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Summary:

Energy efficiency and CO_2 emissions in the Norwegian transport sector 1994-2050

This report presents estimated potential for reduced energy use and CO_2 emissions per passenger and tonne kilometre in Norway from 2004 to 2050.

The potential for energy efficiency improvements and reductions in CO_2 emissions are highest for light vehicles. For these vehicles a massive transition to electric engines can result in an up to a 97 per cent reduction in CO_2 emissions and up to 76 per cent reduction in energy use per transport unit.

The potential for energy efficiency improvements and reductions in CO_2 emissions per transport unit in aviation is estimated at maximally 67 per cent between 2004 and 2050.

The potential for reduced CO_2 emissions per passenger and tonne km in the same period is estimated at maximally 42 per cent for heavy vehicles and 34 per cent for ships, while for rail the CO_2 emissions can be eliminated with a completely developed electrification.

This report presents energy use and CO_2 emissions per tonne km and passenger km in Norway from 1994 to 2004 and 3 different scenarios for 2020, 2035 and 2050.

Introduction

The Institute of Transport Economics (TØI) has calculated three scenarios for the developement in average energy use and CO_2 emissions per transport unit (vehicle km, tonne km and passenger km) in Norway for each mode of transport until 2050.

The calculations are based on the three resource papers; NOU 2006:18 “Et klimavennlig Norge (A Climate Friendly Norway)”, Future Climate –Engineering Solutions 2009 and “Can Cars Come Clean”.

Definitions

The calculations only cover direct energy use and emissions (Tank to Wheel) and do not differentiate between different transport situations (for instance urban/rural and short/long haul).

The report can be ordered from:
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In many cases carriers are used to transport both people and freight. In these cases energy use and emissions must be split between passengers and tonnes of freight. For railways we have used calculations made by the Norwegian State Railways (NSB). For aviation we have used the standard measure where 1 passenger km equals 86,5 kg of freight. For sea transport we have assumed that 1 passenger km equals 1 tonne km.

Technological assumptions

Light vehicles

Emissions and energy use for light vehicles can be reduced by making the vehicles lighter and by using more efficient and different propulsion technology, especially in the following areas:

- More energy conserving vehicles including hybrid
- Lighter vehicles with less engine power
- Transition from fossil fuels to biofuels
- Transition from fossil fuels to hydrogen and electric engines

Heavy vehicles

Heavy vehicles use mainly diesel engines. At 45 % efficiency these engines are already relatively efficient. The potential for increased energy efficiency in long haul transport is limited, but use of alternative fuel may reduce the CO_2 emissions. In short haul urban transport hybrid technology could reduce energy use significantly.

Domestic shipping and fishing

The merchant navy and fisheries in Norway use approximatley 100 different kinds of ships and it is difficult to generalize the potential for reductions in energy use and emissions. At the time being use of compressed natural gas (CNG) seems to be the most promising technology at sea. Converting from marine diesel oil (MDO) to CNG will reduce CO_2 emissions by 25 %.

Domestic aviation

The two major air carriers in Norway, SAS and Norwegian, are either renewing their entire fleet now or plan to do it before 2020. With these and other measures fuel consumption and CO_2 emissions per available seat km (ASK) is expected to fall by between 30 % and 40 % by 2020. Between 2020 and 2050 further developments in engine and aircraft design are expected to reduce energy use and emissions by another 20 % to 40 %.

Railways

NSB is planning a 15 % reduction in electricity consumption for electric trains. For diesel trains it is assumed that diesel consumption will follow the same pattern as for heavy vehicles. In addition it is possible to electrify remaining rail tracks without power supply.

The Reference Scenario

Our reference scenario is closely related to the reference scenario in NOU 2006:18.

By 2050, 15 % of Norwegian vehicles will be low-emission and 17 % will be based on renewable sources of energy. By 2050 improvements in energy efficiency are estimated at 40 % for light vehicles and 30 % for urban bus transport while improvements for heavy vehicles and diesel trains are esimated at only 5-10 %. Further reductions are expected from the use of biofuel.

The merchant navy and the fisheries will by 2050 have increased energy efficiency by 10 % compared to 2005. Increased use of CNG will reduce CO_2 emissions somewhat more then 10 %.

In domestic aviation, energy efficiency is expected to increase by 30 % in 2020 and by another 20 % in 2050.

Energy efficiency for electricity trains will increase by 15 % before 2020.

The Low Emission Scenario

Our low emission scenario is closely linked to the low emission scenario in NOU 2006:18.

In this scenario the use of low and zero emission vehicles is combined with use of biofuel for remaining vehicles. Usage of electric vehicles will by 2050 reduce energy consumption by 50-60 % compared to the reference scenario. Greenhouse gas emissions from heavy vehicles will be 15 % less then the Reference Scenario.

For the merchant navy and fisheries energy consumption will be reduced by another 20 % in 2050 compared to the reference scenario. Usage of CNG will decrease CO_2 emissions even further.

In domestic aviation, energy consumption and emissions will be reduced by another 14 % by 2020 and by 36 % in 2050 compared to the reference scenario. Railways will in this scenario be completely electrified by 2050, and electric trains will have gained another 10 % increase in energy efficiency.

The Compromise Scenario

The compromise scenario represents a mixture between the reference and low emission scenarios. In addition it takes into consideration technological developments since 2006.

In this scenario a large fraction of the light vehicles will be based on electric propulsion by 2035, and CO_2 emissions will be reduced by 60 % to 80 % compared to the reference scenario. Electric propulsion will also increase energy efficiency by 50-60 % compared to the reference scenario. Plug-in hybrid cars will combine electric propulsion on journeys up to 40-60 km with regular hybrid drive on longer distances.

CO_2 emissions from heavy vehicles will be reduced by another 5 % compared to the reference scenario.

For the merchant navy and fisheries energy efficiency will increase 10 % by 2050 compared to the reference scenario. Converting to CNG will decrease CO_2 emissions even more.

In aviation energy efficiency will increase by 35 % to 2020 and by another 30 % by 2050.

Railways will improve energy efficiency for electric trains by another 10 % by 2035 compared to the reference scenario and 50 % of diesel based traffic converted to electricty by 2035.

Results are given for personal transport in tables E1-E2 and for freight in tables E3-E4.

Table E1. Energy consumption per passenger km 1994-2050 in three scenarios.

MJ/pkm	Historic			Reference scenario			Compromise scenario			Low emission scenario		
Year	1994	1998	2004	2020	2035	2050	2020	2035	2050	2020	2035	2050
Train	0,70	0,63	0,62	0,50	0,49	0,49	0,50	0,45	0,42	0,49	0,42	0,34
Moped	0,82	0,82	0,82	0,61	0,57	0,49	0,46	0,37	0,29	0,43	0,29	0,20
MC	1,29	1,29	1,29	0,97	0,90	0,77	0,73	0,59	0,46	0,68	0,45	0,31
Bus	0,98	0,85	1,06	0,87	0,82	0,77	0,87	0,78	0,74	0,83	0,78	0,70
Car	1,49	1,46	1,37	1,05	0,98	0,84	0,79	0,64	0,50	0,73	0,49	0,34
Taxi	2,98	2,65	2,32	1,74	1,62	1,39	1,30	1,05	0,83	1,22	0,81	0,56
Air	2,69	2,78	2,61	1,52	1,36	1,21	1,35	1,14	0,94	1,24	0,95	0,70
Hurtigruta*	6,53	5,72	5,02	5,02	4,76	4,51	4,76	4,29	3,61	4,76	4,05	3,61
Ferry	9,13	8,02	8,48	8,48	8,06	7,63	8,06	7,25	6,11	8,06	6,85	5,73
Speed boat	10,66	10,46	12,35	12,35	11,73	11,11	11,73	10,56	8,89	11,73	9,97	8,89

*The Norwegian Coastal Voyage

Table S2. CO_2 emissions per passenger km 1994-2050 in three scenarios.

g CO2/pkm	Historic			Reference scenario			Compromise scenario			Low emission scenario		
Year	1994	1998	2004	2020	2035	2050	2020	2035	2050	2020	2035	2050
Train	14	10	8	7	7	6	7	6	3	7	3	0
Moped	59	59	59	44	41	35	31	17	7	31	12	2
MC	68	66	63	47	44	38	33	18	8	33	13	2
Bus	72	63	78	64	61	57	64	58	54	58	51	46
Car	108	105	100	77	72	61	54	29	12	54	21	3
Taxi	210	195	172	129	120	103	90	48	21	90	36	5
Air	196	203	191	111	100	89	98	84	69	91	70	51
Hurtigruta	479	419	367	367	345	323	349	276	226	331	276	242
Ferry	669	588	621	621	584	547	590	467	383	559	467	410
Speed boat	781	767	904	904	850	796	859	680	557	814	680	597

Table S3. Energy consumption per tonne km 1994-2050 in three scenarios.

MJ/tkm	Historic			Reference scenario			Compromise scenario			Low emission scenario		
Year	1994	1998	2004	2020	2035	2050	2020	2035	2050	2020	2035	2050
Lorry	2,04	1,60	1,84	1,41	1,17	0,95	1,30	1,00	0,80	1,23	0,94	0,72
Ship	1,04	0,80	NA	0,80	0,76	0,72	0,76	0,68	0,57	0,76	0,64	0,57
Air	31,10	32,10	30,20	17,50	15,80	14,00	15,50	13,20	10,90	14,30	11,00	8,00
Train	0,34	0,32	0,26	0,18	0,12	0,09	0,26	0,20	0,15	0,18	0,12	0,09
Ferry	9,13	8,02	8,48	8,48	8,06	7,63	8,06	7,25	6,11	8,06	6,85	6,11
Hurtigruta	6,53	5,72	5,02	5,02	4,77	4,52	4,77	4,29	3,61	4,77	4,05	3,61

Table S4. CO_2 emissions per tonne km 1994-2050 in three scenarios.

g CO_2/tkm	Historic			Reference scenario			Compromise scenario			Low emission scenario		
Year	1994	1998	2004	2020	2035	2050	2020	2035	2050	2020	2035	2050
Lorry	150	117	135	97	74	54	85	54	35	78	47	27
Ship	87	74	57	57	53	50	54	43	35	51	43	37
Air	2270	2350	2210	1280	1150	1020	1130	960	790	1050	800	580
Train	NA	13	12	8	7	6	7	4	3	5	1	0
Ferry	669	588	621	621	584	546	590	467	383	559	467	410
Hurtigruta	479	419	367	367	345	323	349	276	226	330	276	242