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Summary:

Alternative transport technology
Reduced CO_2-emissions from the transport sector

In this report we look at various aspects of alternative and ”eco-friendly” transport technologies in connection with CO_2 emissions from the transport sector. The purpose is to shed light on how transport technology can make a contribution to reducing transport-specific and overall CO_2-emissions in Norway. An important question is whether the use of eco-friendly transport technology can reduce the socio-economic cost of implementing a Norwegian climate policy, for example in connection with the Kyoto Protocol. We have also attempted to find out the technologies which in the short and long term are best suited to reducing CO_2-emissions in the transport sector, and to which degree more stringent environmental standards per se will hasten the introduction and use of alternative transport technology.

Alternative eco-friendly transport technology comprises motor technology and new fuel systems with low or no CO_2-emissions. Electric and gas-powered cars can for example remove or yield lower CO_2 emissions compared with current alternatives. In the project we have evaluated various alternative technologies in various parts of the transport sector, and have arrived at four types that have something to offer in connection with CO_2-policy.

The project consists of two parts. The first part, which is an overview of the development of different technological transport solutions until 2020, is documented in further detail by the National Institute of Technology (Skedsmoe and Hagman, 1998), and in an abbreviated version in Chapter 6 of this report. In the second part we have conducted macroeconomic model calculations to determine what alternative transport technology can offer vis-à-vis Norwegian climate policy and national CO_2-emissions.

Regardless of wherever and fromwhichever sector the emissions emanate, the consequences of human-generated CO_2-emissions are the same. Since CO_2-emissions are caused inter alia by the burning of fossil energy, unilateral measures to protect the environment in the transport sector may cause unintended effects through energy usage in other sectors. The use of electric cars will for instance reduce CO_2 emissions from the transport sector, but more fossil energy would then be made available for home heating and other energy-intensive purposes. This means that CO_2 emissions could be transferred from transport to these sectors. Consequently, it is appropriate (least costly) to look at all CO_2 emissions as a whole and draft a joint geographically independent climate strategy for all sectors (to whatever degree possible).

It is a poor solution to focus one-sidedly on expensive CO_2 measures in the transport sector if equally good results can be achieved at a lower cost in other

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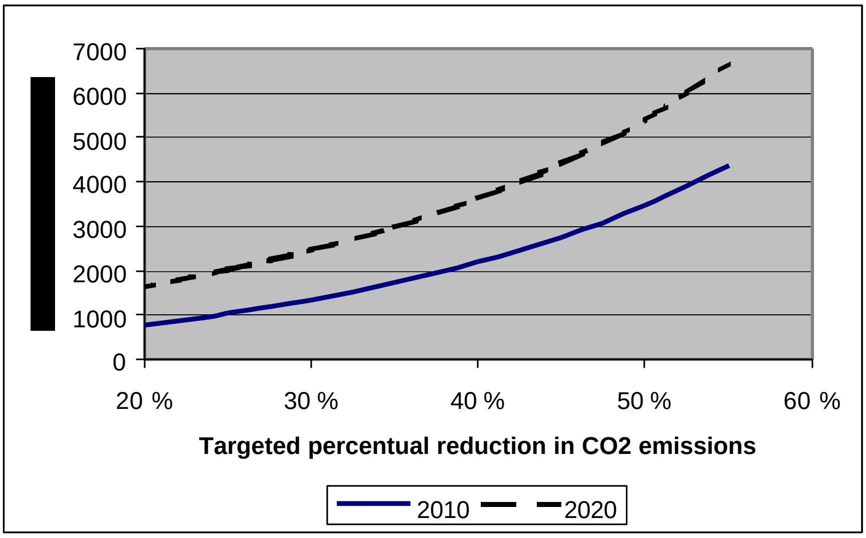
sectors, or if the problems through substitution effects would be transferred to other sectors. To take such factors into consideration we use the computable general equilibrium model GODMOD (Jensen and Eriksen, 1997).

A climate policy goal to reduce CO_2-emissions requires reduced consumption of carbon-containing goods and energy. Such a restriction in the economy has a "*shadow cost*" which can be regarded as the marginal cost of reducing CO_2-emissions by one more unit, given that we have already almost achieved the goal. The marginal cost increases progressively with the ambition level (shown in Figure 1).

The location and incline of the marginal cost curve depends inter alia on transport technology. If we introduce new technology with lower CO_2 emissions, the curve will shift downwards to the right and the curvature of the curve may be changed. How new and alternative transport technology will change the curve depends both on the environmental characteristics and on the relative cost of the technology.

Figure 1. The connection between CO_2 tax and targeted percentage reduction in CO_2 emissions relative to projected emission levels in the year 2010, BASIS alternative, 1992 kroner.



Before discussing the technology calculations, we will say something about the departure point for these, which is a reference path (BAU= business as usual) describing the development of the Norwegian economy until 2020. There is no climate policy goal in BAU. We use BAU as a point of departure to calculate a BASIS alternative with climate policies. The goal in the BASIS alternative, which is to reduce national emissions of CO_2, will be implemented with an equal tax on all CO_2 emissions (excluding international shipping). There is no alternative transport technology in either the BAU or BASIS alternative.

The BAU assumptions give on an annual GDP growth rate of 2.7% between 1992 and 2010. The growth is reduced to 1.9% per year between 2010 and 2020. In the period 1992 to 2010 private consumption increases by 3.2% per year, followed by 2.3% per year between 2010 and 2020. The calculations yield CO_2 emissions totalling 47.2 millions tonnes in BAU in 2010.

Figure 1 shows the connection between CO_2 taxes and the achieved reductions in total CO_2-emissions in the years 2010 and 2020 in the BASIS alternative. The targeted percentage reduction in CO_2-emissions both in 2010 and 2020 (shown along the horizontal axis) is relative to the projected emission level in the year 2010 in BAU.

The goal of complying with an overall CO_2 emission target of 1% above the 1990 level (the Kyoto Protocol) is equivalent to reducing emissions by 19% compared with projected emissions in 2010. This will reduce GDP by 0.5% in 2010 and 0.7% in 2020 in relation to BAU. GDP losses increase to 4.1% with if a 55% reduction in emissions in 2010 is sought and correspondingly 5.0% to maintain the same emission level in 2020.

Two drawbacks have curtailed the large-scale use of alternative transport technology. First, the technology is costly and secondly a number of practical problems are associated with it (e.g. short range and long recharging time for electric cars). These circumstances do not motivate transport users to use alternative technology, and the disadvantages must be compensated through emission standards, physical measures or through economic measures in the form of taxes and subsidies favouring such technology.

In the project we study two different approaches to the implementation of alternative transport technology. In the first case we study unilateral measures in the transport sector in the forms of pure operating subsidies for alternative technologies. In the second case the technology is implemented as a part of an overall climate policy strategy. *The calculations were done separately for each technology so that the effects were not additive.*

One factor which for a long time will limit the effect of measures directed at the use of alternative transport technology is the rate at which vehicles will be replaced. Cars normally have a lifetime of c. 10 years and the transition to new transport technology will therefore take time. In addition, only a minority of the new vehicles purchased over the next 10 years will be other than traditional gasoline and diesel-powered vehicles. This means that we cannot expect that more than a maximum of 20% of car stocks will under any circumstance consist of other that gasoline and diesel-powered cars in the year 2010, and maximum 50-60% in the year 2020. Based on differences in applicability and time of introduction, these figures will vary considerably across the various technologies. This is particularly true of fuel cell technology, which will not be in practical use before between 2005 and 2010 at the earliest. We have taken these factors into consideration in all calculations, which inter alia means that fuel cell technology does not do well in the analyses.

We look first at sector specific economic subsidies for alternative transport technology as a means of compensating for high costs in the BAU-scenario. Climate policy instruments (such as the CO_2 tax in the BASIS-alternative) are therefore not used in these calculations which are based on BAU. Table 1 shows the necessary subsidies for each technology to enable it to compete in terms of costs with traditional technology.

Table 1. Necessary subsidy for evening out cost disadvantages for various technology alternatives, in per cent of total long-term operating costs.

	Cars	Heavy vehicles

	2010	2020	2010	2020
Electric, battery	15%	00%	30%	20%
Hybrid	15%	15%	35%	31%
Gas	20%	20%	20%	20%
Hydrogen	40%	40%	50%	50%

Table 2. Estimated percentages of total vehicle kilometres performed by alternative technologies in 2010 and 2020 with general operating subsidies for the technology.

	2010				2020			
	Electric	**Hybrid**	**Gas**	**Hydrogen**	**Electric**	**Hybrid**	**Gas**	**Hydrogen**
Taxi	-	-	-	-	-	-	-	-
Com. vehicle <10 tonnes	26 %	27 %	19 %	0.7 %	72 %	74 %	64 %	16 %
Com. vehicle 10-15 tonnes	25 %	26 %	18 %	0.7 %	72 %	73 %	63 %	16 %
Com. vehicle >15 tonnes	25 %	25 %	18 %	0.7 %	71 %	72 %	62 %	16 %
Bus	-	-	-	-	-	-	-	-
Private vehicle <10 tonnes	25 %	26 %	18 %	0.7 %	72 %	73 %	63 %	16 %
Private vehicle 10-15 tonnes	25 %	-	-	0.7 %	-	-	62 %	15 %
Private vehicle >15 tonnes	-	-	-	-	-	-	-	15 %
Car	14 %	26 %	14 %	1.0 %	52 %	77 %	51 %	7 %

Table 2 shows how much of the total number of vehicle kilometres is performed with alternative technologies given these subsidies. The effects of transport-specific and total CO_2 emissions are shown in Table 3, while Table 4 shows, in the form of lost private consumption, the cost of implementing the measures.

The conclusion is that isolated measures to introduce alternative transport technology (shown in Table 4) are costly to implement, but the potential for reducing the CO_2 emissions through the application of eco-friendly transport technology is good (shown in Table 3). In the following we will see that the cost can be turned into a gain if we use eco-friendly transport technology as part of a general climate strategy instead of isolated CO_2 measures in the transport sector.

Table 3. Reduction of CO_2-emissions with the use of alternative transport technologies.

	2010				2020			
	Electric	**Hybrid**	**Gas**	**Hydrogen**	**Electric**	**Hybrid**	**Gas**	**Hydrogen**
Total reduction	-2.0 %	-1.0 %	-0.1 %	-0.1 %	-5.7 %	-2.1 %	-0.8 %	-0.9 %
Reduction in emissions from cars	-14.2 %	-11.3 %	-1.2 %	-1.2 %	-51.5 %	-32.0 %	-6.4 %	-6.8 %
Reduction in emissions from heavy vehicles	-4.3 %	-1.7 %	-0.2 %	-0.1 %	-8.3 %	-3.9 %	-3.5 %	-3.8 %

Table 4. Kroner reduction in private consumption per reduced kilo of CO_2

	2010	2020
Electric	6.57	4.62
Hybrid	19.57	22.34
Gas	8.89	13.91
Hydrogen	12.49	18.48

In the next calculations the alternative transport technology is introduced in the BASIS-alternative, which incorporates a climate policy goal. With a conservative estimate of technological development in the transport sector only battery-powered cars are *both* eco-friendly *and* cost-effective compared with traditional transport technology by the year 2010. The introduction of battery-powered cars reduces the CO_2 tax by 9% in relation to the BASIS alternative with a 19% reduction in CO_2 emissions in relation to projected emissions in 2010 (Kyoto requirement). We find little effect on GDP. With a 40% reduction in CO_2 emissions in relation to expected emissions in 2010, the GDP gain in relation to the BASIS alternative is relatively small, only 0.1%.

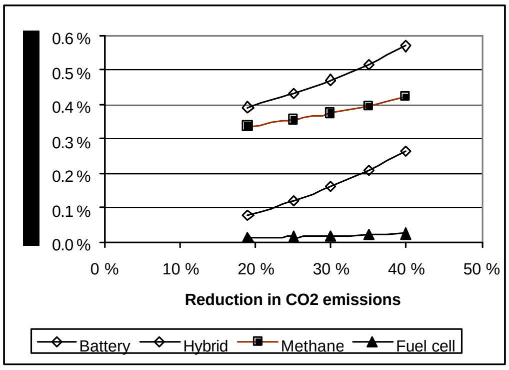
By 2020 cars with fuel cells (hydrogen) and cars with hybrid technology will also be an eco-friendly *and* cost-effective alternative to traditional cars (still using conservative estimates for technological developments in transport). With a targeted reduction in CO_2 emissions to a level corresponding to a 19% reduction in relation to emissions in *2010*, the introduction of battery-powered cars will reduce the CO_2 tax by 20% in relation to the BASIS alternative. The corresponding effect for hybrid cars is 15% and for hydrogen cars 2%. The effect on the GDP is somewhat stronger than in the calculations for 2010 (0.3% GDP gain for battery and hybrid cars).

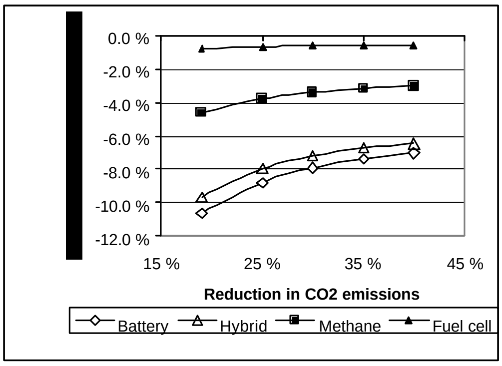
In heavy road and sea, rail, and air transport the emissions gains from alternative technologies are small in proportion to the technological costs, even with optimistic technological expectations. The best climate strategy in heavy transport by road and all sea, rail and air transport is a further development of current solutions, which can be strengthened through new emission standards.

In the last calculations we have introduced more optimistic estimates of the technological development in the transport sector. The environmental characteristics of alternative transport technology are then assumed to develop at a faster pace (is better) and the costs relative to traditional transport technology are significantly lower. All in all, this entails more favourable results for alternative transport technology. At the same time, we note that the optimistic estimates for technological development also apply to traditional transport technology. The estimates will therefore all affect the BASIS alternative henceforth referred to as BASIS(+).

Figure 2. Percentage change in CO_2 tax in 2010 in relation to BASIS(+), optimistic estimate for development of new technology.

Figure 3. Percentage change in GDP in 2010 in relation to BASIS(+), optimistic estimate for development of new technology.





Firstly, we now find that under the Kyoto requirements battery-powered, fuel cell, hybrid and gas cars are eco-friendly and cost-effective alternatives to traditional gasoline or diesel vehicles in the car market as early as the year 2010. Next we see that all four technologies reduce the CO_2 taxes relative to the BASIS-alternative. Figure 2 shows the effects of the tax in 2010, and Figure 4 shows the effects on the tax in 2020.

The effects on GDP are more favourable than in the previous cases. The GDP gain in relation to the BASIS alternative in 2010 is shown in Figure 3. Figure 5 shows the GDP gain in 2020.

Figure 4. Percentage change in CO_2 tax in 2020 in relation to BASIS(+), optimistic estimate for development of new technology.

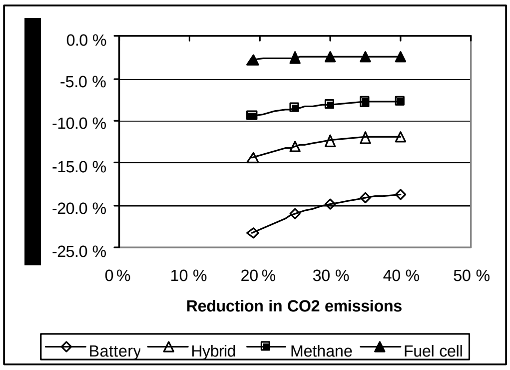
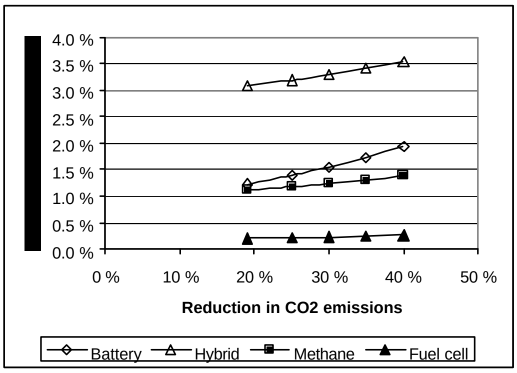
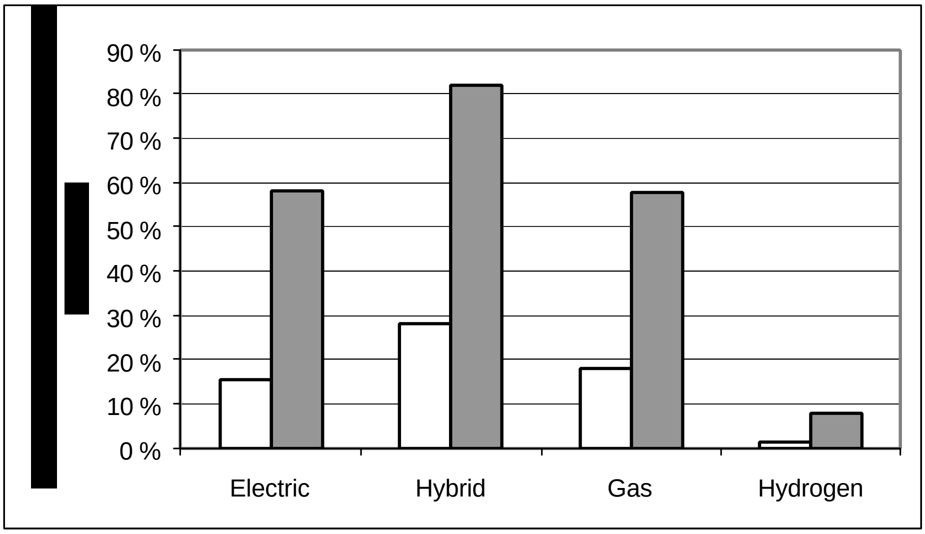


Figure 5. Percentage change in GDP in 2020 in relation to BASIS(+), optimistic estimate for development of new technology.



Transport technologies' effect on the CO_2 tax and GDP must be judged in connection with the degree of use for the technology alternatives. In Figure 6 we have for instance shown how large a percentage of transport with cars is performed by the various technologies in compliance with the requirement that emissions of CO_2 do not exceed 19% of the projected emissions in 2010. (The percentages increase with a maximum of 1% in the year 2010 and 3% in the year 2020 when the emissions reduction standard is increased to 40%.)

Figure 6. Percentage of transport by car performed with various transport technologies with a 19% reduction in CO_2 emissions in relation to projected emissions in 2010.



In conclusion we see that battery-powered cars and hybrid cars are the technologies which in the short term (until the year 2010) have the best potential of lowering CO_2 emissions from the transport sector. Due to short range and long recharging time, however, battery-powered cars will to only a limited degree function elsewhere than in special niches. Our belief in hybrid cars is strengthened by the most favourable income effects we see in connection with this technology (Figure 2). The most realistic alternative in the short term is therefore probably a mixture in which electric cars are used in the segment of the market in which they function (in-town deliveries) and hybrid technology in the segment of the market that is willing to pay for environmental technology. Until the year 2010, a large portion of the transport in the car market will still be served by traditional gasoline and diesel cars, but with significantly better environmental properties through improved combustion systems, power transfer and pollution-abatement technology.

In the long term it is hoped that hydrogen technology will mature and that the storage problems connected with hydrogen will be solved. However, the costs of and energy use with this technology are relatively high, weakening our belief in the hydrogen solution in reducing CO_2 emissions. As an alternative, we believe that longer ranges and shorter recharging times are within reach for battery-powered cars, which will then offer a good, perhaps even better, alternative when energy use and energy costs are taken into consideration. Hybrid cars, however, offer the best income effect on GDP, including in the perspective until the year 2020. (Figure 5).