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Initial analyses of transport and energy demands in the CEESA 100 renewable energy scenarios

Internal WP2 CEESA working paper

Currently there is three scenarios in the CEESA project, the ***Biomass scenario*** based on the IDA 100% RES low demand mainly biomass, the ***Wind scenario*** based on the IDA 100% RES low demand mainly wind, and the ***High demand*** based on the 2004 energy demand, both wind and biomass. The two IDA 100% RES scenarios are described in the paper "Energy System Analysis of 100 Per cent Renewable Energy Systems" [1], the high demand scenario is described in a separate internal work paper.

Initially the transportation needs in these three scenarios are identical. This may however be modified, so that the transport demands are changed to low and high transport demands. The 2050 scenarios with biomass and with wind is based on the principle of stabilising the transportation demand at the 2004 level concerning land based passenger transport and the transport of goods at the 2030 level. However the fuel consumption is different since the IDA 2050 scenarios involve a long list of more efficient vehicles, replacing oil with electricity, hydrogen and bio fuels together with shifting form vehicle transportation to ships and trains. The transport scenario is described in detail in [2].

The transport demands can either be found in official publication or can be calculated from information about fuel consumption, efficiencies, amount of good and passenger pr. vehicles etc. Here the transport demands are found in background calculations to the Energy Strategy 2025 [3]. Defining and projecting transport demands are connected to considerable uncertainties like other types of projection. Some of the major faults in the projection are elaborated in this working paper.

Dataset available in official publications on transport demands

The 2004 energy demands for transport are the outset for the analyses of the IDA 2030 / 2050 scenarios. For the scenarios in CEESA more detailed knowledge about transport demand is necessary. The projected energy demands used in the IDA scenarios are connected to projected transport demands. The background of the transport energy demands in Energy Strategy 2025 is from the Danish Road Directorate from 2002 [4].

In [5] only the resulting emission data until 2010 is available. The Ministry of Transport and Energy has provided the background dataset for the projection until 2030. The dataset is consistent with the energy demands for transport in the Energy Strategy 2025. This dataset consist of the following elements:

- Traffic work (km)
- Passenger transport work (person km)
- Fright transport work (ton km)
- Load factors (persons or tons pr. vehicle km)

- Emission data (NO_x, CO, HC, particles, SO_2, CO_2)
- Energy consumption pr. mode of transport divided into fuels

All these elements are divided into yearly values pr. mode of transport and pr. type of fuel. The modes of transport available in the dataset are:

- Vehicle petrol (all under 2 ton)
- Vehicle diesel (all under 2 ton)
- Van petrol (between 2 and 6 ton)
- Van diesel (between 2 and 6 ton)
- Heavy vehicle diesel (all above 6 ton)
- Domestic aviation
- International aviation
- Ferry diesel
- Cargo ship diesel
- Bus diesel
- Train diesel
- Train electricity
- Fright train diesel
- Fright train electricity

Key parameters in the official transport demand and energy demand projections
The key preconditions in this projection of the transport demands and energy demands is the following

- Only adopted initiatives are taken into account (the EU agreement with the European vehicle manufactures)
- The key economic parameters in the projection are based on the Ministry of Finance's Economic Surveys and Review.
- There is a clear distinction between pre-2010 and the period from 2010-2030. This is mainly due the fact that another economic prognosis is used from 2010, in which the economic development is lower.

For personal vehicles the transport demand projections are dependent upon a projection of the amount of vehicles and assumptions about these vehicles annual average traffic work (km pr. vehicle pr. year). The amount of vehicles includes personal vehicles, taxis, medical vehicles and vans under two tons in total weight. The amount of vehicles is dependent upon new vehicles and lifetime of existing vehicles. The elements defining the amount of new vehicles are dependent on the following economic parameters:

- The change in gross domestic product at factor cost from one year to the next
- Real interest rate in the year considered
- The price of petrol and oil in the year considered
- The price of repairs and maintenance of vehicles in the year considered
- The price of purchasing a new vehicle

The passenger transport demand for busses is expected to be constant. Passenger transport demand for trains is constant from 2005. The demand for domestic aviation is expected to increase considerably, i.e. more than 2.5 per cent annually until 2030. The demand for ferry passenger transport work is directly connected to development in vehicle transport.

The international aviation transport demands are not included in the dataset from the Ministry of Transport and Energy. International passenger transport demand has been added to the dataset from The Ministry of Transport and Energy. Here the development in international aviation fuel consumption from the Energy Strategy 2025 is connected to the person km travelled pr. energy unit in domestic aviation. For bicycle transport demand, data from the Danish Transport Research Institute's examination of Danish transport habits from 2003.

The transport demand for vans (between 2 and 6 tons) is connected to the projected GNP, while heavy vehicles (above 6 tons) are also dependent on the economic development within different commercial sectors. For heavy vehicles and fright trains the amount of goods transported pr. vehicle is expected to increase which influences the projected goods transport demands.

The reference transport demands for 2030 and 2050

The dataset is divided into traffic work on one side and passenger or goods transport demands on the other side. In fig. 1 and 2 these transport demands are illustrated. Both the passenger and goods transport demands are dominated by road based modes of transport.

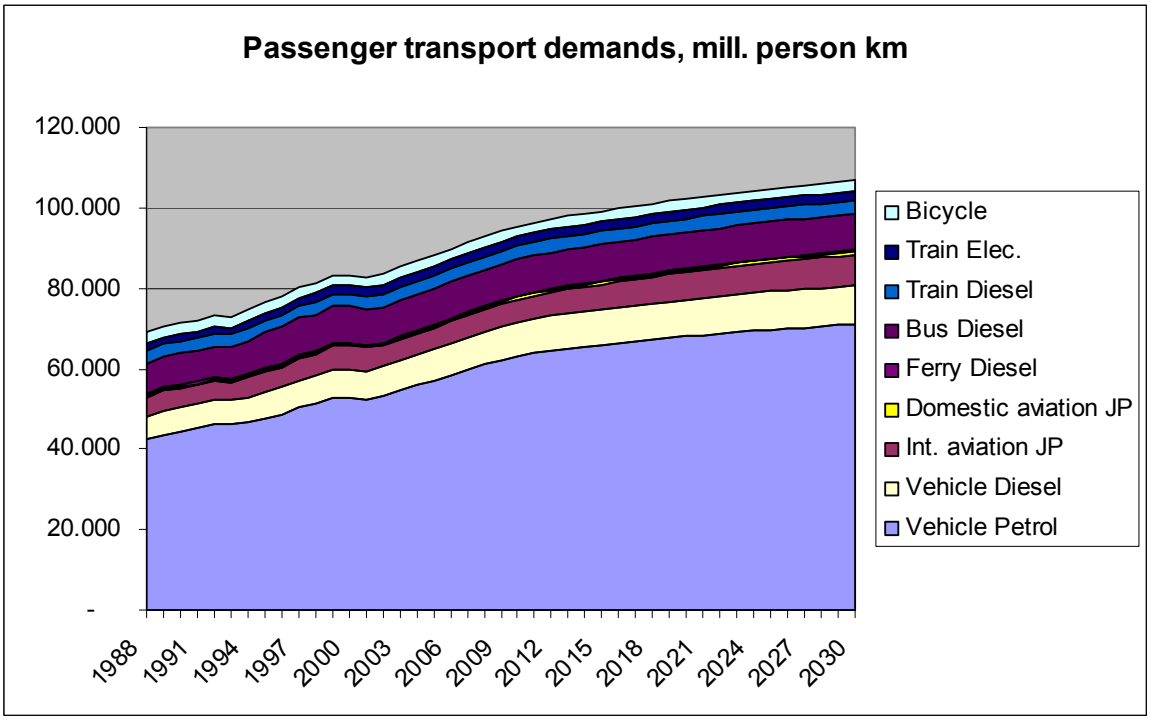

Fig. 1, Passenger transport demands in person km pr. year pr. mode of transport.

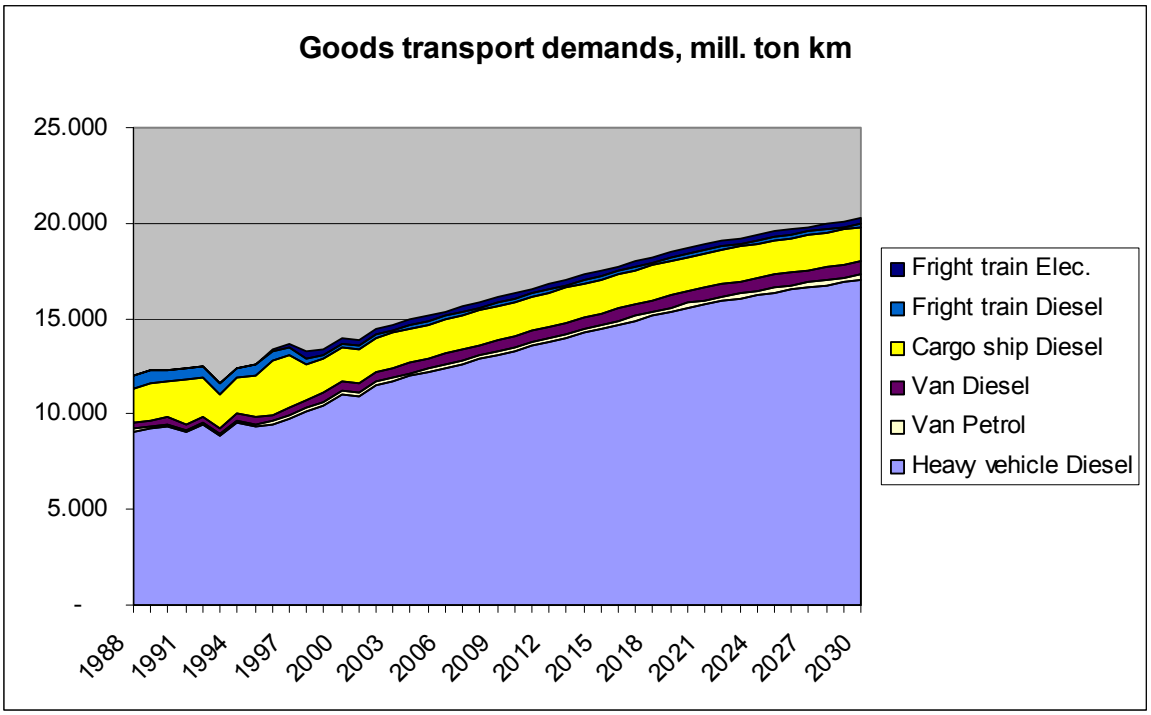

Fig. 2, Goods transport demands in person km pr. year pr. mode of transport.

The reference transport demand until 2050

No official projections of transport demands are available after 2030. For the CEESA project, the transport demands are projected until 2050. A conservative measure is to use the same rate of increase as for the last ten years in the official projection period, i.e. from 2020 to 2030, for the transport demands for 2030 until 2050. These rates of increase are the lowest in the projection period. In table 1 and 2 the transport demands and rates of increase for each mode of transport is listed for 2030-2050. Passenger transport in vehicles, airplanes and ferries is expected to increase. Goods transport in heavy vehicles and van is also expected to increase. All other modes of transport are expected to be constant after 2030. The transport demands until 2030 from the dataset from the Ministry of Transport and Energy is also listed in table 1 and 2.

Mode of passenger transport	Vehicle	Bus	Train	Domestic aviation	Ferry	Int. aviation	Bicycle	Total
Mill. person km / year								
Ref. 2000	59.835	9.133	5.381	363	247	5.875	2.238	83.072
Ref. 2004	63.465	9.031	5.611	407	262	5.274	2.609	86.658
Ref. 2010	71.523	9.031	5.668	491	295	5.748	2.609	95.366
Ref. 2020	77.167	9.031	5.668	648	319	6.803	2.609	102.245
Ref. 2030	80.598	9.031	5.668	799	333	7.741	2.609	106.779
Ref. 2040	84.181	9.031	5.668	985	348	8.809	2.609	111.630
Ref. 2050	87.923	9.031	5.668	1.214	363	10.023	2.609	116.832
Annual rate of increase 2030-2050	*0,44*	*0,00*	*0,00*	*2,12*	*0,44*	*1,30*	*0,00*	*0,45*

Table 1, Passenger transport demands and annual rates of increase from 2030 used for constructing the reference transport demands for 2050.

Mode of goods transport		Heavy vehicle	Van	Fright train	Cargo ship	Total
Mill. ton km / year						
Ref.	2000	11.052	644	456	1.800	13.952
Ref.	2004	11.959	706	456	1.800	14.920
Ref.	2010	13.318	768	456	1.800	16.342
Ref.	2020	15.584	865	456	1.800	18.705
Ref.	2030	17.047	946	456	1.800	20.250
Ref.	2040	18.648	1.035	456	1.800	21.922
Ref.	2050	20.399	1.132	456	1.800	23.732
Annual rate of increase 2030-2050		*0,90*	*0,90*	*0,00*	*0,00*	*0,80*

Table 2, Goods transport demands and annual rates of increase from 2030 used for constructing the reference transport demands for 2050.

The reference energy for transport demand until 2050

The transport demands elaborated above can be converted into energy demands for each mode of transport. This has been done by the Ministry of Transport and Energy until 2030. For the period from 2030-2050 energy demands have been projected for the purposes in CEESA. In table 3 and 4 the efficiency of the different modes of transport in this investigation is presented. These efficiencies have been calculated from the dataset mentioned and the projected energy demand for 2050. The efficiencies are connected to considerable uncertainties as the road based transport is based on assumptions about the km travelled pr. personal vehicle and for heavy vehicles, upon samples of reported mileages.

Mode of passenger transport		Vehicle	Vehicle	Bus	Train	Train	Domestic aviation	Ferry	Int. aviation
km/ liter or km/kWh		Petrol	Diesel	Diesel	Diesel	Elec.	JP	Dielsel	JP*
Ref.	2000	14,5	16,4	2,7	0,53	0,08	0,31	0,033	0,31
Ref.	2004	14,7	16,6	2,7	0,53	0,12	0,30	0,042	0,30
Ref.	2010	15,3	17,2	2,7	0,54	0,14	0,30	0,046	0,30
Ref.	2020	16,3	18,3	2,7	0,54	0,14	0,30	0,046	0,30
Ref.	2030	16,4	18,4	2,7	0,54	0,14	0,30	0,046	0,30
Ref.	2040	16,6	18,6	2,7	0,54	0,14	0,30	0,046	0,30
Ref.	2050	16,7	18,7	2,7	0,54	0,14	0,30	0,046	0,30

Table 3, Efficiencies for modes of passenger transport in selected years in the 2050 reference

Mode of goods transport		Heavy vehicle	Van	Van	Train	Train	Cargo ship
Mill. ton km / year		Diesel	Petrol	Diesel	Diesel	Elec.	Diesel
Ref.	2000	2,3	6,8	5,7	0,25	0,14	0,12
Ref.	2004	2,3	6,8	5,7	0,27	0,14	0,12
Ref.	2010	2,3	6,8	5,7	0,27	0,14	0,12
Ref.	2020	2,3	6,8	5,7	0,27	0,14	0,12
Ref.	2030	2,3	6,8	5,7	0,27	0,14	0,12
Ref.	2040	2,3	6,8	5,7	0,27	0,14	0,12
Ref.	2050	2,3	6,8	5,7	0,27	0,14	0,12

Table 4, Efficiencies for modes of goods transport in selected years in the 2050 reference.

In fig. 3 the resulting fuel consumption in a business-as-usual (BAU) scenario is presented. The total demand is expected to increase to 249 PJ in 2030 with the given assumptions. In the projection from 2030 until 2050 the total fuel consumption increases to 283 PJ.

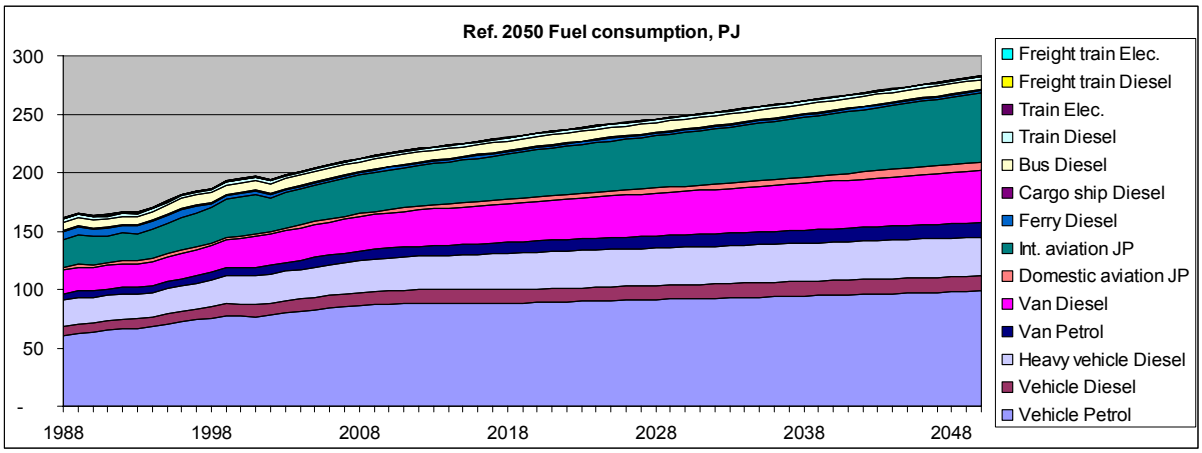

Fig. 3, Historic and projected energy consumption for divided into modes of transport

Considerations for future projections of transport and energy demands

As mentioned, the projection of transport demands are connected to considerable uncertainties. Apart from the uncertainties in the models used for the projections by the Ministry of Transport and Energy and by the Ministry of Finance some other uncertainties are:

- Future investments in expanding the infrastructure - either road or rail tracks - is not a parameter in the projection. Thus traffic leaps and the perceived distances for travellers are not included in the projection.
- One of the key assumptions behind the development in the passenger transport in vehicles is how far each car is expected to drive every year. The outset in the analyses from the Ministry of Transport and Energy is that every vehicle travel 20,000 km in 2002 and developes app. 2 per cent annually. Later studies have indicated that vehicle travel app. 17,000 km annually. Thus the efficiencies for vehicles in table 3 are lower in reality today as the fuel consumption, found in statistics from the Energy Authority, is the same while the length travelled is shorter.
- According to the Ministry of Transport and Energy the rate of increase in the domestic aviation is too large.
- The effect of the EU agreement with the European vehicle manufactures has not had the effect hoped for, thus new vehicles have lower efficiencies than expected in the future.

The Ministry of Transport and Energy expects to create a more dynamic model for energy and transport projection which can be updated annually and which can be used to create alternative scenarios. The work on creating a model is expected to start in the autumn of 2007 and to finish in the spring of 2008.

It could be possible for the CEESA project participants to give inputs and contribute to the parameters included in this modelling. If this is of interest the Ministry of Transport and Energy has to be contacted.

The energy for transport in IDA 2030 and IDA 2050
In the IDA Energy Plan, a wide range of measures has been proposed and analysed. The following proposals for Denmark are part of the transport theme for 2030:

- Passenger transport work (person km) in vehicles, trains and bicycles is stabilised at the 2004 level in 2030.
- The rate of increase in passenger air transport is limited to 30 per cent instead of 50 per cent in the period from 2004 to 2030.
- 20 per cent of the road transport is transferred to trains, ships and bicycles in 2030:
  - 5 per cent transport of goods (ton km) transferred from roads to trains and 5 per cent to ships
  - 5 per cent passenger transport is transferred to trains and 5 per cent to bicycles.
- 30 per cent more energy efficiency in the transport sector compared to the reference situation in 2030 with stable passenger transport at the 2004 level and with a lower increase in air transport.
- 20 per cent bio fuels and 20 per cent battery electric vehicles in road transport.

From 2030 until 2050 the following additional initiatives are made:
- The total passenger and goods transport demand is kept constant at the 2030 level
- 50 per cent of goods transport is transferred to trains
- All remaining use of oil product within the transport sector is converted into electricity, hydrogen and bio fuels.

The initiatives mentioned above have been implemented in the reference development for transport. In table 5 and 6 the results are listed. The reference dataset is more detailed than the dataset used in the IDA Energy Plan, so the resulting figures are not exactly the same. The overall results however is the same.

As an example, the petrol and diesel consumption is divided into mode of transport for passengers and goods which was not the case for the data used initially. Also transport demands and energy demands for busses are separately listed.

In these initial calculations, the same efficiencies as in the IDA Energy Plan have been used. The technologies and efficiencies for the different modes of transport still have to be investigated and dicided upon. Here an example of a 100 per cent renewable energy transport system is illustrated. The technologies and energy carriers for different modes of transport have to be decided upon, i.e. hydrogen, methanol or other kind of energy carries. Also it is uncertain which technologies and fuels should be used for aviation.

Mode of pass. transport	Vehicle	Vehicle	Vehicle	Vehicle	Vehicle	Bus	Bus	Train	Train	Domestic aviation	Domestic aviation	Ferry	Ferry	Int. aviation	Int. aviation	Total
PJ/year	Petrol	Diesel	Bioethanol	Elec.	H2	Diesel	H2	Diesel	Elec.	JP	Bio fuel	Dielsel	H2	JP*	Bio fuel	
2000	77,3	10,1	-	-		8,4		2,5	0,6	2,0		3,0		33,1		137
2004	81,1	10,6	-	-		8,3		2,5	0,5	2,4		2,3		30,8		138
2010	66,9	9,4	5,1	0,8		8,3		1,3	1,3	2,5		2,3		32,6		131
2020	43,2	7,4	13,5	2,3		8,3		1,3	1,8	2,8		2,3		36,7		120
2030	19,5	5,4	22,0	3,7	-	8,3	-	1,3	2,1	3,1	-	2,3	-	40,1	-	108
2040	9,7	2,7	22,0	3,9	2,5	4,2	4,2	0,6	2,5	1,5	1,5	1,1	1,1	20,0	20,0	98
2050	-	-	22,0	4,2	5,0	-	8,3	-	2,9	-	3,1	-	2,3	-	40,1	88

Table 5, Fuel consumption for transport divided into modes of passenger transport and fuels.

Mode of goods transport	Heavy vehicle	Heavy vehicle	Van	Van	Van	Train	Train	Cargo ship	Cargo ship	Total
PJ/year	Diesel	H2	Petrol	Diesel	H2	Diesel	Elec.	Diesel	H2	
2000	24,1		7,1	25,1		0,30	0,05	0,89		58
2004	25,6		7,8	27,7		0,23	0,04	0,89		62
2010	25,2		7,7	27,1		0,11	0,23	0,99		61
2020	24,4		7,3	25,7		0,11	0,39	1,14		59
2030	20,5	-	6,7	23,7	-	0,11	0,54	1,29	-	53
2040	10,3	5,1	3,4	11,9	7,6	0,05	2,37	0,65	0,65	42
2050	-	10,3	-	-	15,2	-	4,20	-	1,29	31

Table 6, Fuel consumption for transport divided into modes of goods transport and fuels.

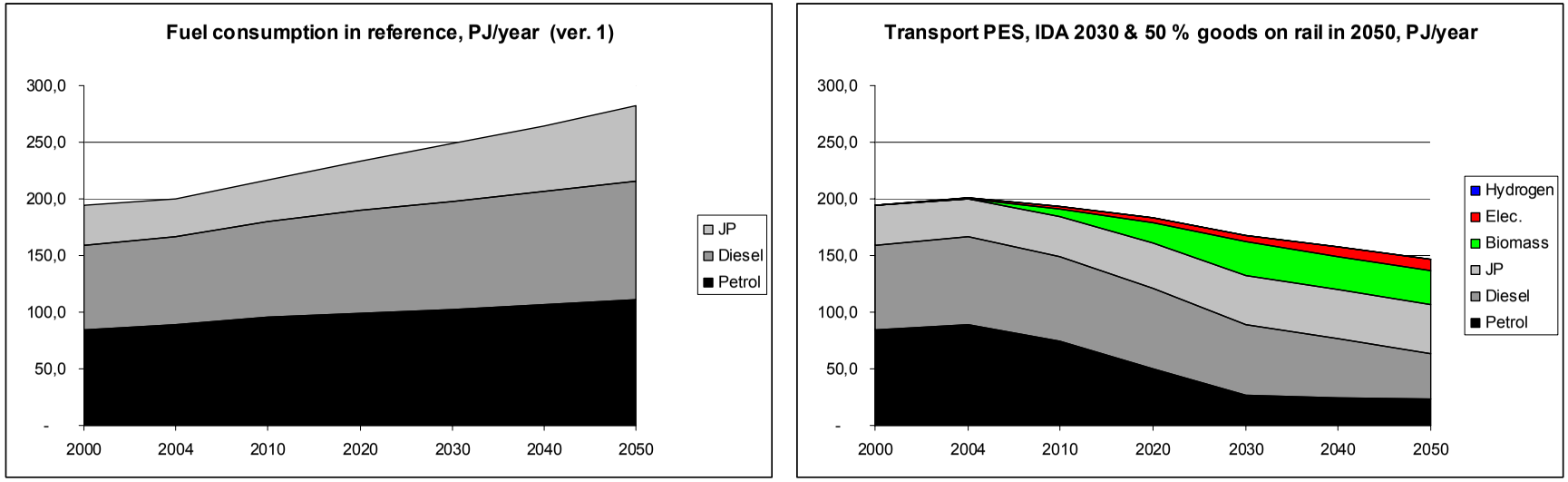

Fig. 4a and 4b, Fuel consumption in the reference for until 2050 (a) and for the IDA 2030 combined with 50 percent more goods on rail in 2050 (b).

In the figures 4a, 4b and 5 the results in the resulting primary energy supply are illustrated. In fig. 4a the BAU energy for transport demand is illustrated. In fig. 4b a development where the IDA 2030 initiatives are combined with 50 per cent more goods transport via rail is illustrated.

In fig. 5 it is evident that the biomass needed to supply the transport demand is highly dependent upon whether the transport demand is stabilised or not, and whether other more efficient modes of transport are used. In the example here, jet petrol has been replaced by a bio fuel using bioethanol as a proxy for the losses connected to procuring the fuel for aviation.

Because the dataset used is more detailed, some minor changes have been made in comparison with the IDA Energy Plan. In the example here, the remaining oil products consumption in 2030 has not been divided equally between bio fuels, electricity and hydrogen. Here 20 per cent has been replaced by electricity and 40 per cent by both bio fuels and hydrogen. A major reason for this, is the amount of bio fuels needed for aviation and the fact that it is unlikely for road based goods transport to be based on electricity.

In the IDA Energy Plan the biomass demand for transport is 75 PJ. In the example here 88 PJ of biomass is necessary. This may be lowered if more of the transport demand can be covered by electricity. In a worst case scenario where the only remedy for attaining a 100 per cent renewable energy system at least 382 PJ of biomass has to be used in the transport sector in 2050.

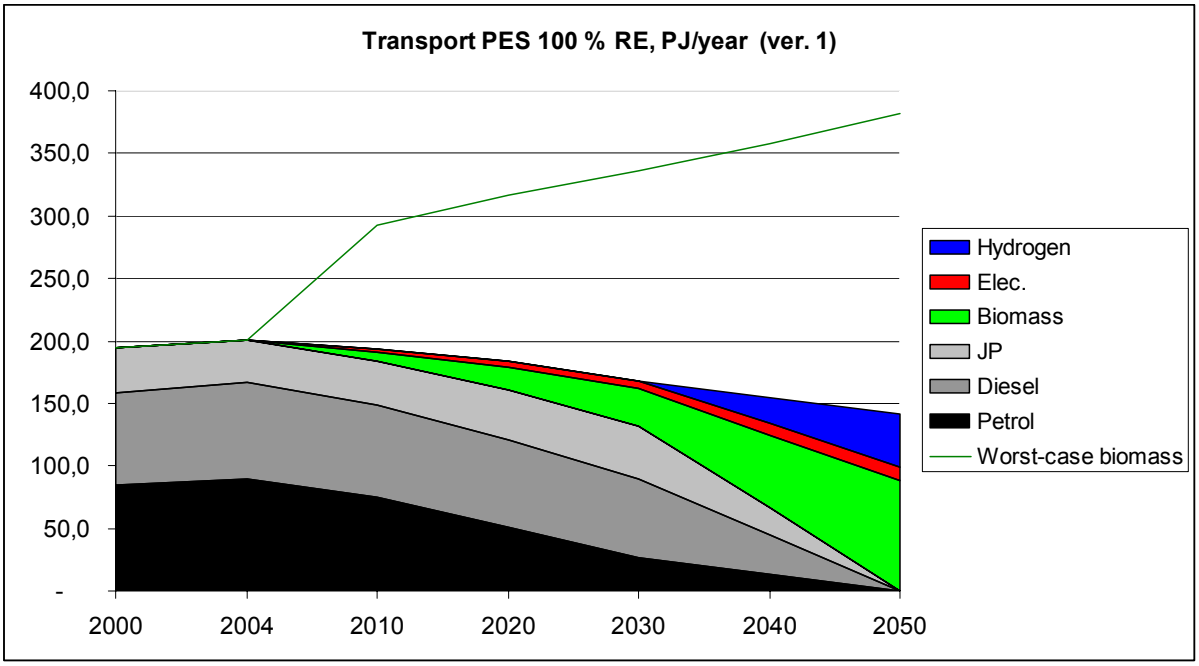

Fig. 5, Fuel consumption an example of a 100 per cent renewable energy development toward 2050.

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