.
- **Elbil Sverige** promotes electrical vehicles in Sweden.
- **Cykelfrämjandet** is the national cycling advocacy organisation.
- **Svensk Kollektivtrafik** (Swedish Public Transport Association) is the trade organisation for public transport in Sweden.
- **Transportföretagen** (Swedish Confederation of Transport Enterprises) is the umbrella trade organisation for associations and companies in the transportation sector in Sweden.

As the areas of mobility services and community planning are growing, the importance of the regions and municipalities as policy actors are growing too, since policy issues related to sustainable cities and public transport are handled on a local level.

Existing national objectives, strategies and focus areas regarding green transport

Sweden is a leader within green innovation, including sustainable transport. A key step in moving forward within the green transition of the transport sector was the climate policy framework[13] established in June 2017. The framework consists of a climate act, a climate council and climate goals. The climate goals focus on emission reduction and the overall aim is net zero emissions of greenhouse gases by 2045[14]. The transport sector is responsible for a third of the greenhouse gas emissions in Sweden and thereby plays a big role in achieving this goal. Being a *net* zero goal rather than a zero goal is reflected in the emphasis on transitioning to sustainable fuels including biofuels, however, the goal is also meant to be achieved through the promotion of electrical and hydrogen (emission free) vehicles; walking; biking and public transportation.

In the Government's strategy to achieve fossil fuel free transport, it is stated that there should be a reduction of road and air transport and that the use of transport by railway, water, biking, walking and public transportation is to be enhanced while exchanging fossil fuels with sustainable fuels and electricity. The inquiry *Freedom from fossil fuels on the road* (SOU 2013:84 - *Fossilfrihet på väg*[15]) lays the groundwork for this strategy[16].

In the strategic plan towards the transition to a fossil free transport sector published by Energimyndigheten (and five other public authorities) in 2017[17], some measures proposed are to modernise the railway and to support the use of emission free vehicles by reducing taxes on electricity to electrical boats, continue the work on electrical roads, only allowing biofuel and emission free vehicles in certain zones and allowing biofuel and emission free vehicles to drive in the public transportation lanes.

[13] http://www.Government.se/articles/2017/06/the-climate-policy-framework/
[14] http://www.regeringen.se/regeringens-politik/fossilfria-transporter-och-resor/
[15] http://www.regeringen.se/contentassets/7bb237f0adf546daa36aaf044922f473/fossilfrihet-pa-vag-sou-201384-del-12
[16] http://www.regeringen.se/artiklar/2017/04/regeringens-arbete-for-att-minska-transporternas-klimatpaverkan/
[17] https://energimyndigheten.a-w2m.se/Home.mvc?ResourceId=5642

Additionally, it is stated in a Government Official Report of 2016 (SOU 2016:47 - *En klimat- och luftvårdsstrategi för Sverige*[18]) that transport by foot, bike and public transportation should make up 25 pct. of the total passenger transport (counted in kilometres) by 2025 and that transport by foot, bike and public transportation should be the norm in community planning. Moreover, a national cycling strategy[19] was released 2017 with the purpose of more and safer cycling.

Existing funding schemes/programmes supporting R&D and innovation projects focusing on the green transition of the transport sector

The main actors in supporting R&D and innovation projects within green transport are **Vinnova**, **Trafikverket** and **Energimyndigheten**. System research on infrastructure and logistics is mainly financed by Vinnova and Trafikverket, while research on renewable motor fuels, vehicles and emissions is funded by Energimyndigheten[20]. Vinnova has two funding programmes (strategic innovation programmes) that focus on the transport sector and the climate; Fordonsstrategisk forskning och innovation (FFI)[21] – a major funding programme financed by the Government and the industry with the objective of reducing the environmental impact of road transport in total amounting to around 1 billion SEK per year – and InfraSweden2030[22] contributing to climate neutral transports by bringing the latest technologies to road and rail transport with activities worth almost 16 million SEK in 2016.

Energimyndigheten is a co-funder of FFI and is funding projects related to the area of emission free and hybrid vehicles, for example through the programmes Energieffektiva fordon[23] (amounting to 88 million SEK during the programme period of 2015-2019) and Demonstrationsprogrammet för elfordon[24] (amounting to 285 million SEK during the programme period 2011-2018). The programmes focus on the development and dissemination of electrical and hybrid vehicles. Trafikverket is also a co-funder of FFI and is additionally in the process of developing a 10-year programme focusing on the transition to a fossil fuel free transport of goods, where electrification of road transport and attracting transport of goods to the railway are parts of the programme objective.[25]

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[18] http://www.regeringen.se/49ec6a/contentassets/01cd0e73c9b446a5937a43a347a911b1/en-klimat--och-luftvardsstrategi-for-sverige-sou-201647

[19] http://www.regeringen.se/498ee9/contentassets/de846550ff4d4127b43009eb285932d3/20170426_cykelstrategi_webb.pdf

[20] http://www.energimyndigheten.se/en/innovations-r--d/transport/

[21] https://www.vinnova.se/m/fordonsstrategisk-forskning-och-innovation/om-ffi2/

[22] http://www.infrasweden2030.se/om-oss/

[23] http://www.energimyndigheten.se/forskning-och-innovation/forskning/transporter/fordon/program/energieffektiva-fordon-2015-2019/

[24] http://www.energimyndigheten.se/forskning-och-innovation/forskning/transporter/fordon/program/demonstrationsprogram-for-elfordon-2011-2017/

[25] http://www.trafikverket.se/contentassets/666b4f489fa24ba791e2aca690945c90/trafikverkets_foi_inriktning_2018_2020_ver_slutlig.pdf

A new funding programme, starting during the autumn 2017, is Smart Sustainable Cities with a funding of 40 million SEK per year in the coming twelve years[26]. The programme will partly focus on public transportation and is funded by VINNOVA, FORMAS and Energimyndigheten.

Major public investments supporting the green transition of the transport sector

In recent years, major public investments to promote green transport have been made. A programme for local climate investments worth 1.92 billion SEK called *the Climate Leap – Klimatklivet*[27] is one of these investments. Klimatklivet has so far led to the setup of 9,000 new charging points and 500 million SEK of the funding is earmarked for co-funding public transportation in urban areas. Public transportation is also a significant part of the major investment in sustainable cities called *Stadsmiljöavtalen*.

Investments have also been made to promote vehicles with low-emissions by granting zero-emission vehicles a full premium and low-emission cars a half premium. In addition, a premium to reward electrical buses was recently introduced and the reduced taxable benefit for hybrid and electrical cars is to be extended to 2019.

Additional investments have been made to improve rail traffic as 1.24 billion SEK per year during 2016-2018 is reserved for maintenance. In addition, a political majority has agreed to invest in high speed trains and parts of the new railway are well underway. As a consequence of the national cycling strategy of 2017, 100 million SEK has been set aside to promote cycling as an alternative to less green means of transport.

Key business strengths and specialisations within green transport

On the business side, the main Swedish transport actors are **Bombardier** within railway, **Saab** and **GKN Aerospace** within air and **Volvo**, **Volvo Personvagnar** and **Scania** within road transport. **Nevs** (National Electrical Vehicle Sweden) acquired the assets of the car manufacturing part of Saab in 2012 and are planning to have their first car available on the market in a few years. Other important business actors are **ABB** that produces vehicle batteries, **AGA** that produces hydrogen for vehicles through wind power and **PowerCell** that is a leading fuel cell company in the Nordics. The company **Sandvik** produces parts for fuel cells.

One of the key business strengths within green transport lies in the road sector where Sweden is a major actor. As global companies, Volvo, Volvo Personvagnar and Scania are significant drivers towards new green technologies and innovations. For example, Scania has developed heavy trucks compatible with electrical roads and Volvo is well on their way to phase out fossil fuel cars and exchange them with electrical or hybrid solutions. During the interviews, the flat structure of Swedish organisations and the ability of employees to make independent decisions were mentioned as reasons why they handle new green technologies well.

With world leading actors in the road sector, railway, water and air transport easily get overshadowed. Railway transport has a big part to play in the green transition in the transport sector and investments are made to maintain and develop the Swedish railway system. State investments in railway maintenance was increased by 1,34 billion SEK per year for 2016-2018, and is proposed to increase even more the following decade. The objective of the increased funding in the long-term infrastructure investment plan is to establish a new grid of

[26] https://www.kth.se/aktuellt/nyheter/kth-leder-storsatsning-pa-smarta-och-hallbara-stader-1.692875
[27] http://www.regeringen.se/pressmeddelanden/2017/06/1000e-klimatatgarden-beslutad/

high speed railway tracks between Stockholm, Gothenburg and Malmö.[28] However, electrical solutions within commercial air transport are not yet available and the electrification of water transport is still in its early stages.

Besides road transport, another Swedish strength discussed in the interviews is the ability to produce affordable, fossil free electricity and this strong point in combination with the dominance of road transport in Sweden has accelerated the technical development of electrical roads compatible for heavy vehicles. At the moment, there are two electrical roads being tested; one north of Stockholm in Arlanda by the Rosersbergs Utvecklings AB and one near Gävle by the Region of Gävleborg[29]. A Swedish company providing the technical solutions for electrical roads is **Elways**.

Another key strength assessed by the interviewees is the public authorities' willingness to cooperate with industry and academia and their common ambition to work at the forefront of the green transition of the transport sector. Examples are **Trafikverket**, being a founding member of the Joint Technology Initiative *Shift2Rail*[30] and several municipalities, for example the City of Stockholm, which in 2010 was the first city to receive the *European Green Capital Award* by the EU Commission. The award emphasised the policy making mindset in the city administration assuring that environmental aspects are considered in all parts of the organisation. In 2017, the Smart City Sweden Export and Investment Platform for Swedish green tech businesses and sustainable city solutions was established by **IVL**[31], where Hammarby Sjöstad in Stockholm works as a showroom.

Emerging business strengths and growth potentials within green transport

In the future, Sweden is likely to keep developing the existing strengths within road transport and electrification. The interviewees anticipate a further development of electrification, mainly in electrical buses, heavy vehicles and the accompanying infrastructure. At the moment, **Volvo** and the **City of Göteborg** is cooperating in a project called *ElectriCity*, where a new electrical bus is being tested on one of the public bus routes. The electrical part of the green transport sector also has future possibilities in **Northvolt**'s plans to build Europe's largest battery factory in Sweden.

There is also development within the market for small electrical vehicles, where the Swedish company **Clean Motion** has developed a small three-wheeled vehicle called *Zbee*. Zbee has since 2014 provided vehicles for the taxi service Bzzt in Göteborg and has recently expanded to Stockholm.

Another emerging business strength concerns hydrogen. A fourth hydrogen fuelling station was recently built in Sandviken as a cooperation between the municipality of Sandviken and the companies **AGA** and **Sandvik**. The new fuelling station utilizes the already existing hydrogen pipes that run between AGA and Sandvik. In

[28] http://www.regeringen.se/pressmeddelanden/2016/10/ny-infrastrukturproposition-presenterad/
[29] http://www.trafikverket.se/resa-och-trafik/forskning-och-innovation/aktuell-forskning/transport-pa-vag/elvagar--ett-komplement-i-morgondagens-transportsystem/ ; https://www.scania.com/group/en/worlds-first-electric-road-opens-in-sweden/
[30] https://shift2rail.org/about-shift2rail/ju-members/
[31] http://smartcitysweden.com/about/; http://www.ivl.se/english/startpage/top-menu/pressroom/news/nyheter---arkiv/2017-06-27-a-new-sweden-china-business-match-making-platform-for-swedish-green-tech-businesses.html

addition, **Kalmar Global** and **SSAB** are developing a fuel cell forklift and **PowerCell Sweden** develops, produces and export fuel cell stacks and systems for vehicles.

Regarding water transport, **Echandia Marine** have developed *Movitz* – promoted as the world's first super-charged electrical ferry that will run for an hour after ten minutes of charging. The ferry runs in Stockholm and the project is supported by Energimyndigheten.

The interviewees also asses that an emerging strength lies within mobility services, with public transportation actors such as **Nobina** and **Transdev** cooperating with the regional actors to promote passenger transport by walking, biking or public transportation rather than by car.

An overview of key R&D strengths (research fields) and environments (research institutes, test and demonstration facilities) within green transport

In research and development, the key actors are the universities of **KTH**, **Chalmers** and **Linköping**, the Swedish Environmental Research Institute (**IVL**), the Swedish National Road and Transport Research Institute (**VTI**), Research Institutes of Sweden (**RISE**), a network of research and technology organisations, and the research council for sustainable development (**FORMAS**).

The strengths in R&D reflect the overall Swedish strengths within green transport which is road transport, electrification and a cooperative culture between sectors and actors. In the universities, the strengths are the technical development of vehicles (mainly KTH and Chalmers) and transport systems and logistics (mainly KTH and Linköping University but also Lund University). **KTH** is also the host of an *Integrated Transport Research Lab* (KTH ITRL), where KTH and **Scania** gather interdisciplinary competence within sustainable transport systems. The interviewees asses that Sweden is less strong within behavioural and "softer" issues related to transport, however, some research is conducted within the area at Stockholm University and Karlstad University.

Even though road transport is dominating the Swedish R&D green transport scene, railway transport and policy development are also assessed as strengths. As mentioned in the section above, the field of mobility services is an emerging strength and that is partly due to it being a well-covered research area. A key actor within mobility services research is **Viktoriainstitutet**, which is a part of RISE. A key actor within public transportation is the **Swedish Knowledge Centre for Public Transport** (K2).

Examples of good practices on cross-Nordic collaborations within green transport on different levels (business level, research level, policy level)

The overall assessment of the interviewees is that much cross-Nordic cooperation within green transport falls under research projects and policy development and not industrial cooperation. This is due to the world leading status of Swedish road transport actors, **Volvo** and **Scania**, who are more likely to work with other leading road transport actors rather than in the geographic vicinity.

On the research level, there have been several successful Nordic cooperation projects. For example, **VTI** has cooperated with its Norwegian counterpart **TØI** and Institut for planlægning at **Aalborg University** in a project aimed at explaining why some regions have more successful transportation systems. In the project,

case studies (on Nordic regions where innovative solutions were used) were conducted and the project resulted in a report in 2013 called *Innovations for sustainable public transport – Experiences and challenges in the Scandinavian countries*[32]. Another fruitful Nordic cooperation project was the development of the Nordic edition of the International Energy Agency's (IEA) publication *Energy Technology Perspectives 2016*[33]. The **IVL** led project focused on how the Nordics can become carbon dioxide neutral by 2050 and includes the issue of transitioning to a green transport sector. **VINNOVA** and the Finnish Funding Agency for Innovation (**Tekes**) have cooperated within mobility services.

Examples of cross-Nordic EU projects within green transport are the Joint Technology Initiative on Hydrogen & Fuel Cells called *H2moves Scandinavia*, which ran between 2010 and 2012, with the objective of gaining customer acceptance for Hydrogen Fuel Cell Electrical Vehicles and the ongoing Interreg funded project *The Blue Move for Green Economy*, where Sweden, Norway and Denmark cooperate to increase public knowledge on hydrogen and fuel cells vehicles.

On the policy level, an area of cooperation that was mentioned during the interviews was the possibilities of learning from the policy successes in the other Nordic countries, an example being the Norwegian *Bymiljøavtalen* (public funding for sustainable city solutions) as an inspiration for the Swedish equivalent *Stadsmiljöavtalen*. There have also been successful cross-Nordic projects in developing green infrastructure, one of them being the **Sweco**-lead Nordic Hydrogen corridor with the plan to build eight new hydrogen fuelling stations, connecting Stockholm, Oslo, Helsinki and Copenhagen. There is also a cooperation between the municipalities of Sundsvall, Östersund och Trondheim called the Green Highway, connecting the participating cities with charging and biofuel stations.

Potential for increased cross-Nordic collaboration within green transport on different levels (business level, research level, policy level)

The interviewees see a potential of further cooperation with the other Nordic countries through research projects and policy making. An example of a research project in the pipeline is the proposal of having the car free city project in Oslo as a subject of an ongoing evaluation with the purpose of comparing different emission reducing methods. Another point made regarding the future of cross-Nordic cooperation on the research level is to make use of the fact that the Nordic countries in general have companies that are willing to cooperate with academia and provide useful data. The point that was made was that a lot could be learned from asking the same research questions across the Nordic countries, for example comparing the different ways industry cooperate with public authorities by having access to comparable data in the different countries.

Continuous learning from the other Nordic countries' successes (and failures) and knowledge sharing in regards to policy instruments (carrots and sticks) within green transport are seen as possibilities for policy cooperation. An interviewee expressed a wish to further develop Nordic standardisations in the area of green transport, for example electrical roads. The interviewee highlighted that the Nordic countries have been successful in the past regarding standardisations with the Nordic Mobile Telephone (NMT) network that later became the predecessor of the global standard GMT.

[32] https://www.vti.se/sv/sysblocksroot/forskningsomraden/planerings--och-beslutsprocesser/nordisk-kollektivtrafik/workshop-2/innovations-for-public-transport.pdf
[33] http://www.nordicenergy.org/wp-content/uploads/2016/04/Nordic-Energy-Technology-Perspectives-2016.pdf

The interviewees were in general reluctant to point out specific strongpoints in the other Nordic countries, however some strengths were picked up during the course of the interviews. The key strength in Norway is considered to be the extent of electrical cars being used and to some extent, like Iceland, the usage of hydrogen and fuel cells within green transport. As for Finland (like for Sweden), the great forest industry calls for a strongpoint in biofuels. However, fuel cell technology within marine transports and technology development were also mentioned as strengths for Finland. In Denmark, the strongpoints mentioned are infrastructure and policy making for biking and water transports. A Danish strength is also considered to be the capacity to produce fossil free electricity through wind power.

NORWAY

In Norway, the following interviews have been carried out.

Universities, research and technology organisations:

- Grønt Kystfartsprogramme – Narve Mjøs, Programme Director
- Transportøkonomisk Institut – Harald Aas, Chief of Communication

Cluster organisations, trade/professional organisations:

- NHO Sjøfart – Frode Sund, CEO
- NHO Transport – Jon Stordrange, CEO
- NCE Maritime Cleantech – Marte Jensen, Project Coordinator
- ZERO – Kari Asheim, Academic Responsible

Public authorities:

- Klima- og miljødepartementet – Tom Johnsen, Advisor

A brief overview of the main policy actors and key stakeholders within green transport

The overarching administrative and political sectorial responsibility for transport lies with the **Ministry of Transportation and Communications** (SD). The **Ministry of Climate and Environment** (KLD) and **Trade, Industry and Fisheries** (NFD) constitute other relevant policy actors, along with the **Ministry of Research and Education** (KD) which has the overall responsibility for research in Norway. Research activities are mainly funded by the **Research Council of Norway** (RCN), while **Innovation Norway** (IN) funds commercialisation of technology. **Enova** grants subsidies and incentives for businesses and citizens to implement climate friendly technology.

Key stakeholders are the industry associations under **NHO** and the labour union **LO**. Important industry actors are logistics and transportation companies, represented by NHO Logistikk og Transport and NLF (federation of lorry owners). Public transportation companies, such as Tide and Boreal are represented by NHO Transport. Shipping and ferry companies that operate along the coast are represented by NHO Sjøfart. Off-coast shipping businesses are represented by **Norges rederiforbund** (Norwegian Shipowners' Association). In addition, there are certification and R&D companies, such as **DNV GL** and manufacturing and R&D companies, such as **Siemens** that play an important part through their cooperation with industry and public actors in projects. Interviewees point out **ASKO** and the logistics operator **Bring** as some of the most proactive companies in the green transition. In addition, the ferry operator **Norled** can be mentioned. Through projects and cluster organisations, such as the **NCE Maritime CleanTech-Cluster**, enterprises from other sectors are included in the transportation ecosystem as well.

Important NGOs with relevance for the transport sector are climate protection foundation **Zero**, committed to promoting zero-emission solutions, and the climate and environment protection foundation **Bellona**.

Among the most prominent research institutions within transport and applied energy research, we find Transportøkonomisk institutt (**TØI**), **SINTEF** and Norsk Marinteknisk Forskningsinstitutt (**MARINTEK**),

Norwegian University of Science and Technology (**NTNU**), the universities in Bergen, Oslo and Ås (**UiB**, **UiO**, **UMB**) and the Institute for Energy Technology (**IFE**).

Existing national objectives, strategies and focus areas regarding green transport

Reduced emissions in the transport sector, as well as green shipping is among the government's top priorities for Norway's climate policy[34]. Emissions can be reduced by 1) reducing the scope and volume of transport in general, 2) a transition towards modes of transport with lower emissions, 3) lowering emissions from existing modes of transport. The national strategies combine these three alternatives, but emphasize 2 and 3.

Land transport: The strategies for the transport sector include increased focus on public transport solutions by reducing the use of passenger cars for personal transport. In addition, through selective taxing of cars, the government seeks to contribute towards modernising the passenger car park with low-emission, zero-emission and hybrid cars. By 2025, all new passenger cars and inner city busses will be zero-emission vehicles or use bio gas[35]. Transport of goods and commodities is aimed to be transferred from road to rail and ship. Consequently, appropriations for maintenance of the Norwegian rail grid have been made. In addition, fossil fuels used in lorries and cargo vehicles are expected to be partly substituted by bio-generated fuels, such as bio diesel. Furthermore, the government has launched a national strategy for bio gas[36] and has announced investments in a pilot facility for research on bio gas.

The national transport plan for 2018-2029 states that by 2030 all new heavier vans, 75 pct. of long distance busses and 50 pct. of new lorries will be zero-emission vehicles[37].

Sea transport: The government's maritime strategy[38] includes transport by ship, including long-distance shipping and near-coast transport by ship. In both areas, the government expects the use of greener fuels and more energy efficient ships to contribute to lower emissions. The government seeks to substitute diesel propulsion with liquefied natural gas, biofuel and electricity. In addition, use of land based power supply for docked ships is an option. The government finds that a large share of the transport ships operating along the Norwegian coast is made up of older ships that will need replacement in the future. Through scrapping bonuses and state grants for technology development, the government seeks to contribute to a greener fleet of ships for transport along the coast. Furthermore, as soon as technologically viable, future operating licenses for short distance ferry transport will require the use of low-emission or zero-emission technology. Through state grants and R&D incentives, Norway has established itself among the leading nations in the development of electricity-based and LNG-based ship propulsion[39]. The national plan for transportation for 2018-2029 states the ambition that 40 pct. of all ships that operate near the coast will use biofuel or be low-emission or zero-emission ship by 2030

[34] Meld. St 13 (2014-2015) Ny utslippsforpliktelse for 2030 – en felles løsning med EU
[35] Meld. St. 33 (2016-2017) Nasjonal transportplan 2018–2029, Samferdselsdepartementet, 2017
[36] Nasjonal tverrsektoriell biogasstrategi, Klima- og miljødepartementet, 2014
[37] Meld. St. 33 (2016-2017) Nasjonal transportplan 2018–2029, Samferdselsdepartementet, 2017
[38] Maritime muligheter – blå vekst for grønn fremtid. Regjeringens maritime strategi, Nærings- og fiserkidepartementet, 2015
[39] Meld. St 13 (2014-2015) Ny utslippsforpliktelse for 2030 – en felles løsning med EU

Existing funding schemes/programmes supporting R&D and innovation projects focusing on the green transition of the transport sector

There are a range of funding schemes and programmes supporting R&D, innovation and implementation of projects focusing on the green transition within the transport sector. R&D activity is mainly supported by the **RCN** through a range of research programmes for energy (**ENERGIX**) and maritime value creation (**MAROFF**), along with a range of programmes and a tax deduction scheme (**SkatteFUNN**) that are not targeted at specific sectors, but are used by research institutions and enterprises within the transport sector. Furthermore, the RCN co-funds research centres (**FME, SFI, SFF**). Some of these centres develop technologies relevant for the sector.

Innovation Norway, tasked with supporting commercialisation of innovation and technologies, has few transport-specific schemes, but some of the loans, grants and guarantees, along with the support scheme for environmentally friendly technology are granted to enterprises within the transport sector. Lastly, the state agency **Enova** has a range of supporting schemes for implementation of relevant technology, ranging from fast-charging stations to hydrogen charging terminals, development of bio gas and next generation biofuel, zero-emission vehicles and installation of energy efficiency measures and batteries on ships.

The **RCN**, **IN** and **Enova** have entered a collaboration for supporting green technology projects from idea to market, covering all stages of the STI-process. The collaboration, labelled *PILOT-E*, has so far had two calls for proposals, the first one focussing on projects within green, zero-emission sea-based transport[40], while the second call (deadline in October 2017) focuses on zero-emission land-based transport and distribution and public transportation, among others[41]. The 2016 call resulted in five projects[42]:

- Kongsberg Maritime AS – autonomous ferries
- Wärtsila Norway AS – urban water shuttle
- Siemens AS – zero-emission maintenance ship for offshore wind parks
- Brødrene Aa AS – battery for sightseeing boat
- Fiskerstrand Holding AS – the world's first hydrogen-powered ferry

The **Ministry of Transportation and Communication** has planned a similar programme for green modes of transportation and fuel, titled *Pilot-T*.

In addition to the funding schemes mentioned, regulations, conditions and eligibility criteria are used to promote the development and implementation of low-emission or zero emission solutions, e.g. when granting licenses for operating ferries or in public procurement of vehicles. For instance, future operating licenses for short distance ferry transport will require use of low-emission or zero emission technology, if technologically feasible.

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[40]https://www.forskningsradet.no/no/Utlysning/ENERGIX/1254019027436/p1173268235938?progId=1253979646833&visAktive=false

[41]https://www.forskningsradet.no/no/Utlysning/ENERGIX/1254027064680/p1173268235938?progId=1253979646833&visAktive=false

[42] http://www.innovasjonnorge.no/no/Nyheter/pilot-e-100-millioner-til-utslippsfri-transport-pa-land/

A non-public instrument is the NOx-fund. The fund is based on an agreement between industry-organisations and the Norwegian ministry of climate and environment. Industry can be exempted from the NOx tax, but are in return committed to reducing NOx-emissions in their own operations, and paying into the NOx-fund. The fund in turn, supports measures for reducing NOx-emissions. There are desires from the industry to implement a similar fund or agreement for CO_2-emissions.

For further readings on public funding schemes and programmes, see the below table.

Sector/ area	Research Council of Norway (RCN)	Innovation Norway (IN)	Enova	Other
Road transport	• FME (Research centre for environmentally friendly energy) • ENERGIX (research programme on energy)	• (IN have no support schemes specifically targeting land-based transportation)	• Support for implementation of networks for fast charging of passenger cars • Support for implementation of hydrogen-propelled lorries and hydrogen charging terminals • Support for implementation zero-emission lorries and utility vehicles • Support for demonstration of energy technology • Support for production of biogas and biofuel	
	PILOT-T (no calls so far) PILOT-E (environmentally friendly technology) (second call for tenders)			
Sea transport	• MAROFF programme	• Subsidies for green shipping, targeted towards private and commercial actors	• Subsidies for land-based electricity supply terminals for ships • Support for energy efficiency measures on ships and installation of batteries • Support for on shore electricity • Support for demonstration of energy technology	
	PILOT-E (environmentally friendly technology) (first call for tenders)			
Non-thematic	• BIA (User-driven innovation arena) • SkatteFUNN • SFI (Centre for research-driven innovation) • SFF (Centre for excellent research) • IKTPLUSS (research programme on ICT)	• Environment technology programme • Market loans • Low risk loans • Garanties • Subsidies • Innovation loans/ risk loans • Arena, NCE, GCE (cluster programmes)		

Major public investments supporting the green transition of the transport sector

There are several public investments that aim to support a green transition of the transport sector. These count both broad investments in infrastructure that do not explicitly target the green transition but nevertheless contribute to it, and investments with an expressed goal to develop and implement green transport solutions. Examples of the broad investments are within expansions and upgrades to harbours and the national rail network. For instance, the *National Transport Plan* has announced an 18 billion NOK package for rail-based transport of goods in the next years, and a reduction in fees and taxes for ships with a high ESI-score, used for transport of goods. According to the National Transport Plan, the total reduction in fees and taxes for ships amounted to 90 million NOK in 2016.

The National Transport Plan also contains an announced subsidy programme for transition of land-based to sea-based transportation of goods. The subsidy programme will have an annual budget of 100 million NOK.

In terms of R&D, the Centres for Environment-Friendly Energy Research (**FME**) programme was awarded 190 million NOK in 2016, and the PILOT-E programme has so far been granted 170 million NOK for projects. In addition, research programmes such as ENERGIX, MAROFF, BIA, etc. and several services under **Innovation Norway** receive funding that in part contributes to the green transition within transport.

Enova's fund for energy has so far granted over 1100 million NOK to projects in the transport sector. The grants in 2016 amounted to 823 million NOK. Grants and subsidies within transport include development and introduction of new technologies within biogas, energy-efficiency, charging infrastructure for cars and ships, public transportation (electrical busses), etc. The biogas component amounts to a relatively small share of Enova's grants within transportation. There are also grants for production of biofuels.

Key business strengths and specialisations within green transport

The government's white paper on Norway's future energy policy[43] underscores Norway's competitive advantages in terms of high availability of clean energy and Norway will continue to be a supplier of renewable energy. In addition, there is a high consumption of renewable energy domestically. Several interviewees point out that the availability of low-cost renewable energy is an important supporting factor in the green transition of the Norwegian transport sector. This has led to electricity-based modes of propulsion for personal cars and ferries, but can potentially be harnessed in the production of hydrogen, too. An interviewee contrasts this with the greater emphasis on biofuels in other countries.

Several interviewees also point out the impact of the public support programmes, most notably the RCN, Innovation Norway and Enova. The public agencies and their programmes have made sizeable contributions to development, implementation and commercialisation of new technology and new solutions. Most of the spearheading projects within green transport involve some degree of government funding, for instance the *Green Coastal Shipping Programme* (partially funded by Innovation Norway), the electrical ferry *Ampere* (built under a development contract with the Norwegian Public Roads Administration (**NPRA**)), and a range of projects that have received funding under the *PILOT-E* programme. In addition, the public agencies and authori-

[43] Meld. St 25 (2015-2016) Kraft til endring – Energipolitikken mot 2030

ties reinforce and support the green transition through other means as well. The NPRA is involved as a research partner in the *ELinGO* project that seeks to enable electrification of land-based transport of goods. Other public bodies, such as county administrations and municipalities use the leeway given in public procurement processes to create a demand for low- or zero-emission solutions. As soon as technically feasible, county procurement of ferries is set to demand that ferries with electricity-based propulsion are used. Three Norwegian municipalities are in the process of integrating busses with electrical propulsion in their short distance public transport. One interviewee also points out the importance of Norwegian regulation and a favourable tax scheme for the introduction and subsequent spreading of electrical personal cars in the Norwegian market. According to one interviewee, the effectiveness of the public tax schemes and support schemes is underscored by the fact that the goods transport sector lacks similar incentives and consequently has had little progress towards electrification.

Several interviewees point to the maritime sector as an area with a high potential. The maritime sector has a long tradition in Norwegian business and value creation, and incorporates several R&D-actors and innovative businesses organised within cluster organisations and outside of the clusters. In addition, businesses throughout all parts of the chains of value creation cooperate in developing new solutions. The maritime sector has produced several innovations with relevance for the green transition within the sector. The high concentration of ferries make for suitable platforms for testing out new technology, and the domestic markets for the solutions developed in Norwegian maritime businesses is growing. Consequently, in terms of new technology and green solutions, the Norwegian maritime sector is ahead of the maritime businesses in most other countries, according to several interviewees. Several businesses are looking into solutions based on digitalisation and automation, giving the industry a head start when demand for autonomous and crewless ships arises. Another interviewee underscores the readiness of Norwegian authorities to support innovation in the maritime sector, reinforcing the speed of development and innovation. Nevertheless, there are parts of the maritime branch that are far from becoming completely renewable. According to one interviewee, the fishing industry and other offshore branches are not ready for implementing electrical propulsion yet. LNG and measures for the reduction of emissions are next in line before electrical solutions can be implemented in the future, according to the interviewee.

Several sources also discuss Norwegian climate and geography as an important factor in the green transition. Representatives of the land-based transport sector consider this a main obstacle to electrical propulsion of lorries and busses. Steep hills and low temperatures quickly deplete the vehicles' batteries. On the other hand, the *ELinGO* project states that: "*Norway is significantly well-positioned for development and testing of future solutions for electrification of heavy transport. Solutions developed and tested under demanding conditions in Norway will have good chances of success in international markets*"[44]. The same message is repeated in the transport industry's roadmap towards zero emissions in 2050[45].

Emerging business strengths and growth potentials within green transport

There is a significant growth potential in further spreading electricity-based solutions in both land-based transport and sea-based transport. In sea-based transport, electrical solutions still need to be spread to more near coast ferries, and subsequently, to offshore ships. One interviewee points out the advantages of fast and

[44] Prosjektbeskrivelse ELinGO – ENERGIX; translated from Norwegian by Oxford Research
[45] Veikart for næringslivets transporter – med høy mobilitet mot null utslipp i 2050

high output in electricity-based propulsion as opposed to slower diesel-based engines. This can be used in offshore operations near oil platforms, for instance. The Norwegian transport line along the coast, *Hurtigruten*, is in the process of building two hybrid ships, allowing for electricity-based propulsion of large-size ships during parts of the operation time.

The transport industry sees a potential in hydrogen-based propulsion in the future[46]. Hydrogen may be a good supplement for electricity, especially in long distance transportation, and may be used both in transport of goods and persons on land, and in ships. In addition, hydrogen may replace fossil fuels in construction machines. Oslo municipality are testing hydrogen-propelled busses, and Akershus county have prioritized hydrogen busses in their strategy for zero-emission public transport. However, hydrogen-based solutions require both infrastructure for production and distribution of hydrogen.The production of hydrogen requires high amounts of energy. According to the industry, hydrogen production may therefore be especially interesting in countries with high fluctuations in energy prices, such as Denmark. Nevertheless, there is also Norwegian-based research on the production of hydrogen from natural gas. Furthermore, hydrogen production may be integrated in Norwegian processing industry. **TØI** estimates that when and if fuel cells become competitive, hydrogen-powered vehicles *will* find a place in the Norwegian transport system as a supplement to electrical cars[47].

An overview of key R&D strengths (research fields) and environments (research institutes, test and demonstration facilities) within green transport

Within energy-related R&D, the petroleum sector is still the most important and most funded area of research[48]. The **RCN** differentiates between R&D carried out by businesses, and R&D carried out by academia and specialised research institutions. Within *business* R&D, the main investments are in petroleum and not in transportation or renewable energy. The differences between petroleum and renewable energy in R&D expenditures within the institute sector and the higher education sector, however, are significantly smaller.

The Research Council of Norway concluded in 2013 that R&D by businesses within the transportation sector is at a low level compared to other sectors[49]. Some R&D is procured by businesses, but relatively little R&D is conducted by businesses themselves. Consequently, most R&D is conducted by some of Norway's largest environments for technical and societal research, such as **TØI**, **SINTEF**, **NTNU** and **University College of Molde**. Other research actors specialising in energy research also have research projects with relevance for transportation, such as UiB, IFE, UMB and UiO. IRIS, DNV and the private university college BI are also mentioned. Among the public institutions and agencies, the **NPRA** and the national rail infrastructure agency, **Bane NOR**, are mentioned. Several interviewees commend the Norwegian research institutions for seeking a close relation with the industry, in particular the maritime sector, and contributing to projects with high chances for commercialisation.

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[46] Veikart for næringslivets transporter – med høy mobilitet mot null utslipp i 2050
[47] TØI rapport 1571/2017 Klima- og miljøvennlig transport frem mot 2025 - Vurderinger av mulige teknologiske løsninger for buss, TØI, 2017
[48] Report 2016:37: Social science research on environmentally friendly energy in Norway, NIFU, 2016
[49] Ingen vei utenom – Kunnskapsgrunnlag for transportforskning, Norges forskningsråd, 2013

Transportation research in Norway is in part funded through the RCN's energy research programme ENERGIX and the Maritime offshore operations programme MAROFF, as well as through the SFI and FME-centre schemes. Among the most relevant research environments receiving funding through the FME- and SFI-schemes are FME-MoZEES, focussing on battery and hydrogen technology, FME-Bio4Fuels, SFI-Smart Maritim researching reduced emissions in the maritime sector, and SFI-SAMCoT researching sustainable artic and coastal technology. There is also significant innovation activity in the marine cluster NCE Maritime CleanTech.

Norwegian research actors participate in some EU research programmes. As of 2017, there are 60 projects with Norwegian participation that have been granted funds under *Societal Challenges – Transport*. Transport being among the areas with the highest Norwegian participation. SINTEF and TØI are among the most active institutions. EU-funded research projects with Norwegian participation focus on e.g. maritime transportation and zero-emission ships, rail-based goods transport, dynamic energy storage in car batteries and hydrogen refuelling.

From a Norwegian perspective, the most important thematic areas in green transportation are covered by the existing R&D, except for air travel. One interviewee expresses concern that emission reduction has not progressed correspondingly given the emissions in air travel. The interviewee also points out that R&D in transportation constitutes a small share of public expenditures on transportation and infrastructure.

Examples of good practices on cross-Nordic collaborations within green transport on different levels (business level, research level, policy level)

The Norwegian grocery logistics company **ASKO** has stated the ambition to become climate neutral, in part by using renewable fuels and modes of propulsion in transport. Consequently, ASKO has ordered four hydrogen lorries from Swedish Scania for testing. The project has received funding from Enova. Furthermore, Norway, Iceland, Denmark and Sweden are part of the **The Scandinavian Hydrogen Highway Partnership**, seeking to install refuelling stations for hydrogen, and thus create an infrastructure for hydrogen. The Norwegian industry organisations seek cooperation with their respective sister organisations in Denmark and Sweden, especially in the area of biofuel and in the exchange of experiences from public procurements.

In terms of sea-based transport, upgrading and retrofitting batteries on two ferries operated by **Scandlines**, is an example of Nordic cooperation. Norway-based Plan B Energy Storage (**PBES**) supply the batteries required for the hybrid ferries[50]. PBES have specialised in batteries and industrial scale energy storage. The Finnish ferry operator FinFerries is set to purchase an electrical ferry, based on the Norwegian Ampere ferry. The Norwegian branch of **Siemens** are contracted to deliver steering systems[51]. In the Norwegian *Green Coastal Shipping Programme*, Swedish ABB are among the project partners. Furthermore, Norwegian maritime stakeholders are working to influence international shipping regulations, and are working towards support from Swedish and Danish authorities, with the goal to establish a Nordic cooperation towards the international shipping regulations.

[50] SCANDLINES HELSINGBORG-HELSINGØR - 89 tonn batterier i verdens største el-ferge, Teknisk ukeblad, 21.06.2016

[51] Siemens - Verdens første store batteriferge har gått i et år. Dette blir ferge nummer to, Teknisk ukeblad, 04.03.2016

Furthermore, the *Nordic Marina* project can be mentioned. The project's goal is to contribute to reduced emissions by using alternative fuels in the maritime sector. The project aims to create networks among stakeholders from the Nordic countries, enabling them to exchange ideas and potential projects, and to produce a Nordic roadmap for technological development and further greening of the maritime sector[52].

2.4.1 Potential for increased cross-Nordic collaboration within green transport on different levels (business level, research level, policy level)

In terms of land-based transportation, the industry sees a potential for Norwegian-Swedish collaboration in developing technology and markets for the zero-emission vehicles[53]. This is especially relevant in the production of busses and lorries. For instance, TØI mentions Swedish solutions for integrating electrical motors into rear axles and wheels, enhancing traction uphill and on ice[54]. Furthermore, TØI mentions that Sweden has progressed significantly further than Norway in terms of biofuels, such as HVO and RME. Consequently, there is a potential for cooperation in biofuels for busses. The same argument is echoed by an interviewed industry representative. The interviewee elaborates that Swedish bus and lorry production may play an important part in meeting the demand for low- and zero-emission vehicles in Norway, most notably in municipality procurements. A potential barrier, according to the interviewee, are the variations in technical specifications from the municipalities. Harmonising technical specifications and demands on busses and lorries holds a significant potential for cost reduction and large-scale production.

One interviewee points out the opportunities of importing Danish hydrogen-powered utility vehicles, such as garbage trucks.

The RCN mentions that the Norwegian industry demonstrates a low level of research and innovation activity, making them dependent on research institutions and public financing. This is contrasted by higher levels of research activity in the Swedish industry. The RCN therefore sees a potential for cooperation between Norwegian industry and Swedish industry partners[55]. However, the research environment may have changed since the RCN's assessment of 2013.

The interviewees in the maritime sector see few potential areas of collaboration. The Green Coastal Shipping Programme has experienced some interest from Swedish policy makers, but a Norwegian interviewee points out that the structure and technical solutions in Norwegian and Swedish should be standardised to allow for more industrial cooperation. One interviewee from the maritime industry mentions the potential for collaboration in hydrogen-based propulsion in ships.

The key strengths in Norway, Sweden and Denmark are described as different, but potentially supplementing each other. While Norway's strengths lie in shipping and electrification, Denmark is mentioned for its hydrogen and fuel cell technology, while Sweden seems to be leading in biofuels and manufacturing. Most inter-

[52] The Nordic Bioeconomy Initiative, NordBio. Nordic Council of Ministers, 2017
[53] Veikart for næringslivets transporter – med høy mobilitet mot null utslipp i 2050
[54] TØI rapport 1571/2017 Klima- og miljøvennlig transport frem mot 2025 - Vurderinger av mulige teknologiske løsninger for buss, TØI, 2017
[55] Ingen vei utenom – Kunnskapsgrunnlag for transportforskning, Norges forskningsråd, 2013

viewees describe the other Nordic countries' strengths in terms of industry and research. Businesses such as **ABB** and **Fortum** are important players in the electrification in the transport sector. Furthermore, the Swedish industry for vehicles and lorries is mentioned as a strength. This is underscored by the fact that low- or zero-emission busses and lorries in Norway have been partially or completely produced in Sweden. Several interviewees consider Denmark to be leading in city planning and transportation infrastructure. For instance, TØI mention in their report[56] on low- and zero-emission busses that Danish R&D on fuel cells may contribute to a faster introduction of fuel cells in the markets, including the Norwegian market. The Danish shipping industry is mentioned as well. A strongpoint here is the high availability of capital and opportunities for funding.

[56] TØI rapport 1571/2017 Klima- og miljøvennlig transport frem mot 2025 - Vurderinger av mulige teknologiske løsninger for buss, TØI, 2017

ICELAND

In Iceland, the following interviews have been carried out.

Universities, research and technology organisations:

- **INE** - Icelandic New Energy - CEO Jon Björn Skulason

Cluster organisations, trade/professional organisations:

- **CRI** - Carbon Recycling International - Omar Sigurbjörnsson, CTO
- **Federation of Icelandic Industries** - Bryndis Skuladottir, Head of Clean Tech Consortium
- **Marorka** - COO Svana Bjarnadottir and Technology officer Gunnar Stefansson

Public authorities:

- **Ministry of Environment and Natural Resources** - Director General Hugi Olafsson

A brief overview of the main policy actors and key stakeholders within green transport

The most important policy actor is the **Ministry of Environment and Natural Resources**. We spoke to director general Hugi Olafsson, who has extensive experience in the Ministry but also international experience. He has represented Iceland a number of times in the COP negotiations and have been active in an extensive Nordic cooperation the preparation of and the course of these negotiations.

Other main policy actors are:

- **The Ministry of Transportation**
- **The Icelandic Transport Authoriy**
- **The Ministry of Energy**
- **The National Energy Authority**
- **The Ministry of Industries and Innovation**
- **The City of Reykjavik**

Also, a number of key stakeholdes should be mentioned:

- **The Icelandic Federation of Industries**, who e.a. is managing a present Clean Tech Consortium, which is a public-private consortium
- **The Icelandic Chamber of Commerce**

Existing national objectives, strategies and focus areas regarding green transport

Icelands existing INDC (Intended National Declared Contribution) presently deposited with the UN[57] includes a commitment to be part of a broader European commitment to decrease the total weighed emission of a number of greenhouse gasses with 40 per cent in 2030 measured with 1990 as a base year. Iceland´s con-

[57] http://www4.unfccc.int/ndcregistry/PublishedDocuments/Iceland%20First/INDC-ICELAND.pdf

tribution to the total European commitment has not yet been decided but a government committee is working on this subject and is due to present a proposal before the Althing before the end of 2017.

Iceland is also part of the European Trading System, ETS.

The challenge for Iceland is that almost all electricity production and central heating is already sustainable - as has been so before 1990, which is the bae year for the Kyoto protocol and prospective climate reductions. This means that Icelandic reductions in CHG emissions must be made within the areas of transportation and industrial processes - and Icelands manufacturing sector is heavily dependent on its ability to compete internationally. Iceland will therefore also consider the possibilities of including measures like forestry, wetlands, etc. Also the treatment and use of garbage and waste is included. Nevertheless, as much emphasis will be on transport, whose emissions in most countries have proven to be more difficult to reduce than other sectors emissions, reducing total greenhouse emissions with 40 per cent will be a challenge.

Some municipalities have also ambitious climate plans. The City of Reykjaviks objective is to be CO_2-neutral in 2040[58]. The bulk of reductions necessary to reach this objective will have to be made in transportation. Prospective sub-objectives will be:

- In order to decrease transportation needs and densify the city 90 per cent of all new residential units must be constructed within existing city limits,
- Before 2018, employees of the city will be encouraged to commute in eco-friendly ways to and from job,
- Before 2025, all vehicles owned and used by the city should be CO_2-free,
- In 2030, 12 per cent of all personal transportation in the city should be done with public transportation (buses), and 30 per cent by walking or bicycling,
- By 2030, the number of fossil fuel stations should be halved from the present number
- In 2040, all transportation should be fossil-free, and all fossil fuel stations closed

Existing funding schemes/programmes supporting R&D and innovation projects focusing on the green transition of the transport sector

In the decade leading up to the financial crises after 2007-8 Iceland supported a number of car projects, including electrical cars and hydrogen cars. The financial crises forced Iceland to dismantle these schemes. The Climate Act of 2012 also included provisions to set up funds to support the green transition in a number of sectors, including transportation, but these have not come into effect yet.

In the last two-three years, where Icelands economy has improved, some initiatives have been taken. Hence, Iceland has had a huge increase in the number of electrical cars in the last two years. Measured on a per-capital level, the sale of new electrical cars has been the second-highest in the world, after Norway. The purchase of electrical cars is supported through lower tariffs, but also the establishment of charging stations has

[58]https://www.google.dk/search?dcr=0&source=hp&q=goals+for+carbon-neutrality+and+climate+change+adaptation+reykjavik

been publicly subsidized[59]. There is today 1.500 electrical cars plus more than 2.000 hybrids out of a total stock of a little more than 200.000 cars, as well as approx. 1000 cars on methanol.

In the spring of 2017 Iceland had 15 charging stations - half of these in the Capital area and the rest in other Icelandic cities. A scheme has now been set up with the objective of having 200 charging stations before the end of 2020. The Ministry of Industry and Innovation has established a fund with 200 MISK (1,65 MEUR) to this end. The plan is to establish 30-40 new stations the first year, most of which should be fast-charging. Most of the rest of the stations will not be fast-charging.

The energy company **Orkusalan** announced in October 2016 that it would donate 80 smaller charging stations to smaller Icelandic municipalities.

Last but not least Iceland participate in EU´s Horizon 2020-programme. This has e.g. lead to a renewal of plans to re-introduce hydrogen cars in Iceland, but also to a number of projects carried out by **INE, Græna Orkan** (Green Energy) and others.

Key business strengths and specialisations within green transport

Behind many of Icelands strengths lies the fact that Icelands electricity production is entirely sustainable. 75 per cent of the production is hydroelectric and 25 per cent is geotherminal. Electricy is also relatively cheap seen in an international perspective, however presently on more or less the same level as in the other Nordic countries.

One of Icelands strongholds is the world-known company **CRI - Carbon Recycling Internationa**l. It produces 5 mill liter of methanol annually. In Iceland methonol is not produced as a biofuel, but by combining CO_2 as a byproduct from geothermal processes with water (which is decomposed to oxygen and hydrogen through electrolysis) and electricity. The present plant was finalised in 2011.

CRI´s business model is to run the existing plant while learning from the use of present technologies and selling licenses and turn-key factories worldwide. CRI has 11 employees in Iceland and 29 in sales offices in the rest of the world, including Germany and Asian countries. CRI hopes to be able to build a new plant in Iceland in a number of years with a production capacity more than tenfold the present - which CRI evaluates to be necessary if the plant has to reach the "minimum efficiency size" with the present technologies.

Marorka is a company specialised in providing systems end technologies enabling ships to reduce energy consumption and CO_2 emissions significantly through better ship design, better route planning, better use of machines and equipment on board and better combinations of different motors and energy sources. Marorka provides its customers with data-driven energy management and operational performance. Marorka in other words provides CO_2-efficient solutions to the marine sector through a holistic approach to energy use on ships. Marorka was established in 2002 and has today 38 employees in Iceland and 10 employees in Germany,

[59] Johannes Kester, Lance Noel, Gerardo de Rubens, Xiao Lin and Benjamin Sovacool, Aarhus University, 2017: Reconsidering the future of electrical vehicles in Iceland

Athens, Singapore and Dubai. 98 per cent of Marorkas turnover is to non-Icelandic costumers. In 2008, Marorka received the Nordic Council Environmental Price for its achievements.

Marorka cooperates with other Nordic environmental frontrunners, esp. Kongstad and Vard in Norway. They also cooperate with the University of Iceland and has received project support from the Icelandic government and from EU´s Horizon 2020-program.

INE - Icelandic New Energy - was founded in 1999 as a spin-off from a research project in the University of Iceland. It has approx. 10 employees. It is owned by **Vistorka**, a public-private development company primarily owned by the **Icelandic New Business Venture Fond**, and by **Daimler, Norsk Hydro** and **Shell.** It was originally established to lead the way to a massive use of hydrogen as a means to store energy from Icelands vast hydroelectric and geothermal resources to be used in the transport sector. I the beginning of the 2000´s a number of hydrogen project were carried out by INE in Iceland. But after the financial crisis in 2007-10 most projects were closed down. In the last years, however, a renewed interest in hydrogen projects has emerged, and **INE** has decided to build 3 hydrogen stations and to expand the present fleet of hydrogen cars from only a few to 30-40. INE has gained significant knowledge and experience in the areas through its projects.

INE has also spread its activities to all kinds of sustainable transport, having a role in the rapid expansion of the number of electrical cars mentioned above.

INE cooperates with other Nordic companies as **NEL Hydrogen** in Norway, its daughter company in in Denmark and Swedish battery manufacturers.

Lastly, it can be mentioned that Iceland has a number of IT-companies specialised in monitoring and controlling systems enabling not only the marine industry, but also land-based industries, to make their energy production much more efficient. One of these is **Klappir**, a Reykjavik-based company with costumers in many countries.

Emerging business strengths and growth potentials within green transport

In the future, Iceland will probably need to keep developing the existing strengths within transport by sea and roads. The interviewees anticipate a further, steep increase in the number of electrical cars, but also methonal-driven cars and hydrogen cars. Many believe that Icelands ample resources of relatively cheap, renewable energy can be used much better than today in providing sustainable solutions for the future - especially in green transport.

Iceland, however, faces a number of difficult choices to make in the area of green transport. Our interviewees think that a "natural" division will be that personal cars will be mostly electrical whereas hydrogen and methanol will be the most used fuel for buses, ferries and trucks. All three modes of energy supply still requires some level of subsidies, but may all also be profitable without subsidies in the near future as technologies improve. Much will depend on the international price level for fossile energy - the more expensive, the more profitable will the development and use of renewable and sustainable technologies be.

An overview of key R&D strengths (research fields) and environments (research institutes, test and demonstration facilities) within green transport

With only few universities, research is naturally more focused and centralised in Iceland than in other countries. But the University of Iceland has a big department for research, education and business cooperation in areas of environment, natural resources and energy. There is also some research in the University of Reykjavik, which has a more technical profile

The University of Iceland has a number of faculties and institutes working with environmental issues, hereunder the Faculty of Civil and Environmental Engineering, the Faculty of Life and Environmental Sciences, the Faculty of Physical Sciences and the Faculty of Electrical and Computer Sciences. There is also a cross-disciplinary Institute for Sustainable Development.

A leading figure is professor Brynhildur Davidsdottir, director of the Department for Environment and Natural Resources. She has been an active researcher in ecological economics and industrial ecology and has chaired a number of government committees dealing with environmental questions.

Examples of good practices on cross-Nordic collaborations within green transport on different levels (business level, research level, policy level)

Icelandic authorities, universities and enterprises have cooperated with Nordic partners in a number of ways and projects through the years. The physical distance, however, as well as limited resources in the last decade has made it necessary for Iceland to prioritise the projects Icelandic partners could participate in.

On the ministerial level, cooperation with the Nordic countries is close - both directly and bilaterally, but also through the Nordic Council of Ministers and through EU programs. In the COP negotiations there has also been a good and fruitful Nordic cooperation in the last decade or more. The Nordic countries have for two years had a common presentation at COP-meetings under the heading New Nordic Climate Solutions, which inter alia showcases low-carbon solutions in transport.

The City of Reykjavik cooperates with the other Nordic capitals. Recently, where focus has been put on urban densification and promotion of bicycling, Reykjavik has looked to Copenhagen for inspiration.

In the promotion of use of electrical cars Iceland has looked to Norway and Oslo for inspiration and industrial partners. **Norsk Hydro** has e.g. participated in a number of projects in Iceland. Also the Swedish battery manufacturer **Varta** has been involved in projects in Iceland.

Norwegian firms have also been natural partners for Icelandic enterprises developing energy-saving solutions for the marine sector.

CRI (Carbon Recycling International) cooperates with **Perstorp** in Sweden (chemical products) and **Serenergy** in Denmark (electrolytical products).

Potential for increased cross-Nordic collaboration within green transport on different levels (business level, research level, policy level)

Nordic cooperation continues to be very important. Iceland has its own strongholds and can therefore contribute with own competences and experience in international projects but is also very dependent on international cooperation. All the technologies used in "greening" transport - except perhaps electrification - still need public subsidies in order to be profitable and is dependent on a continued development of technologies. This requires a continuous flow of projects, experiments and research on an international level.

The interviewees are aware that the existing cooperation projects do not necessarily cover the full spectrum of strengths in the other Nordic countries, and that examples should not be used to generalise too much. But in general Norway is considered leading in maritime technologies and use of electrical cars. Sweden is a Nordic leader in production of vehicles, batteries and biofuels and hydrogen solutions. Finland is a more rare cooperation partner for Icelandic businesses but is also assessed to have a huge potential in biofuels. Denmark is considered to be strong in particular technologies as electrolysis and windpower but also in city planning, traffic planning with a view to intermodality, and bicycling.

FINLAND

In Finland, the following interviews have been carried out.

Universities, research and technology organisations:

- VTT – Nils-Olof Nylund, Professor

Cluster organisations, trade/professional organisations:

- Transport and logistics Federation Skal - Ari Herrala, Specialist

Public authorities:

- Ministry of Environment - Emma Terämä, Research Programme Coordinator
- TEKES - Martti Korkiakoski, Programme Manager

A brief overview of the main policy actors and key stakeholders within green transport

The main policy actors are the **Ministry of Transport and Communications** and institutions under its oversight, which are **Trafi** - Finnish Transport Safety Agency and the Finnish **Transport Agency**. Trafi is responsible for traffic safety concerns, and the Finnish Transport Agency maintains transport infrastructure i.e. roads, railroads, and waterways. **Finavia** is a state-owned company which operates Finnish airports. The ports and harbours are typically run by companies owned by municipalities. These form the framework for Finnish transportation.

The leading Finnish technical universities, **Aalto University** and **Tampere University of Technology**, both have professorships or departments for transportation technology. University of Oulu and Lappeenranta University of Technology have both participated in research projects and consortiums in the field of green and smart transportation. **VTT Technical Research Centre of Finland** is an important player in the field and the leading partner in many research projects. Several other Finnish universities of applied sciences provide education and research in the field of transportation as well. An important example of that is Metropolia University of Applied Sciences, where the department of vehicle technology has been active in developing new concepts for automotive industry, including electrical solutions and new materials making cars lighter and thus more environmentally friendly.

Finland is a host to many business activities in the different fields related to green transportation. A rising industry in the field is biofuels. **Finnish Neste** (oil refining company) is a leading supplier of biodiesel. Other companies in the industry include St1 and UPM.

Finland has a strong presence in maritime industry where green solutions are an important aspect of remaining competitive. Companies like **NAPA** and **Eniram** make optimization solutions for sea vessels. **ABB**, **Wärtsilä**, and **Rolls Royce** produce engines for sea industry.

Several companies in Finland are also working to electrify different types of vehicles, mainly utility vehicles. Examples of that include mining vehicles (**Sandvik**) and buses (**Linkker**). **Visedo** is working to electrify a wide variety of vehicles ranging from ferries to commercial vehicles.

Existing national objectives, strategies and focus areas regarding green transport

The Finnish *Energy and Climate Strategy 2030,* published in 2016, aims to reduce emissions of road transportation by 50 pct. from 2005 levels. This should be done by increasing the amount of electrical or gas-powered cars and by renewing transportation systems. Since the number of electrical cars needed to fulfil this goal is huge, Finland will also need to increase the use of biofuels during the transition period. One of the Finnish government's key projects is bio economy. The project also promotes the use of biofuels. The idea is to use wood as raw material for different kinds of biofuels. In the future, Finland's ambition is that 30 pct. of fuels used should be biofuels. That is also the theoretical maximum, since after that point there will be shortage of suitable raw materials if new ones are not found.

Finland has a smart mobility strategy. The idea is to promote smart solutions in traffic which are also environmentally friendly. The smart mobility strategy has many goals which are in line with green transportation. The plan is to cut CO_2 emissions and promote public transportation, walking, and bicycling. The smart mobility strategy aims to increase the use of data (congestion, weather etc.) for better planning of traffic. That will enable a more efficient use of the transportation capacity. Well operated transport systems need to be internationally compatible which requires international cooperation, for instance in standardization. In the strategy, the main arena for that collaboration is the EU.

Mobility as a Service (**Maas**) is a concept that takes smart mobility a bit further. Maas aims to combine different forms of transportation to provide flexible services to the customer. The final goal of the concept is that less people need to have a personal car, and they can rely on the other means of transportation. Changes in Finnish legislation support that goal by promoting sharing data and opening API's of different service providers' ticketing systems. The idea is that the customer can combine different means of transportation conveniently in one package. The system brings together public transportation, taxis, and car rental. It will also be made possible to combine cargo and passenger traffic in a more flexible way.

Existing funding schemes/programmes supporting R&D and innovation projects focusing on the green transition of the transport sector

VTT's *TransSmart* programme aims to produce efficient transportation services by minimizing both costs and environmental impact (societal aspect) and to develop new business opportunities for Finnish companies in the fields of smart transport, cleantech, and smart cities (e.g. biofuels, electrical vehicles and ICT/ITS). A four-year programme ended this year, but the follow up programme, with a working title **TransDigi,** is already planned. TransDigi will focus on creating a common platform for the public sector, the private sector, and the research sector to cooperate in solving issues of green transportation.

Horizon 2020 is a programme conducted by **Tekes** – the Finnish Funding Agency for Innovation. The programme's goal is smart, green, and integrated transport and its methods include funding innovations aiming to further greener transportation.[60] Tekes' role is crucial in public Finnish R&D funding. Tekes is also running a programme called Artic Seas. Despite its name, the programme is applied more widely for all sea traffic. Traffic is also included in many other current programs like *Smart City*, which has a subprogramme called *Smart Traffic* that aims to develop Mobility as a Service, autonomous vehicles, and electrical traffic.

[60]https://www.tekes.eu/horisontti-2020/yhteiskunnalliset-haasteet/alykas-ymparistoystavallinen-ja-yhdentynyt-liikenne/

Trafi and **Liikennevirasto** have allocations in their budgets for innovation and R&D projects as well because it is considered important for officials to learn what new technologies and solutions mean for safety, regulation, and other issues. Trafi's funding is mainly used as co-funding to enable joint projects between Trafi and Liikenevirasto where each institution requires funding of their own.

In addition to these national and EU programmes, the parties developing green transport may use other funding tools that are suitable even though not specifically created for traffic. A good example is a project run by **Skal**. The final goal is to create a company to operate the information processing to make the transportation as smooth as possible. Furthermore, a tool was developed to measure the carbon footprint of the logistics in the project. *ENPI* was a similar project between Russia and Finland. In the project, actors from both Russia and Finland worked to make the border-crossing smoother and faster. These examples are related to green transport. The interviewees emphasized that smart and smooth traffic is also more environmentally friendly; less idling motors running while the trucks are not moving etc. The smartness also helps to evaluate the greenness of traffic, since it is based on the collection and utilization of data.

Major public investments supporting the green transition of the transport sector

Major public investments in green transportation in Finland have mainly been in rail transport. The investments are used to make transport smoother, to increase the capacity, and to speed up the rail traffic to make it more competitive compared to other means of transportation.

In Helsinki region, there are two major rail investments. The first, already operational, is the rail connection from Helsinki airport to the city centre. That connection is intended to replace bus traffic between the city and the airport and to decrease congestion. The other major investment is the extension of the metro from Helsinki to Espoo, which is the second largest city in Finland and a part of the Helsinki region. The completion of the metro has been delayed for several years and it should have been running in autumn 2017.

A third investment in the planning phases is a fast tram connection between Helsinki and Espoo to increase the capacity of the current fairway. In Tampere region, the first tram line is under construction.

The city rail connections are electrical which reduces CO_2-emissions. They also enable an increase in population density. When population is living closer to each other, there is less need for transportation. On the other hand, that raises air quality issues like amount of microparticles in the air. There is some evidence that in conditions like in Finland, tram traffic may be harmful for air quality.

Major investments in rail connections between cities include laying a double track between the cities Seinäjoki and Oulu. That is a part of the railroad connection from Helsinki through Oulu up to Lapland. That is the busiest railroad connection in Finland and the single track was creating delays and other issues. The rail connections compete with air traffic, especially between Helsinki and Oulu.

Smaller investments include subsidies for charging infrastructure for electrical cars. 30 million euros have been spent in the last five years on such subsidies. There have also been investments in improving bicycling and walking conditions in many city regions. The Finnish government is looking for avenues of the cooperation with municipalities to further promote those investments.

Key business strengths and specializations within green transport

Finland has a strong biofuel sector with many large companies (**Neste**, **ST1**, **UPM**). The Chinese Kaidi is planning a huge investment in biofuels in Finland. Neste is one of the leading companies in the world in biofuels and it can produce biofuel profitably (based on green policies globally). Neste is collaborating with US Navy and it is developing biofuels for air traffic. Even if electricity replaces fuel in cars, it is likely that air traffic will need liquid fuels in the future as well.

Finland has a very strong presence in many kinds of utility vehicles. In that field, Finnish companies are developing both fully electrical and hybrid solutions. These vehicles are for instance cranes (**Konecranes**, **Cargotec**) and mining vehicles (**Sandvik**). These companies are already well established in their market segments and they are in a good position to promote their innovations in the global markets. Besides those, **Bombardier Recreational Products** has produced prototypes of hybrid snow mobiles and ATVs. Those are not in production but the know-how to produce them is in place in Finland.

Examples of new companies are **Linkker** that produces electrical buses and **Visedo**, which produces hybrid and electrical propulsion for marine vessels and commercial vehicles. They are both growth companies.

More generally, Finland has a wide expertise in electrical engines and frequency converters that are used in the drives. **Danfoss** and **ABB** both produce and develop their solutions in Finland. The production has a long history and now these technologies are also used in traffic solutions.

Finland has strong expertise in electrical charging technologies. Even though the market penetration of electrical cars in Finland is low, Finnish companies have been successful in developing technologies and infrastructure for charging e-cars. Finnish companies like **Liikennevirta** and **Fortum** are expanding their e-car networks globally.

The maritime industry is a strongpoint of Finnish industry. Environmental responsibility is an important competitive factor for the whole industry. Optimization of fuel consumption is one aspect of that where the Finnish companies are global leaders. Efficient ship engines are also a big industry in Finland. Since Finland has a long history in cruise ship building, Finnish companies have developed methods for waste water treatment and many other systems to make sea traffic cleaner. A new avenue for innovation is the test region for unmanned ships in Finland. Without crews, ships can carry more cargo improving efficiency. There are also plenty of companies making hybrid solution for maritime industry like **Visedo**, **Danfoss**, **Protacon** and **Rauma Marine Construction**.

Actors in the logistics sector found that a strength of the Finnish market is that bigger trucks are allowed in Finland than in many other countries. Bigger trucks can take more cargo and that means less traffic. That is a core strength for Finnish logistics sector and it is in the process of being developed even further.

Emerging business strengths and growth potentials within green transport

The most interesting emerging field in green transportation is the combination of ICT and transport. Due to downsizing in the mobile phone industry, there has been plenty of ICT workers and companies that have expanded to new market segments including transport.

The two most relevant trends in the field for Finland are mobility as a service (Maas) and autonomous vehicles.

Maas is a part of Finnish transportation policy. The idea is to combine different forms of transportation to one package so a combination of forms of transportation can be bought in one ticket. There are globally similar solutions but they typically combine only public transportation like buses and trains. In Maas, the plan is to take it a step further and bring in taxis and car rental as well. In principle, carpooling or similar systems could be included.

The environmentally beneficial consequences of a successful Maas system are a reduction of personal car usage and ownership.

There are two start-ups in that field: Maas Global that provides Whim application and Tuup. Maas Global has attracted VC investment of 14 million euros and the Whim application is in pilot use in many cities including Helsinki. Tuup has extended its services to the US. In general, both companies are in the start-up phase, scaling up their services.

Another important emerging technology is autonomous vehicles. Finland has a strong position in utility vehicles and the same companies that are developing hybrid solution are typically also developing autonomous vehicles – that includes cranes, mining machinery and forklifts. The new opening in the field is autonomous sea vessels which are developed by **Rolls Royce**. A test region for unmanned ships has recently been opened in Finland.

Finland has strong expertise in AI and machine learning. Both of those technologies could be utilized more in transportation. Autonomous vehicles are a good example of the application of novel ICT solutions, but there are numerous other opportunities as well.

In general, autonomous vehicles are in used in closed regions like warehouses, ports, mines, and airports. There are many pilot programs where robot buses are used for short routes. There are several different actors running new pilot projects, like the robot buses at Helsinki airport.

5G mobile technology is important for Finland since **Nokia** has managed to remain strong in network technologies. This technology is believed to revolutionize smart transport since it allows for better connectivity between vehicles, infrastructure etc. So far 5G technologies are in test use and there are many test beds for that in Finland. One application of 5G is platoon – the idea that trucks drive in queue and in the future, it could be that only the first one needs a driver. That could be a step toward autonomous vehicles in road traffic as well.

Smart traffic requires utilization of many kinds of data and creating applications based on that data. Finnish Meteorological Institute has been active in creating new applications for transportation and providing its data openly, enabling different application based on that. There are similar processes to provide real time information for transportation making traffic faster, smoother and safer. The data used includes locations of construction zones, traffic jams, accident etc.

An overview of key R&D strengths (research fields) and environments (research institutes, test and demonstration facilities) within green transport

Finland has many R&D strengths in green transportation. Even if not solely focused on traffic, many Finnish R&D sectors can support research in green transportation in many forms.

Finland has a long history in both machinery and ICT, both of which are cornerstones of the Finnish economy. Since the collapse of the mobile phone industry, Finnish companies and professionals have had to find new fields to utilize their expertise, traffic being one of those fields. That has contributed to the rise of smart traffic and Nokia itself is expanding into traffic business, especially in utilization of 5G in smart traffic. ICT is a strong field in each Finnish technical university or faculty (Aalto University, Tampere University of Technology, Lappeenranta University of Technology and University of Oulu).

Utility vehicles and ship building are a speciality of the Finnish machine industry. Both of those have expanded to create both hybrid solutions and autonomous technologies. Greenness and energy efficiency have always been a part of the competitiveness of those industries and thus R&D efforts have been focused on those issues. Environmental technology is studied in some form in all Finnish technical universities.

VTT Technical Research Centre of Finland is a key player in Finnish transport R&D. It leads several consortiums in the field of green transportation. It combines Finnish expertise in biofuels, electrical and hybrid vessels and smart traffic.

The strength of Finland is that it has a wide variety of different test beds and demonstration facilities in the field of transportation. There are test fields for different autonomous vehicles such as utility vehicles, sea vessels, and drones. Finland also has a test bed for 5G smart traffic. Finland also has many testing facilities for arctic conditions. Those facilities are especially used by tyre manufacturers but also for other purposes.

There are both private and public test facilities. In general, Finnish legislation has been relatively flexible enabling new opportunities like the test region for unmanned ships or allowing the use of the drones out of the pilot's sight.

Examples of good practices on cross-Nordic collaborations within green transport on different levels (business level, research level, policy level)

On the business level, the most important aspect is that the leading companies in the field are often international companies. That means that they may have facilities in many Nordic countries. Companies like **ABB**, **Danfoss** and **Sandvik** are Nordic companies that have facilities in Finland. For many Finnish companies, Nordic countries are the starting point for international expansion, like **Fortum** building their electrical car charging infrastructure in other Nordic countries. **Linkker** has been successful at selling their electrical buses to Copenhagen as well. Finland and Sweden both allow bigger trucks than most European countries. The manufacturers of those trucks are Swedish **Volvo** and **Scania**.

On research level, Nordic actors are in the same research consortiums and there has been, to some extent, Nordic funding for such projects. An example of a Nordic collaboration project is *Nordic Way*, which generates mobile data about accidents etc. The project brings together transport officials from Finland, Sweden,

Norway, and Denmark. **VTT** has strong knowhow in many fields of green transportation and for that reason it is a partner in many Nordic projects.

Finnish **Aurora** is an artic testing ecosystem for smart transport and automated driving in Finnish Lapland. It is operated by Trafi. That test region is expanded with the Norwegian Borealis test region. That is a good example of a border-crossing project.

On policy level, there is an open dialogue between the Nordic countries. Partly because of the EU, Nordic cooperation is not particularly common when most of the decision are made at the EU level. There are few examples of Nordic co-operation however. The present Finnish Minister of Transport and Communication, Anne Berner, is also responsible for Nordic cooperation. She has organized a joint meeting for Nordic traffic and energy ministries to reduce the CO_2 emission.

Potential for increased cross-Nordic collaboration within green transport on different levels (business level, research level, policy level)

Potential exists within bigger and more capital-intensive aspects of green transportation. For example, developing and implementing more environmentally friendly wood-based biofuels and building infrastructure for greener transportation (like electrical cars) together. It is important that the infrastructure of bordering countries should be coordinated for seamless flow of traffic.

In logistics, there would be a need to be the same standards for vehicles in all countries. That means, for instance, the size of the vehicle. That is also a field for collaboration in the EU since truck sizes are bigger in Nordics than in most of the EU. Those standards can be promoted also in EU.

Finland, Norway, and Sweden have somewhat similar climate and similarly sparsely populated areas, though each country has its own characteristics. That is a challenge for green transportation in many ways. Rail connections are challenging to build, public transportation is difficult to organize, and it is expensive to build infrastructure for e-cars etc. For that reason, it is important to share best practises in remote location traffic solutions and find out how environmental friendliness can be promoted in these conditions.

Nordic counties share also similar climates. There are already different kinds of test facilities in Nordic countries. Those are typically competing against each other. There is also potential to create an international, cross-border test region. Currently the test regions are limited regions, at most city-wide.

Smart transportation and ICT-solutions are created in smaller units and are less capital intensive so it's not a very fruitful area for increased cooperation. There is some potential here because some parts of digitalization require cooperation. Examples of that is the data flows related to logistics. There's still actual paper work in logistics. A shared standard is required for the adoption of paperless sharing of information.

New concepts like Mobility as a service and sharing economy require critical mass. There is potential for Nordic cooperation in developing **Maas**. The concept could be extended to other Nordic countries to accelerate the development and to create critical mass. A parallel could be drawn between this and when NMT and GSM standards were created for mobile phone industry. When NMT was launched, the Nordic countries

were the biggest region using the same mobile phone standard. The same feat could be repeated in Maas services creating shared standards for the Nordic countries.

Each Nordic country has their own strengths and policies, which are only partly overlapping. The strength of the Nordic countries is that they take environmental issues seriously and they are willing to invest in green transportation systems. The public infrastructure is in good condition and generally green energy solutions are favoured. For instance, electricity is produced in many of Nordic countries through renewable ways making electrical transportation genuinely green.

The Nordic countries have also high level of knowhow in technology and engineering which is utilized or can be utilized in green transportation. The industry structures, and for that reason the focuses of green transportation, vary from country to country but that can make the countries complementary to each other. For instance, Sweden has a strong car industry, Norway has a significant energy sector, Finland has expertise in smart solutions etc.

All Nordic countries have had to develop their transportation systems to be weather-proof, meaning that the solutions made there will work in the rest of the world as well.

DENMARK

In Denmark, the following interviews have been carried out.

Universities, research and technology organisations:

- Technological Institute – Lars Overgaard, Programme Director

Cluster organisations, trade/professional organisations:

- **CONCITO** – Henrik Gudmundsson, Senior Consultant
- **Confederation of Danish Industries** (DI Transport) – Michael Svane, Director
- **The Transport Innovation Network** – Mikkel Hansen, Director

Public authorities:

- **Ministry of Energy, Utilities and Climate** – Lisa Bjergbakke, Chief of Departement
- **Road Safety Authority** – Jesper Høgh Bach, Head of Office
- **Capital Region's Secretariat for Green Transport** – Kaare Albrectsen, Chief of Departement
- **Municipality of Copenhagen** – Jørgen Abildgaard, Chief of Climate

A brief overview of the main policy actors and key stakeholders within green transport

The main policy actors in Denmark are:

The Ministry of Transport, Building and Housing is the main governmental policy actor in Denmark on transport. The ministry is involved in the policy formulation, management of the ministerial area, strategic planning and the drafting of laws. The main responsibility of the Ministry of Transport, Building, and Housing within transport is the following areas: Transport, roads, vehicles, railways, rapid transit systems (e.g. the Copenhagen metro), fixed links, harbours, ferry operations, aviation, airports and postal services. The Ministry at large consists of a department, several executive agencies and state-owned companies.

Issues related to maritime transport are under the responsibility of **The Danish Maritime Authority** – a part of the Ministry of Industry, Business and Financial Affairs. The Danish Maritime Authority contributes to the work of the Ministry of the Environment and the Ministry of Energy, Utilities and Climate in the maritime field on the environmental and climate issues.

The Ministry of Energy, Utilities and Climate is also a key policy actor, as the ministry is responsible for implementing the governmental climate policy and sets the Danish emission standards. Thus, the ministry is indirectly involved in the green transition of the transport.

Besides these governmental actors, on the regional/local level the Danish regions are responsible for the regional busses and local traffic by investing in initiatives that can create a more energy efficient public transport system. The Danish municipalities are in varying degrees active in creating the conditions for promoting the use of green transport by investing in new infrastructure and projects.

Key stakeholders in Denmark include business organisations (e.g. the Confederation of the Danish Industry that has a transport division, cluster organisations (e.g. CLEAN, The Transport Innovation Network), think tanks and different interest groups (e.g. CONCITO).

Existing national objectives, strategies and focus areas regarding green transport

Denmark has ambitions of complete carbon neutrality (including transport) by 2050. Denmark has in accordance with other EU Member States an objective that 10 pct. of the transport sector's energy consumption in 2020 should come from renewable energy. In 2015, renewable energy sources made up 6,67 pct. of the energy consumption in the Danish transport sector. This is close to the average EU level of 6,71 pct.[61] Renewable energy constitute more than 20 pct. of the energy consumption in the transport sector in comparable countries like Sweden and Finland.

Denmark applies high vehicle taxation rates on cars compared to global and EU averages. These measures explain why personal vehicle ownership in Denmark (this is also the case in Norway) is low compared with countries of comparable per capita income. Earlier, a registration tax reduction was in place for energy-efficient cars, but this tax advantage was phased out in 2016. In spring of 2017, a broad coalition decided to reintroduce the tax reduction on electrical vehicles by cutting the registration tax by 80 pct., while hydrogen-powered vehicles have been entirely exempted from registration taxes. However, the tax reduction is meant to be phased out over time. Another central policy change is the weight tax continuously paid throughout the lifetime of the car, which is no longer based on the size of the car, but its carbon emission. As pointed out by a few interviewees, tax instruments have an impact on the Danish purchase of electrical vehicles.

The Danish government continuously supports the development of alternative energy sources. Approx. 1.3 million Euros have been reserved for further research into hydrogen-powered vehicles and a pilot plant for production of biofuels has largely been funded by the national EUDP programme alongside the EU's Horizon 2020 programme.

Existing funding schemes/programmes supporting R&D and innovation projects focusing on the green transition of the transport sector

On the state level:

Innovation Fund Denmark supports projects within a broad range of thematic areas and different sectors, including transport and infrastructure. In 2017, a budget of DKK 1,291 billion has been allocated to the fund.

Energy Technology Development and Demonstration Programme (EUDP) supports the development and demonstration of innovative energy technologies. The aim is to promote the efficient use of energy and help to make Denmark independent of fossil fuels by 2050. From 2016, EUDP has had a targeted action regarding development and demonstration projects on energy efficient transport.

[61] EUROSTAT – Renewable Energy Statistics

The Cycling Fund administered by The Danish Road Directorate has a subsidy scheme of DKK 1 billion. The goal of the Cycling Fund is to facilitate projects that can improve conditions for cyclists so that the bicycle becomes a more attractive, widespread, and safe form of transport for both commuting and leisure all over the country. The national government can thereby stimulate and support local initiatives through the subsidy scheme. The fund has also fostered long term strategies and financing of cycle projects. There has been a huge interest for the scheme; more than 1.000 applications have been submitted and 340 different cycling projects have been co-funded by the scheme.

On the regional/local level:

Regional partnerships. These partnerships focus on promoting electrical vehicles – one is placed in Western Denmark (Elbilpartnerskabet Vestdanmark) and one in the Capital Region (Hovedstadsregionens Elbilpartnerskab). The idea behind these partnerships is to support the municipalities' efforts in increasing the total number and use of electrical cars in Denmark. The municipalities generally lack an overall strategy on electrical vehicles which result in few or no electrical cars, but the binding partnerships can support the municipalities by subsidising the municipalities with nearly 15.000 DKK for a purchased electrical car.

Secretariat for Green Transport (Capital Region). The Capital Region aims to be the most sustainable region in Denmark. The Secretariat for Green Transport works to eliminate the use of fossil fuels in transport by 2050. More specifically, the region invests in low-emission busses, parking and charging stations for electrical vehicles, super bike paths and campaigns encouraging people to bike to work.

Municipality of Copenhagen. In realising its aim to become CO_2 neutral by 2025, the municipality of Copenhagen focuses on transport. Today, 68 pct. of all commutes within the municipality happen by walking, biking or using public means of transportation – a share not matched by any other city and not far from the 75 pct. objective. 85 pct. of the municipality's own passenger cars are electrical and sustainable heavy vehicles are on the way.

Major public investments supporting the green transition of the transport sector

The Fehmarn Belt fixed link. With the new fixed link across the Fehmarn Belt, freight between Hamburg and Copenhagen can be rerouted to the Fehmarn Belt fixed link instead of the current route via Flensburg, across Jutland and the Great Belt Link. The shorter distance of the Fehmarn Belt corridor will reduce transport time, reduce costs and decrease the environmental impact. In addition, the implementation of the ERTMS signalling system will further increase the efficiency and safety of the transport corridor. Consequently, air pollution, noise pollution and climate impact will be reduced considerably. The main contribution to these reductions will come from the termination of the ferry services between Rødby Harbor and Puttgarden. Calculations show that CO_2 emissions will be reduced by 220,000 tonnes annually, which is equivalent to the amount of CO_2 currently emitted by approximately 20,000 persons a year[62].

The Cycling Fund. The Fund has stimulated investments of more than DKK 2 billion on cycle-promotion as the Cycling Fund covers 40 pct. of the total project costs. With support from the fund, the municipalities

[62] Ministry of Transport (2015): A Greener Transport System in Denmark

can make long-term planning and thereby facilitate the integration of new initiatives in planned projects in relation to the strategy[63].

Additionally, a number of projects have been initiated on the regional and local level. Examples include:

New Urban e-Mobility Bycyklen. The world's first electrical smart bike-share system. A combination of state-of-the-art mobility, touchscreen-computing and GPS navigation. Bycyklen is the "fourth leg" in the public transport, which complements the already extensive infrastructure in Copenhagen, allowing users to travel by rail, metro and bus hassle-free. Most of the Bycyklen stations are located close to a train, metro or bus station to facilitate easy use and journey integration. Through a partnership with City of Copenhagen, Frederiksberg and DSB, Bycyklen has been able to implement a solution designed to suit different types of users with a flexible pricing model dependent on the type of use, through an easy-to-use solution.

Køge Nord Station. In Køge, south of Copenhagen, Banedanmark, Køge Municipality, and DSB are building Køge Nord Station. The station will be a new gateway to Copenhagen for the more than 100,000 people passing through the area daily, and a significant step on the commute for the expected 8,000 daily users of Køge Nord Station. The station is a part of a new electrified high speed railway line running from Copenhagen to Ringsted via Køge. The line will contribute significantly to meeting the transport requirements of the future by significantly improving the timetable with more frequent departures and by reducing the travel time to and from Copenhagen considerably.

The public owned bus company Movia is focusing on the green transition. Movia has facilitated tests with new technology and green solutions for busses for many years. The knowledge gained through tests is shared with the private operators, enabling them to offer environmentally sound solutions at a more reasonable price than otherwise possible. Many of the tested technologies are in operation today, e.g. numerous lightweight busses, eco-driving and busses using CO_2 free slaughterhouse waste. In the past five years, Movia has commenced tests with hybrid busses, gas busses, lightweight busses, midi-busses, eco-driving etc.

Key business strengths and specialisations within green transport

According to the interviewees and desk research, Denmark only holds a few comparative business strengths and specialisations concerning technologies within green transport. Among these are technologies used in hydrogen cars, i.e. electrolysis, where Haldor Topsøe is a strong player. With 10 hydrogen stations, Denmark has the world's first country-wide hydrogen network

An interviewee describes the Danish approach as a 'soft' approach to green transition of the transport sector, i.e. in Denmark the emphasis is to a lesser extent on technological innovations but more on changing the mindset and approach to green transition.

Broadly, the Danish strength within smart city solutions is assessed to be a core Danish business strength. It stems from a Danish focus and strength in city planning and infrastructure. In Denmark, several innovative and state-of-the-art projects focusing on smart city have been implemented. An example is *CITS* (Copenha-

[63] State of Green (2016): Sustainable Urban Transportation

gen Intelligent Traffic Solutions) - a smart city project to improve traffic flow, reduce emissions and increase safety for the citizens by using big data. The objective is to enable city officials to both monitor traffic conditions in real-time and run a variety of simulations. The CITS platform draws data from a network of wifi access points that have the capability of geo-locating wifi enabled devices on the streets without compromising privacy. The data is aggregated, anonymised and then fed back into a cloud based software dashboard. The dashboard can help categorise traffic, look for patterns and identify long term behavioural tendencies amongst the road users. The system makes it possible to plan and test new traffic scenarios for city planners, build cause-effect relationship, optimise traffic light timings and much more.

As a part of the smart city concept, building a city infrastructure promoting cycling is assessed as a distinctive Danish strength attracting global attention. The term 'Copenhagenization' is used to describe a design strategy in which urban planning and design are centred on making a city more accessible to bicyclists and pedestrians, and less car dependent. Denmark is one of the leading nations in the world for bicyclists, and 95 pct. of the Danish population own a bicycle[64]. According to a report by WHO Europe[65], the share of bicycles in Copenhagen in transportation is 26 pct., which is the second highest in Europe after Amsterdam (33 pct.).

Historically, Denmark has a very limited vehicle manufacturing industry. Consequently, the greater part of technological innovation in vehicles etc. will take place outside Denmark. However, new transport technologies such as electrical cars and bicycles, unmanned vehicles, drones etc. provide an opportunity to address associated issues relating to e.g. the roll-out and design of infrastructure, market penetration and the consequences for the population's transport patterns and the total traffic load, which are relevant to the Danish strengths within transportation. A few interviewees point out that Denmark has a stronghold concerning the development and commercialisation of battery technology for electrical vehicles. An example is the Danish company **Lithium Balance** that develops battery management systems that are necessary for establishing a secure and reliable use of Li-ion-batteries and establish an interface of external systems, including chargers, data displays etc.

Some interviewees emphasise that Denmark has a strong maritime sector and is an industrial leader on a global scale due to a strong tradition of shipping activities maritime transport logistics, but has also built up a strong position within advanced maritime technologies. The green transition of the maritime sector is mostly focused on technologies that improve the energy efficiency of transport. There is however a new electrical ferry on the as a part of the E-ferry project supported by Horizon 2020. The project involves the design, building and demonstration of a fully electrical powered 'green' ferry which can sail without polluting and CO_2 emissions. The E-ferry is planned to be in operation between Søby-Fynshav and Søby-Faaborg.

Emerging business strengths and growth potentials within green transport

In the future, Denmark is expected to nurture the existing business strengths within green transport. Smart city is assessed to become an area with a huge global growth potential, where Copenhagen and Aarhus are highlighted as role models.

[64] The Danish Ministry of Transport (2012): The Danish Transport System – Facts and Figures
[65] WHO Europe (2014): Unlocking new opportunities

A further development of electrification is also expected, but as tax advantages on electrical vehicles were reduced in 2016, purchase of electrical vehicles in Denmark slowed down. The recent reintroduction of the tax break is expected to positively impact sales. Hydrogen-powered transport is assessed as an emerging business strength with a considerable growth potential in Denmark. Commercial development of hydrogen-powered transport is assessed to have a long-term prospects, and assessing hydrogen-powered transport as a Danish business strength is currently difficult. A range of companies are relevant to hydrogen-powered transport such as **Dantherm Power**, **H2Logic**, **IRD A/S**, **Serenergy A/S** and **Topsoe Fuel Cell**[66].

Denmark also shows some initiative inside the field of biofuels. Today, all petrol sold in Denmark is added 5 pct. of biofuel and 0.9 pct. sustainably produced advanced biofuels – double of what it takes to comply with EU regulation.

An overview of key R&D strengths (research fields) and environments (research institutes, test and demonstration facilities) within green transport

The main Danish R&D actors within green transport among universities area assessed to be the Danish Technological University (**DTU**), Aalborg University (**AAU**) and Copenhagen Business School (**CBS**).

DTU has several R&D strengths and specialisations within transport. DTU Transport is the main department at DTU within transport research focusing mainly on traffic and transport planning. A core research area for DTU Transport is transport behavioural studies and how policies influence behaviour. The department DTU Management Engineering has research capabilities within operation analysis of the transport sector.

At AAU, the Division of Transportation Engineering has established a Traffic Research Group (TRG) consisting of experts within traffic and roads. TRG primarily works with traffic planning and traffic management, Intelligent Transport Systems (ITS), road safety, public transportation in built-up and rural areas.

CBS is specialised in city logistics at the Department of Operations Management and has specific focus on maritime research at CBS Maritime.

Other relevant research actors include the research and technology company **Technological Institute** that has an expertise within areas such as electrical transport, lean logistics, logistics analyses, transport analyses etc. Also **FORCE Technology** has experience and specialised competences in the transport sector, including condition assessment and corrosion monitoring, testing and analysis of materials, emissions measurement, calibration, certification and authorisations.

In the interviews, it is pointed out that Denmark has a cooperative culture and tradition of collaboration between research institutes, authorities and businesses. **The Innovation Fund Denmark** has supported a range projects focusing on the interaction between academia, public sector and private companies such as the research project SUSTAIN supported with a budget of 15,8 million DKK. The project involves partners from academia (Technical University of Denmark, Copenhagen Business School, Oxford University etc.), public authorities (The Danish Road Directorate, The Danish Ministry of Transport, Building and Housing)

[66] Damvad (2014) - Analyse af erhvervsmæssige potentialer ved grøn omstilling af transportsektoren

and private companies (COWI). The focus of the project is to adopt an approach to the study of strategic transport planning that is rooted in cross-disciplinary sustainability research. This approach recognizes that transition towards sustainability is a process that must involve three dimensions: a normative dimension (referring to the underlying value orientations operationalised through sustainability principles, goals, and indicators), an analytic dimension (addressing the 'objective' conditions for sustainability versus non-sustainability using scientific evidence, models, and other tools), and a strategic dimension (referring to actor strategies and organisational change).

Examples of good practices on cross-Nordic collaborations within green transport on different levels (business level, research level, policy level)

Below are examples of good practices on cross-Nordic collaborations:

NISA (Nordic Initiative for Sustainable Aviation): NISA is an active Nordic association working to promote and develop a more sustainable aviation industry, with a specific focus on alternative sustainable fuels for the aviation sector. Nordic stakeholders within the aviation sector have joined forces to form the association NISA, in order to realise the development of new sustainable aviation fuels. The association is established to work with biofuels issues on behalf of the aviation sector in the Nordic region.

The Scandinavian Hydrogen Highway Partnership: The Scandinavian Hydrogen Highway Partnership (SHHP) consists of regional clusters involving major and small industries, research institutions, and local, regional and national authorities. The national networking bodies – Norsk Hydrogenforum in Norway, Hydrogen Sweden in Sweden and Hydrogen Link in Denmark – act as SHHP coordinators.

The SHIFT project: Shift is led by IVL Swedish Environmental Research Institute and researchers from DTU Technical University of Denmark, TOI Institute of Transport Economics and Viktoria Swedish ICT. Shift will develop and apply tools that integrate poorly understood factors – modal shifts, fuel options, new business models and consumer behaviour – into scenario modelling, and carry out in-depth analysis of two key areas: long-haul freight and urban passenger transport.

The GREAT project: Great hosts a combination of private companies and regional authorities. The lead partner in the project is Region Skåne that in turn is supported through Partnership Agreements by the Supporting Partners. These partners are E.ON Sverige AB, E.ON Denmark A/S, E.ON Biofor AB, Fordonsgas AB, Nissan Europe, Renault, DTU.

Potential for increased cross-Nordic collaboration within green transport on different levels (business level, research level, policy level)

All interviewees see a clear potential for increased cross-Nordic collaboration within green transport. One interviewee sees that there is a potential for increasing mutual learning from research projects and policy making between the Nordic countries, as he believes that there is a range of interesting projects in the Nordics that are not shared. Also, the potential for taking advantage of the research and business strengths in the different Nordic countries and initiate larger scale and more capital intensive projects is seen as a potential focus area.

Generally, there is an awareness among the interviewees of the key strengths in the other Nordic countries within green transport. Based on the interviews, the self-image in Denmark is that Denmark has a 'soft' approach to the green transition of transport focusing on city planning and integration of different transport modes. In Sweden and Finland, biofuels are assessed as a key strength, while Norway is used as an example of a country in the lead concerning electrification. The knowledge of Iceland is lower, but one interviewee points out Iceland's focus and projects related to hydrogen.

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