DRAFT

Additional CO_2e-factors in goods transport

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1. Summary

This report addresses the issues of variations in climate impact due to factors not always considered.

Fuel consumption in road transport varies due to load and operational circumstances. The CO_2-impact from various operational situations with regard to fuel consumption has significant importance on the outcome. Our recommendation is to interpolate fuel consumption based on the engine load in tonnage on the truck. Furthermore should the mix of operational circumstances be reflected in the vehicle used. Best is always to use real measured fuel consumption data.

Additional fuel consumption due to use of thermo equipment is considerable for almost all technical applications. The exception is the Cryogenic (CO_2) technique although of little significance with a marginal market share (1 %). We recommend the use of an average default factor of 1.3 times the general fuel consumption for all road solutions. There should be no difference between frozen and refrigerated goods due to the fact that the cargo units used differ with regard to insulation. FNA-classed cargo unit with insulation for refrigerated goods and FRC-classed cargo unit with insulation for frozen goods compensate for additional energy use in these two applications. In container solutions in rail and sea transport we recommend the factor of 1.4, a somewhat higher factor due to lower relative emissions in these transport modes.

The climate impact from infrastructure is often neglected. This is a considerable factor that should be included in order to determine a more realistic climate impact. Important when using this factor is that comparison is carried out with similar assumptions for other transport solutions. In summary we recommend the below factors:
Road transport: 1.15
Sea transport: 1.2
Rail transport diesel and general electricity: 1.3
Rail transport renewable electricity: 5
Air transport: 1.05

In this brief study the leakage of refrigerants with a climate impact was analyzed. Our study shows a significant leakage estimated to 7.5 %, but the climate impact of the estimated amount leads to the conclusion that this factor can be neglected in this kind of analysis.

2. Background

The NTM data presented at the web page is basically based on four reports covering each mode of transport. In addition lifecycle data for traditional and alternative fuels are presented. The data includes delimitations with regard to the use of energy and emissions from infrastructure, usage of thermo equipment. Fuel consumption in the NTM models considered low for road transport and is therefore given some further analysis in this report. Another topic not included in present NTM documentation is leakage of refrigerants that has a high global warming potential.

3. Objective

The objective of this report is to assess important additional factors and deviations to present NTM data with regard to energy use and emissions of CO_2e.The aim is to present and quantify these factors. The report also dwells into the variations of fuel consumption in the NTM-models as compared to other sources as well as practical experiences.

4. Method

The method used for establishing additional factors is based on various official reports and practical experiences.

5. Delimitations

This brief report focuses only on goods transport. Some data are valid for passenger transport but the assessment of data was at this stage not intended for that application. In a coming version this may be added to the report.

6. Variations in fuel consumption

Vehicle type			Fuel / engine combina tion	Fuel Consumption [l/km]			
NTM notation		HBEFA notation		Highway / rural		Urban	
				Empty	Full	Empty	Full
1-P	Pick-up	N1-II	**P**etrol	See **Fel! Hittar inte referenskälla. Fel! Hittar inte referenskälla.**			
1-D	Pick-up	N1-II	**D**iesel				
2-P	Van	N1-III	**P**etrol				
2-D	Van	N1-III	**D**iesel				
3-P	Small lorry/truck		**P**etrol	n.a.	n.a.	n.a.	n.a.
3-D	Small lorry/truck	Truck/EURO 0-3 <7,5t	Diesel, Euro '0'-5	0,127	0,141	0,116	0,145
4	Medium lorry/truck	Truck/EURO 0-3 7,5-12t + 12-14t	Diesel, Euro '0'-5	0,172	0,200	0,191	0,259
5	Large lorry/truck	Truck/EURO 0-3 14-20t + 20-26t	Diesel, Euro '0'-5	0,216	0,274	0,307	0,460
6	Tractor + 'city-trailer'	TT/AT/EURO 0-3 <28t	Diesel, Euro '0'-5	0,185	0,233	0,251	0,358
7	Lorry/truck + trailer	TT/AT/EURO 0-3 (28-34t) + (>34-40t)	Diesel, Euro '0'-5	0,236	0,354	0,350	0,604
8	Tractor + semi-trailer	TT/AT/EURO 0-3 (28-34t) + (>34-40t)	Diesel, Euro '0'-5	0,236	0,354	0,350	0,604
9	Tractor + MEGA-trailer	TT/AT/EURO 0-3 >34-40t	Diesel, Euro '0'-5	0,243	0,384	0,371	0,665
10	Lorry/truck + semi-trailer	**N.A.**	Diesel, Euro '0'-5	0,327	0,490	0,484	0,836
No. 10 calculated under the assumption that these vehicles are 10% more energy efficient (per tkm) than No. 8 (Tractor + Semi-trailer).							

Source: Data processed by NTM based on HBEFA 2.1.

Based on the above presented data some example trucks have been selected for establishing the fuel consumption. The method used is an interpolation from empty to full truck using an average degree of utilization of 60 % for small trucks and 70 % for a large truck. In addition their use in traffic has been weighted as described below. In order to specify fuel consumption for general vehicles used this methodology is a general recommendation. If actual truck and fuel consumption is known that is a preferred method.

Type	**Engine**	**Utlization for fuel consumption**	**Share**		**Consumption [l/km]**
			Urban	Highway	
Van i city distribution	Euro 3	1,5 tonne total weight 60 % utilization	100	0	0,13
Small truck in city distribution	Euro 3	5 tonne total weight 60 % utilization	90	10	0,23
Large truck in city distribution	Euro 3	10 tonne total weight 60 % utilization	90	10	0,38
International tractor and semi-trailer	Euro 3	26 tonne, 33 pallets 60 % utilization	20	80	0,35
International tractor and semi-megatraile	Euro 3	26 tonne, 40 pallets, 60 % utilization	10	90	0,35
Truck and trailer (25,25 metres)	Euro 3	40 ton, 48/96 pallets, 70 % utilization	10	90	0,47

Example of establishing relevant general fuel consumptions

7. Thermo equipment and additional fuel consumption

7.1 Diesel equipment

This technology includes a small stand alone diesel engine running the cooling process. Based on fuel consumption data per hour from manufacturer and general assumptions on truck use in combination with assumed distances travelled for each type of vehicle as below:

Cooling equipment	**Distribution**	**Long distribution**	**Long haul**
Number of equipment	1	1	2
Operation hours per 24 hours	12	12	20
Number of 24 hours operation per week	5	5	7
Number of 24 hours operation per year	250	250	360
10 km per 24 hours	15	30	56
Estimated 10 km per year	3750	7500	20000
	Distribution	**Long distribution**	**Long haul**
Capacity (pallets)	18	33	51
Utilization (share)	0,5	0,6	0,7
Fuel consumption (l/km)	0,3	0,35	0,45
Fuel type	Mk1	Mk1	Mk1
CO2-factor (kg/l)	2,6	2,6	2,6
Thermofactor (fuel increase)	1,45	1,28	1,32
CO2 per pallet km	(kg CO2/palletkm)	(kg CO2/palletkm)	(kg CO2/palletkm)
Dry goods gods	**0,087**	**0,046**	**0,033**
Chilled and frozen goods	**0,126**	**0,059**	**0,043**

7.2 Hydraulic driven equipment

This technology relays on the vehicles diesel engine using energy from the transmission shaft running the refrigeration unit. Its advantageous is emission performance and energy efficiency corresponding to the vehicle engine although with transmission losses from shaft to the cooling equipment. Its main drawback is the need for an idling engine or plug in of external electricity at stand still of the vehicle.

Our general assumption on additional energy use in this technology is 0.07 to 0.12 litres per km. For the different trucks this leads to a CO_2-factor of approximately 1.23 in distribution, 1.2 in long distribution and 1.27 in long haul.

7.3 Alternator (generator) driven equipment

This technology relays on the vehicles diesel engine using energy from the transmission shaft running the refrigeration unit via an alternator that runs the electric cooling equipment. Its advantageous is emission performance and energy efficiency corresponding to the vehicle engine although with transmission losses from shaft to the cooling equipment. Its main drawback is the need for an idling truck engine or plug in of external electricity at stand still of the vehicle.
Our general assumption on additional energy use in this technology is 0.07 to 0.12 litres per km. For the different trucks this leads to a CO_2-factor of approximately 1.23 in distribution, 1.2 in long distribution and 1.27 in long haul.

7.4 Eutectic system

This system is based on the usage of various freezing blocks placed in the cargo volume and thereby enabling distribution of refrigerated goods. This technology is rarely used apart for some applications regarding refrigerated dairy goods.

7.5 Cryogenic systems

The cryogenic system uses liquid carbon dioxide as refrigerant and as a power source for unit evaporator and fans. Stored in a vacuum insulated tank, the cryogenic fluid provides instant cooling capacity.

Life cycle analysis from CIT, Chalmers indicates very low energy use and climate impact from the system. An additional calculation presented below confirms the good environmental performance.

Description	value	Entity
Transport unit	13,6 trailer	meter
Time	1	hour
CO2 use	39	kg
CO2 use	33	litre
CO2 Fuel production	6,67	kWh/kg
Energy use	5,85	kWh/h
Primary energy use	6,50	
CO emission		
EU-25 CO2	410	g/kwh
Renewable energy	0	
CO2 emission, EU25	2664	gramme/h
CO2 emission, renewable	0	gramme/h

In a distribution truck with assumptions on transport on distances presented in 7.1 this would in a EU25 electricity scenario mean additional 0- 20 % CO_2 per km in distribution and some 0-10 % in long distribution and long haul The relative high numbers in distribution is due to short transport distances. Renewable primary energy used by definition mean no CO_2 emissions.

7.6 General conclusions on thermo equipment

- Cost, performance and reliability and ability to run as stand alone units are often key criteria’s when choosing technical solutions.
- Extra energy use in conventional techniques (engine, hydraulic and alternator) is considerable when analyzing thermo transports climate and environmental impact.
- Alternator and hydraulic solutions seems slightly more energy efficient than conventional stand alone engine techniques.
- The cryogenic solution is the most energy efficient solution with very good functional performance that in addition can be based on non fossil electricity, hence no fossil CO_2-emissions. At the moment this technique only has one percent of the market.
- Being cautious at this stage we recommend the use of average default values as below for all road solutions.
  Road transport: 1.3
  We do not recommend any difference between frozen and refrigerated goods due to the fact that the cargo units used differ with regard to insulation. FNA-classed cargo unit for refrigerated goods and FRC-classed cargo unit for frozen goods.
- In container solutions in rail and sea we recommend a somewhat higher factor due to lower relative emissions in these transport modes.
  Sea and rail: 1.4

In summary our assumptions are somewhat higher than other reports studied:
In Ritchie K, From farm to table: An energy consumption assessment of refrigerated, frozen and canned food delivery. A report in draft prepared by Scientific Certification Systems on behalf of the Steel Recycling Institute, California, US they recommend a 14 % additions on transport energy.

In Corporate Responsibility Report 2005 J Sainsburys, UK the recommendation is a 15 % addition on transport energy.

8. Infrastructures use of energy and green house effect

All modes of transport depend on sufficient infrastructure. Depending on the mode of transport the additional CO_2e effect of infrastructure varies. The below presented data are based on data the following different sources as well as interviews with some experts in the field:

Ecoinvent. 2007. Spielmann M, Bauer C, Dones R & Tuchschmid M. *Transport Services*. Data v2.0. Ecoinvent report No. 14. Ecoinvent Centre. Swiss Centre for Life Cycle inventories. Villigen and Uster

Svensson, Niclas
Life-Cycle Considerations for Environmental Management of the Swedish Railway Infrastructure
Linköping University, Department of Management and Engineering

IVL report B1526, Miljödeklarerad infrastruktur

Based on data from these sources some very general key average figures are presented for each mode of transport:

Road transport

The available data for additional factor for CO_2e has a spread of 1.08 to 1.24. Given the uncertainties our recommendation is to use a factor of 1.15 which is in the lower range.

Sea data

The available data for additional factor for CO_2e has a spread of 1.19 to 1.31. Given the uncertainties our recommendation is to use a factor of 1.2 which is in the lower range.

Train data

The available data for additional factor for CO_2e has a spread of 1.36 to 5 (electric train). Given the uncertainties our recommendation is to use a factor of 1.3 for electric trains in Europe and diesel trains in general and for trains running on renewable electricity using the factor 5.

Air

The available data for additional factor for CO_2e has a spread of 1.02 to 1.18. Given the uncertainties our recommendation is to use a factor of 1.05 which is in the lower range.

9. Leakage of refrigerants and their green house effect

An area seldom included in the analysis of climate impact from transportation is how thermo equipment leaks refrigerants that have a potential climate impact. Originally the refrigerants were CFC in these equipments but due to negative impact on the ozone layer they were in accordance with the Montreal protocol replaced by HFC.

The most common refrigerants today are R-404A and 134a with no or small ozone depletion potential (ODP). The negative aspects of these refrigerants are their global warming potential (GWP). CO_2 with its climate impact ha a GWP of one (1) as a denominator. In reference to CO_2 other refrigerants have various GWP according to IPCC expressed as CO_2e.

Type	GWP
CO_2	1
134a	3300
R-404A	4800

In theory and in legislation thermo equipments are not supposed to leak refrigerants. In legislation they should undergo annual control and maintenance in order to fulfil the technical specifications of no leakage. This is unfortunately not carried out sufficiently. In general the equipment only under go an ocular inspection and receive approval for another year.

The leakage originates from various wear over the years in pipe connections, valves, compressors, condensers etc. When the equipment is delivered from the factory it can be considered to have no leakage. Estimating the amount for topping up all systems an estimation of annual leakage is 5 to 10 %. In trucks the amount is approximately 4.5 kg and in trailers the amount is approximately 6.5 kg

Calculation example
In Sweden there are some 4000 equipments in trailers and 8000 equipments in vehicles. This would in total sum up to 62 000 kg of refrigerants. Assuming a leakage of 7.5 %, that is 4650 kg annually. The annual CO_2e emissions would be 22 320 tonnes. The total emissions of CO_2 from goods transport in Sweden is approximately 11 000 000 tonnes.

For a truck the economic life length could be assumed at 8 years. Leakage of 7.5 % would correspond to exchanging the amount of refrigerants every 13.3 years. For the 8 years period that would correspond to 60 % of the total leakage (8/13.3). Trailers would approximately have a life length of 10 years that would lead to 75 % (10/13.3).

	Total [kg]	Burden	Annual burden	CO2 factor	CO2e [kg]	Distance [km]	CO2-thermo factor
Distribution truck	4,5	0,6	0,3375	4800	1620	37500	0,0432
Long distribution	4,5	0,6	0,3375	4800	1620	75000	0,0216
Long haul	4,5	0,6	0,3375	4800	1620	200000	0,0081
Trailer	6,5	0,75	0,4875	4800	2340	160000	0,0146

Given the size of the thermo factors we do not recommend to consider this aspect in separate transport evaluations. We do however believe this aspect should be taken better care of in the general preventive environmental work in transport operation and management.