Synthesis report of Flagship II:
Environmentally friendly transport.

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Abstract in Norwegian:

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Syntese rapport Flaggskip II: Miljøvennlig transport

I denne artikkelen har vi en oppsummering av hva som er gjort av arbeid i Flaggskip II.

I kapittel 1 er det en enkel beskrivelse av hovedtemaer og forskerledere. Kapittel 2 inneholder de viktigste forskningstemaene og resultatene. I appendikset er det en oversikt over publiseringene.

Synthesis report of Flagship II:

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1. Overview

Norway has committed to a 40% reduction of greenhouse gas emissions from the non-ETS sectors by 2030. Transport makes up a major share of Norwegian emissions in the non-ETS. Although there will be flexibility available for the non-ETS sector across the EU members, the Norwegian Parliament has announced that they aim for radical domestic emission cuts in transport.

The sustainability of transport can be improved by the following measures: i) reducing the total amount of traveling, ii) modal shift, e.g. from road to rail, and iii) by introducing new technologies (e.g., electric vehicles and increased fuel efficiency). For policy it is important to obtain the right balance between the measures. It is not only the direct cost of the measures that must be taken into account, but also potential market imperfections and external effects.

Cathrine Hagem

The Flagship is headed by Cathrine Hagem, Statistics Norway, and includes researchers from all the research partners in CREE. The flagship constitutes of four independent projects. In addition, research under some of the other Flagships has relevance for the transport sector. There are also CREE Master Thesis that have given valuable insights into the research questions addressed in this Flagship.

The project *International oil market analyses* developed a dynamic simulation model for the international oil market that is used for analyses of how market conditions and climate and energy policies affect the oil market. The project has especially analyzed effects of fuel efficiency improvements.

The project *Environmentally friendly transport* constructed a simple model to analyze the impact of fiscal policies on emissions from cars. The model was used to generate predictions of the effect of fiscal policies on average CO2 emissions of new cars. The model was thereafter tested empirically. The empirical strategy combined a diverse series of data, including a large database of vehicle-specific taxes in 15 EU countries over 2001-2010.

The focus of the ongoing project *Electrification of transport: Challenges, mechanism and solutions* is the increased entwinement of the transportation system and the electricity market following from the electrification of the car fleet. This calls for improved coordination and collaboration between different policy fields and institutions. The project aims to provide knowledge which is essential for making the right investment decisions in electricity production capacities, in charging technologies, in the grids, and in the market for electric vehicles (EVs), as well as for efficient transportation planning. Some of CREEs userpartners are also co-funding this project.

The ongoing project *Driving towards the low-emission society* (DRIVING) aims to obtain accurate and reliable knowledge on the effects of existing and potential future policies to support the transition to zero- and low-emission automobiles in Norway. The analysis will be based on a novel database assembled from administrative registers encompassing the entire Norwegian population, combining disaggregate information on passenger cars with detailed information about their owners.

In total, we have published around 30 publications on topics covered by this Flagship, including 10 articles in international journals (see appendix).

2. Research questions and main results

The Flagship concentrates on three major themes.

2.1 Electrification of the private road transport and the electricity market

Norway is a pioneer when it comes to electrification of the car fleet. In 2018, 30 % of new cars were zero-emission cars, of which almost all were battery electric cars. Electrification of the car fleet will increase the interdependence between the transport system and the electricity market. This will require new policy measures and improved coordination and collaboration between different policy makers and institutions. The pricing of electric cars charging may have a lot to say for the success and costs of the transition to an electrified car fleet.

EV-friendly transport policies increase the demand for power, thus challenging the distribution grid's capacity, while electricity policies immediately impact on the costs of driving EVs. If enough EV-owning agents charge during power peak hours, costly grid expansions may be needed. In a study we examine how the distribution grid company in Norway can respond in order to mitigate these costs with different pricing schemes and how this in turn affects the

transport equilibrium, see Wangsness et al. (2019). It is found that applying peak tariffs for the grid will help support a better balance between investment costs and EV-owners' disutility of charging during off-peak hours.

The organization of the charging market may be crucial for the market diffusion of electric cars. In a CREE study we show that a charging network with incompatible high-speed charging systems will unambiguously imply slower phase-in than a network in which all cars are compatible with all charging stations, see Greaker (2019).

Electric vehicles are dependent on electricity supply from the grid, and they will increase total electricity demand. On the other hand, bidirectional chargers (Vehicle-to-grid, V2G) imply that EVs may also store and supply electricity to the grid. This can smooth out daily variability in demand and supply of electricity from other sources. The larger battery, the larger possibility to store and supply electricity from the EV. Moreover, the EV can also help balancing the grid by supplying quick power when there is a local imbalance. In CREE we have address the following research question: what is the impact of V2G on the electricity market, see Hagem et al. (2019)? To answer this question, we integrate a model of EV users' choice of battery capacity with a simple model of the electricity market. We show how consumers' optimal battery capacity choices affect the equilibrium electricity prices during peak and off-peak hours, and optimal investments in power plants. One finding is that viable V2G solutions increase welfare as the need for investment in backup power capacity decreases.

2.2 Policy instruments for promoting sustainable private and commercial transport

Over the past years, many countries have been greening the car fleet through revisions of purchase taxes, road taxes, or by special privileges for low emission car owners.

In CREE we have exploit the variation in the stringency of vehicle fiscal policies across EU countries and time to address the following research question: to what extent have national fiscal policies contributed to the decarbonization of newly sold passenger cars, see Gerlagh et al. (2018)? The study is based on a data set of vehicle-specific taxes across 15 countries over the years 2001–2010. The study finds empirical evidence that fiscal vehicle policies significantly affect emission intensities of new bought cars. There is evidence that especially the CO2-sensitivity of registration taxes and the level of the fuel taxes are important determinants of the emission intensity of new cars. The diesel–petrol substitution induced by changes in relative taxes for diesel

versus petrol cars is an important factor for the average fleet's fuel efficiency. The study also finds higher CO2-intensities with increasing income and a clear convergence pattern between EU countries.

In CREE we have also studied the implication of the Norwegian reform for vehicle registration tax in 2007. The results show that average CO2 intensity of new vehicles was reduced in the year of the implementation of the reform by about 7.5 g of CO2/km. This reduction is the result of a 12 percentage points drop in the share of highly polluting cars and of an increase of about 20 percentage points in the market share of diesel cars, see Ciccone (2014).

A tax on fuel is implemented in many countries to reduce both greenhouse gas emissions and other negative externalities from road traffic. The road user charge on fuel can partly be avoided by purchasing fuel-efficient vehicles. This may lead to too much investment in fuel-efficient cars and may call for heavier tax on fuel-efficient vehicles, see Bjertnæs (2019).

The large share of electric vehicles of new cars in Norway is induced by a set of policies that include tax exemptions as well as various driving privileges, like the use of bus and collective lanes in cities, exemption from parking fees in city centers, and often battery charging at zero cost. In some of CREEs research it is argued that this policy leads to very high cost for small emission reduction, and that it may lead to more driving causing other externalities, see Holtsmark and Skonhoft (2014).

Although electrification is a viable solution for passenger cars and light-duty vehicles, it is less so for heavy duty vehicles under present technologies. Different policies for inducing less emission intensive commercial transport has been proposed, including both subsidy-schemes and tax-schemes. In CREE we have analyzed the optimal environmental policy for the commercial transport sector in Norway, see Segiet (2018). The result indicates that when the government can commit to the level of tax in the future, or when there is no strategic action when the government cannot commit, the subsidy for the commercial transport sector in Norway is not a cost-effective climate policy and a tax on CO2 emissions is more desirable. However, when we assumed that the government was not able to commit to a certain level of the tax in the future and firms acted strategically, the optimal policy involved a subsidy on capital.

Fuel efficiency improvements in the transports sector leads to less emissions per of unit output (transport services) and can play an important role on the

path to a decarbonized economy. A popular policy instrument to reduce oil consumption has been fuel efficiency standards for new vehicles, and there have been significant improvements in energy efficiency globally over the last decades. However, fuel efficiency measures may be less effective than expected due to the so-called rebound effect; fuel efficiency improvements lower the cost of energy services, thereby encouraging more use of those services. In CREE we have developed a model to investigate the effects in the oil market of fuel efficiency improvements in the transport sector, see Aune et al. (2017). One conclusion from that study is that the rebound effect has a noticeable effect on the transport sector, with the magnitude depending on the oil demand elasticity. In the benchmark simulations, almost half of the energy savings may be lost to a direct rebound effect and an additional 10% to oil price adjustments. If market power is present in the oil market, the directions of change in consumption and price might contrast with those in a competitive market, see Kverndokk and Rosendahl (2013).

Another research question we have address in CREE is whether the promotion to purchase and use electric cars change the driving pattern of the owners of fossil cars, see Kverndokk et al. (2019). Evidence from a survey indicates that Norwegian policies to promote emission free cars have moderately reduced fossil car driving.

2.3 Biofuels in road transport

Biofuel and other forms of bioenergy has been considered as an important alternative to fossil energy. For 2020 there is a biofuel blending mandate of 20 per cent in the in the transport sector in Norway.

Bioenergy is usually considered as carbon neutral. However, food-crop-based biofuels has been criticized for the upward pressure such production has put on food prices. It can also cause greenhouse gas emissions related to growing and processing, and emissions due to land use changes when converting grazing land or forest land to land for producing crops for bioenergy. An alternative to converting grazing land or forest land into land for growing suitable crops for bioenergy production is to use the harvest from standing forests to produce bioenergy. So-called second-generation liquid biofuels can be produced from processing cellulosic biomass. However, one can argue that wood harvesting is not a carbon neutral policy. A higher level of harvest leads to a lower stock of carbon in the forest. So even though the second-generation biofuels replace petrol in the transport sector, and thereby reduce emissions, the carbon stock has decreased, and hence carbon has been released. For the

Norwegian type of forest, it takes a very long time before the carbon stock in the forest is restored, see Holtsmark (2012).

There is a tradeoff between forest as a source for producing bioenergy and as a carbon sink. An unregulated market will not yield the social optimal balance, and thus market intervention through optimal subsidies (on carbon sequestration) and taxes (on fossil fuel emissions) are called for, see Hoel and Sletten (2016).

The results for the analysis of the impact of a biofuel mandate are highly dependent on whether the analysis is static or dynamic. It is well known that a biofuel mandate is equivalent to a revenue neutral combination of a carbon tax and a subsidy on biofuel production. In a static setting, a blending biofuel mandate will lead to less emissions for fossil fuels and increased use of biofuels. However, considering that oil is a non-renewable resource, a blending mandate may not have any effect on accumulated oil consumption. It will however, shift the consumption pattern over time. Extraction of oil is postponed because of the blending biofuel mandate. This has beneficial climate effects, see Greaker et al. (2014).

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Bjertnæs, G. H. M. (2019): Efficient Combinations of Taxes on Fuel and Vehicles, *The Energy Journal*, Vol. 40, 387-408.

Ciccone, A. (2014): Environmental effects of a vehicle tax reform: Empirical evidence from Norway, CREE WP 09/2014.

Gerlagh, R., van den Bijgaart, I., H. Nijland and T. Michielsen (2018): Fiscal policy and CO2 emissions of new passenger cars in the EU, *Environmental and Resource Economics*, Vol. 69, No. 1, 103-134.

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Hoel, M. and T. M. Sletten (2016): Climate and forests: The tradeoff between forests as a source for producing bioenergy and as a carbon sink, *Resource and Energy Economics*, 43, 112-129

Holtsmark, B. and A. Skonhoft (2014): The Norwegian support and subsidy policy of electric cars. Should it be adopted by other countries? *Environmental Science & Policy*, Vol. 42, 160-168

Holtsmark, B. (2012): Harvesting in boreal forests and the biofuel carbon debt, *Climatic change*, Vol. 112, 415-428

Kverndokk, S. and K. E. Rosendahl (2013): Effects of Transport Regulation on the Oil Market: Does Market Power Matter? *Scandinavian Journal of Economics*, Vol. 115. No. 3, 662-694.

Kverndokk, S. E. Figenbaum and J. Hovi (2019): Would my driving pattern change if my neighbor were to buy an emission-free car? CREE WP 04/2019.

Segiet, K. (2018): Should the Norwegian commercial transport sector be subsidized? CREE Working paper 13/2018.

Wangsness, P. B., S. Proost and K. L. Rødseth (2019): Optimal policies for electromobility: Joint assessment of transport and electricity distribution costs in Norway. School of Economics and Business. Working paper 1/2019, NMBU.

Puplications Flagship II

1. Scientific Journals

Author	Title	Publication	Year
Kverndokk, S., Erik Figenbaum, Jon Hovi	Would my driving pattern change if my neighbor were to buy an emission-free car?	Resource and Energy Economics	2020
Bjertnæs, G. H. M.	Efficient Combinations of Taxes on Fuel and Vehicles	The Energy Journal, Vol. 40, The New Era of Energy Transition Special Issue, 387-408.	2019
Grimsrud, K., H. Lindhjem, I. V. Sem, K. E. Rosendahl.	Public acceptance and willingness to pay cost-effective taxes on red meat and city traffic in Norway.	Journal of Environmental Economics and Policy 2019	2019
Gerlagh, R., Bijgaart, I.van den, H. Nijland, T. Michielsen	Fiscal policy and CO2 emissions of new passenger cars in the EU	Environmental and Resource Economics 69(1): 103-134	2018
Aune, F. R., A.C. Bøeng, S. Kverndokk, L. Lindholt, K. E. Rosendahl	Fuel efficiency improvements - Feedback mechanisms and distributional effects in the oil market	Environmental and Resource Economics, Vol. 68, Issue 1, 15–45, 2017.	2017
Gerlagh R., Bijgaart, I.M. van den, Michielsen, T., Nijland, H	Fiscal policy and CO2 emissions of new passenger cars in the EU.	Environmental and Resource Economics, Vol. 65 Issues 263, 1-32	2016
Hoel, M., T. M. Sletten	Climate and forests: The tradeoff between forests as a source for producing bioenergy and as a carbon sink.	Resource and Energy Economics, Vol. 43, 112-129	2016
Greaker, M., M. Hoel, K.E. Rosendahl	Does a renewable fuel standard for biofuels reduce climate costs? .	Journal of the Association of Environmental and Resource Economists 1, 337-363	2014
Holtsmark, B., A. Skonhoft	The Norwegian support and subsidy policy of electric cars. Should it be adopted by other countries?	Environmental Science & Policy Vol. 42, 160-168 .	2014
Kverndokk, S., K.E. Rosendahl	Effects of Transport Regulation on the Oil Market: Does Market Power Matter?	The Scandinavian Journal of Economics. Vol. 115, Issue 3, 662–694	2013

2. Popular Science Journals			
Author	**Title**	**Publication**	**Year**
Bjertnæs, G. H. M.	Efficient taxation of fuel and road use	Discussion Papers,No. 905 2019, Statistisk sentralbyrå	2019
Bjertnæs, G., H.	Effektive bilavgifter og bruk av bompenger.	Samfunnsøkonomen 2019 (4) s.20-28	2019
Greaker, M., C. Hagem, S. Proost.	Vehicle-to-Grid: Impacts on the electricity market and consumer cost of electric vehicles.	Discussion Papers,No. 903 2019, Statistisk sentralbyrå	2019
Grimsrud, K., I. Vestre Sem, H. Lindhjem, K. E. Rosendahl.	Public acceptance and willingness to pay costeffective taxes on red meat and road traffic in Norway.	Discussion papers, No. 909 2019, Statistisk sentralbyrå	2019
Grimsrud, K., I. V. Sem, H. Lindhjem, K. E. Rosendahl.	Preferanser for Grønn skattekommisjons foreslåtte avgifter på rødt kjøtt og veitrafikk.	Samfunnsøkonomen 2019 (2) s.40-53	2019
Fæhn, T., G. Asheim, M. Greaker, C. Hagem, B. Harstad, M. Hoel, D. Lund, K. Nyborg, K. E. Rosendahl, H. Storrøsten	Parisavtalen og oljeeksporten	Energi og klima 21.6.18	2018
Greaker, M. og M. Kristoffersen	Lading av elbiler: Bør vi godta flere standarder?	Samfunnsøkonomen,Nr 4 2017	2017
Aune, F.R. , A.C. Bøeng, S. Kverndokk, L. Lindholt, K.E. Rosendahl	Fuel efficiency improvements – feedback mechanisms and distributional effects in the oil market.	Discussions papers 839, Statistisk sentralbyrå	2016
Aune, F.R., A.C. Bøeng, S. Kverndokk, L. Lindholt, K.E. Rosendahl	Drivstoffeffektivisering – fører det til mindre bruk av olje?	Økonomiske analyser, 4/2015 S69-73	2015
Holtsmark, B.	Skog, bioenergi og klima.	Samfunnsøkonomen Nr 4 2012	2012
Holtsmark, B.	Elbilpolitikken – virker den etter hensikten?.	Samfunnsøkonomen Nr 5, 8 og 9 2012	2012
Kverndokk, S., K.E. Rosendahl	Oil price effects of transport regulation.	EAERE Newsletter, European Association for Environmental and Resource Economists, 9-12	2012
Greaker, M.	Innretning av støtte til biodrivstoff.	Økonomiske Analyser 5/2011, Statistisk sentralbyrå.	2011

3. Other publications			
Author	**Title**	**Publication**	**Year**
Hoel, M.	The Rise and Fall of Bioenergy	CESifo Working Paper No. 6971	2018
Aune, F.R., A.C. Bøeng, S. Kverndokk, L. Lindholt, K.E. Rosendahl	Fuel Efficiency Improvements - Feedback Mechanisms and Distributional Effects in the Oil Market.	CESifo Working Paper No. 5478 (August 2015)	2015
Ciccone, A.	Environmental effects of a vehicle tax reform: evidence from Norway.	Memorandum 3/15	2015
Gerlagh, R., Bijgaart, I. van den, H. Nijland, T. Michielsen	Fiscal policy and CO2 emissions of new passenger cars in the EU.	CPB Discussion Papers, NR 302	2015

4. CREE Working Papers

Author	Title	Publication	Year
CREE	Synthesis report of Flagship II: Environmentally friendly transport	CREE WP 01/2020	2020
Greaker, M., C. Hagem, S. Proost	Vehicle-to-Grid: Impacts on the electricity market and consumer cost of electric vehicles	CREE WP 01/2019	2019
Kverndokk, S., Erik Figenbaum, Jon Hovi	Would my driving pattern change if my neighbor were to buy an emission-free car?	CREE WP 04/2019 / CESifo WP 7679/2019	2019
Segiet, Katarzyna	Should the Norwegian commercial transport sector be subsidized?	CREE WP 13/2018	2018
Elkadi, Nour-Eddine	Husholdningenes transport og miljøpolitikk - Modellering og virkemidler	CREE WP 08/2017	2017
Røgeberg, O.	Competing Technologies in Transport - Battery, hydrogen, or both?	CREE WP 11/2017	2017
Kristoffersen M.	Compatibility Choice: In the Electric Vehicle- and Charging Market	CREE WP 15/2016	2016
Aune, F.R., A.C. Bøeng, S. Kverndokk, L. Lindholt, K.E. Rosendahl	Fuel efficiency improvements – feedback- mechanisms and distributional effects in the oil market	CREE WP 11/2015	2015
Ciccone, A.	Environmental effects of a vehicle tax reform: empirical evidence from Norway	CREE WP 09/2014	2014
Bjertnæs, G.H.	Biofuel mandate versus favourable taxation of electric cars: The case of Norway	CREE WP 20/2013	2013
Bjertnæs, G.H.	Are tax exemptions for electric cars an efficient climate policy measure?	CREE WP 21/2013	2013
Greaker, M., M. Hoel, K.E. Rosendahl	Does a renewable fuel standard for biofuels reduce climate costs?	CREE WP 15/2012	2012
Sletten, T.M.	Framework for Studying the Environmental Impact of Biofuel Policies	CREE WP 07/2012	2012