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FUEL/CARBON PRICE VS. ABATEMENT TECHNOLOGY IN FREIGHT TRANSPORT

Eugen F. Spangenberg

Abstract

The current situation is the exponential increase in greenhouse gases (GHG), which is mainly caused by industrial and transport activities. The recent Paris agreement in 2015 (Framework Convention on Climate Change COP21, UNFCCC) made it clear to everyone that CO2 emissions are to be limited in all areas of life. Alternative fuels with a lower environmental impact than carbon (CO2) emissions are hard to find if the overall footprint is to be taken into account. Nevertheless, there are some fuels that have less impact on climate change. One the other hand, the production of biofuels is a controversial matter, although it is a viable alternative to emissions reduction. CNG or LNG-powered vehicles are also better in terms of environmental pollution, but are hardly better with regard to CO2 impact when a Life Cycle Assessment (LCA) is carried out. LNG (liquid natural gas), for example, is the future fuel in the maritime sector because of the stricter environmental regulations (SOx,NOx) in the shipping industry. The battery-powered vehicle is another example of an environmentally friendly solution. The aforementioned measures can be considered as "abatement" necessary in order to limit CO2 impact. The study shows that there are significant differences in the environmental impact between transport systems and the corresponding drive-system or associated energy base. The polluter should pay, which is a common basic principle in economic research. The Emission Trading Scheme (ETS) has been introduced in order to ensure a reduction in CO2 output – emissions come with a price tag. An overall view is necessary, both environmental and economic impact must be reconciled (cf. Spangenberg - TQI). The future viability of the transport system as we know it may change significantly over time if new environmental requirements or e.g. CO2 taxes or ETS are introduced in the freight sector. The abatement of CO2 should be effected primarily through technological measures such as the correct and sustainable choice of vehicle and energy source.. The imminent introduction of external costs (cf. M.Bac) in the transport sector is another reason for comparative studies.

Keywords: freight transport, abatement CO2, external costs, TQI.

JEL classification: R40

Introduction

Transport is not sustainable and has begun to present an increasingproblem. This paper focuses on the freight sector. The importance of transport is undisputed when the product is processed, manufactured and used in different locations.. Transport is integrated into the production process and is to be considered as a unit in terms of costs and environmental impacts. Transport has impacts that result in cost to society which is taken into account as social or external costs. Social costs reflect costs which arise due to the construction and operation of infrastructure in addition to environmental costs.

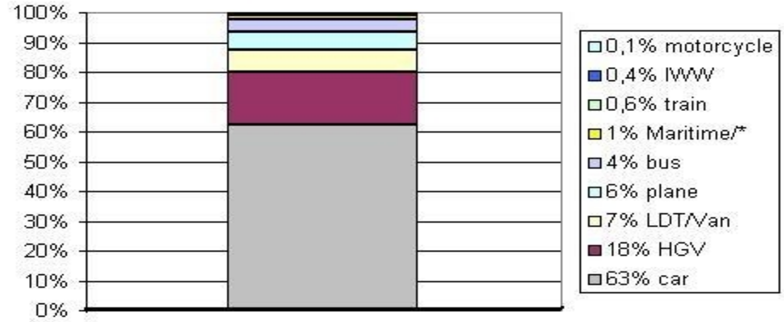
The central problem is that fossil fuels account for more than 90% of energy production, and with that comes a great amount of CO2 emissions. Carbon emissions are responsible for climate change which is a very serious issue caused by CO2 concentration in the atmosphere. The increase in CO2 concentration and global temperatures has been dramatic in recent years and is linked to the largely uncontrolled CO2 emissions (14 warmest years on record have all happened this century; UN World Meteorological Organisation). CO2 emissions are now at the highest level in at least 0.8 million years. Once released, CO2 can hardly be contained and the problems it might create for the future generations (delayed effect of past emissions) are difficult to foresee.

Unlike the US, China and other industrial superpowers, Europe has not set upper limits for CO2 emissions for freight transportby road. This combined with a failure to consider external costs has led to a spread of heavy-weight lorry transport across Europe. The average fuel consumption of semi-trailers in Europe has not diminshed for more than 10 years. Exhaust gas treatment and greater traffic densities lead to higher fuel consumption and CO2 emissions. However, there is a chance that greenhouse gas targets will drive CO2 monitoring, leading to tigher limits on truck traffic in the futureThe possibilities of CO2 savings in the transport sector are overall enormous, comparable to the potential of energy generation. There is a trade-off between greenhouse gas damage and abatement measures. The task is to organise the abatement measures in a cost-effective way, which means that measures should be directed to where the carbon savings can be obtained in the easiest way, rationally and with the existing technology. Also, the timing of implementation is crucial, as any further delay means more stringent requirements for future action, and, if necessary, severe restrictions in all areas of life. Large-scale construction projects, such as erecting concrete dams against rising sea water levels, witness China's plans to shield its coastline with a protective concrete barrier-like structure, require enormous input of energy, contributing to rising CO2 emissions.. Thus, instead of a proactive approach, countermeasures only come in response to climate change. It is usual to assume that later abatement will be more effective than today; this could be a misconception – such as the value of projected damage costs is reduced because of high assumed discount rates. The negative impacts of carbon emitted today will continue to be felt over 200 years from now. For this reason, it is important to limit emissions today,or at least contain CO2 and put a stop to releasing it into the atmosphere.

1. Transport and related facts

1.1. Modal split of carbon impact in the transport sector

The passenger car impact in terms of CO2 is dominant in the EU, while heavy goods transport (HGV) ranks second with almost 20% CO2 emissions (Fig. 1).



/* maritime share excluding OBO freight (OBO, oil, bulk, ore)

Fig. 1. Share CO2 emissions in the European Transport Sector

Source: own calculation.

The CO2 impact has a cumulative effect on the atmosphere as long as carbon emissions abatement is not implemented ('business as usual' scenario). 35 years from now (2015-2050), the additional amount of CO2 will be equivalent to the total EU emissions per year (Fig. 3).

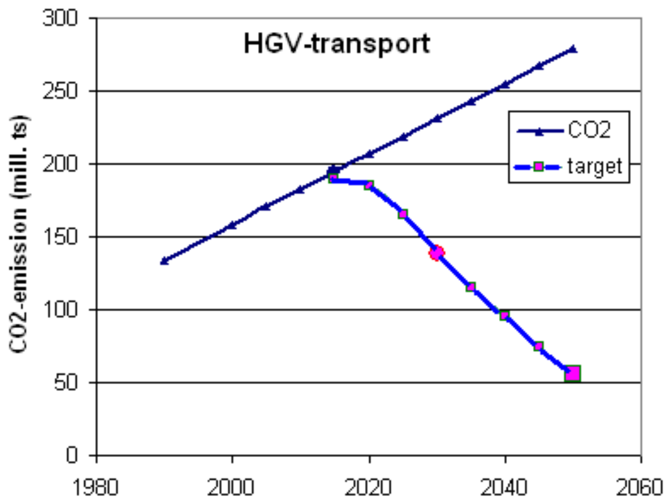


Fig. 2. CO2 emissions (HGV) comparison, EU objectives and prognosis

Source: own calculation, (HGV=HDV heavy duty transport).

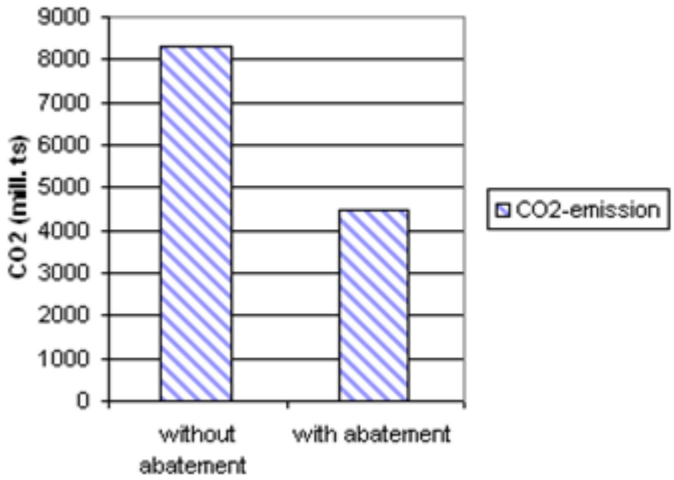


Fig. 3. Cumulative CO2 impact (HGV, period 2015-2050), with and without abatement measures

Source: own calculation.

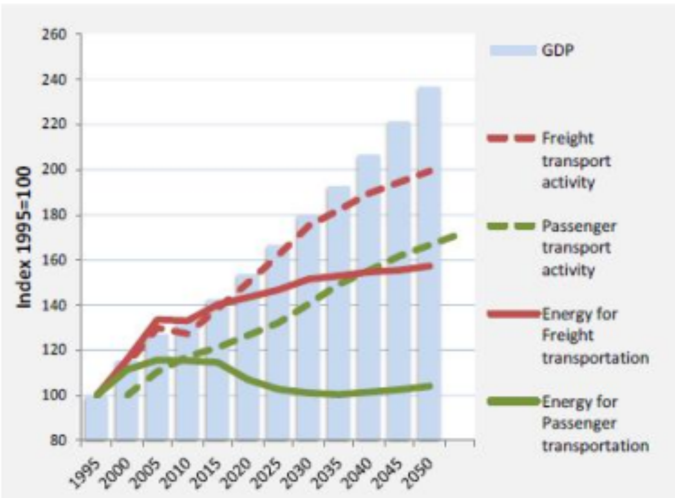


Fig. 4. Relative transport activity and energy consumption

Source: Trends to 2050, European Commission, 2014, p. 40.

The Europen Commision expects that a 25 per-cent increase in efficiency gains in the transport sector will partially offset the increase in traffic (Fig. 4). However, fuel and/or drive systems have to change as well in order to achieve the European objectives in the goods transport sector (Fig. 2). Nevertheless, the absolute increase in energy demand will be a problem. For this reason, it can be assumed that CO2 targets (Fig. 2) can only be achieved when an overall structural change in the transport sector occurs (e.g. shift of transport activities).

1.2. Abatement measures in relation to transport damage

There is a need sustainable abatement measures are required, leading to a diminished carbon footprint overall. Consideration must be given to the possibility of a life cycle assessment e.g. of the fuel and the corresponding drive system. The abatement measures should prevent the largest damage, as there are more and less important issues to take into account e.g. traffic noise and particle emissions cannot be avoided entirely. Abatement costs increase exponentially (Fig. 6). A compromise (ideal equilibrium) must be found and depends on the technology competence and corresponding abatement with respect to social costs (Fig. 5).

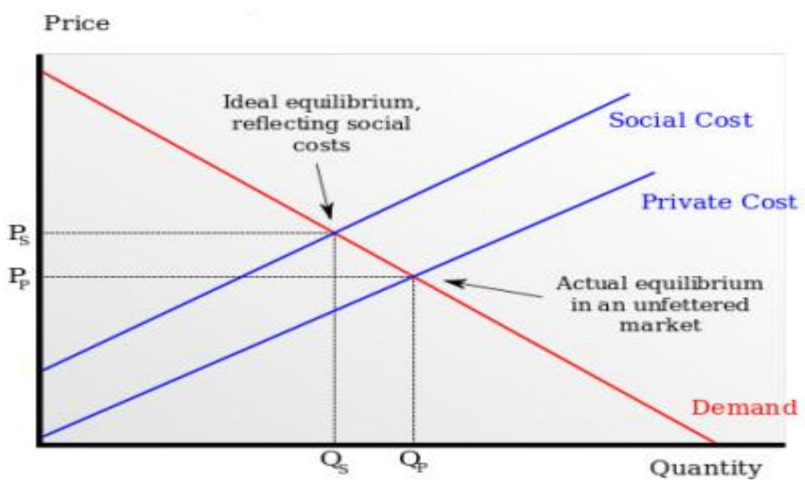


Fig. 5. The influence of social costs on consumer demand

Source: K.Blok et al., Subsidies and costs of EU energy, Ecofys by order of EC, 2014, p.12.

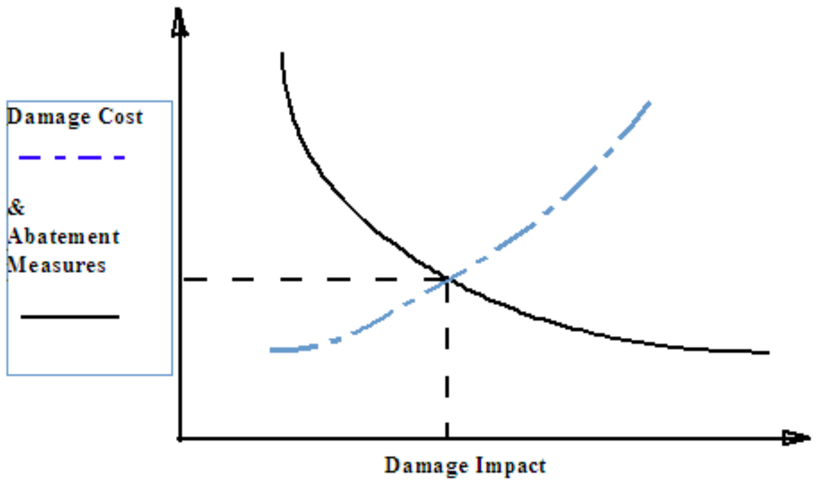


Fig. 6. Damage cost versus abatement measures in relation to costs

Source: own ellaboration.

1.3. Social welfare and associated external costs

Social welfare generally generates additional costs (externalities: taxes, ETS certificates, etc.) and increase the price of transporting goods, which results in the relocation of production and consumption (demand reduction), diminishing the overall environmental impact ('polluter pays' principle). Despite serious environmental impacts, the effects of CO2 are generally underestimated – presumably because global warming is controversial.

Life cycle assessment takes into account the whole impact as production, usage and recycling, with the aim of estimating the total environmental footprint.

The European Union has actually set itself the goal of introducing a smart pricing and taxation system by 2016, which should reflect the total costs of transport in regard to infrastructure and external costs as related to its implementation in the period 2016-2020 (White Paper 2011, European Commission, Brussels 2011, Staff Working Paper, p.123).

As quite a few sectors are clearly opposed to the internalisation of external costs and fear for their competitiveness, it remains to be seen how much of a factor that will be in the future.

2. Comparison of different modes of freight transport in terms of costs

2.1. The impact of external costs and changes in total costs

The following figure 7 documents the vast differences between individual modes of transports. At first glance, maritime transport is by far the least cost-intensive (maritime: by 1000 TEU feeder container ships). But with the addition of loading and unloading operations at the port, the cost rises by 150-300 %[1] p. tkm (depending on the length of voyage), and so the benefits shrink.In addition, further land-based transport by rail or road to the destination incurs further costs. Therefore freight forwarders are trying to transport cargo to the destination directly by road, even on long routes, despite the increased social burdens. A change would occur if external costs were taken into account Also the competitive situation for the rail transport has been improved compared to road transport, but rail transport is also not able to deliver their goods directly to the destination, as additional costs are also incurred.

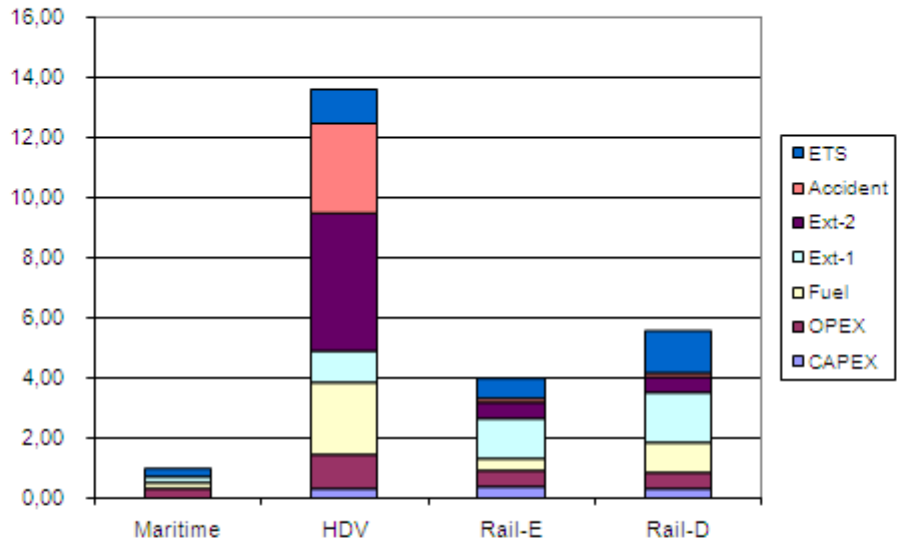


Fig. 7. Comparison of different transport mode (private and external costs)

Source: own calculation, with: EUR-cent p. tkm) containerized freight, calculations do not include material extraction of natural resources and fuel production (WTT) impact as well, for rail-e fuel means electricity and corresponding impact through power generation (other authors define the impact not as extrenal).

Even today, the cost of road transport is approximately six-fold higher than, for example, by ship (excluding external costs and port dues), whereas CO2 emissions are about 3.5 times greater, including in particular WTT and construction footprint (total CO2 impact: HDV 60 g/tkm and ship 17 g/tkm).

Taking into account the sustainable aspect, trucks should only be used on short distances with economical and environmentally friendly engine drives. Truck drivers could then be

[1] Own calculation: 1) loading + discharging of a 20ft. Container by 200 EUR by 500 km voyage results by 2 cents per tkm; 2) ships cost by ca. 0,5 – 1 cent per tkm. Result: 2,5 – 3 cents per tkm, which means rise of cost up to 300 %

employed in logistic centers – meanwhile the overnight stay in the vehicle would be restricted in the future (new regulation of the European Court of Justice).

Taxes on fuel could be better converted into a CO2 tax, which correlates with the required CO2 savings.

In that context, shipping businesses should be following the implemented policy measures by developing independent intermodal transport[2]:

1. organisation of regular transport services,
2. partnership with freight forwarders for hinterland transport,
3. development of own ports and loading structures,
4. purchasing community regarding environmentally friendly fuels,
5. lending of environmentally friendly vessels,
6. compliance with sustainability criteria in all areas by LCA,
7. RoRo and RoPax ships (freight) should be replaced if possible by container ships.

2.2. Further aspects regarding external costs as part of social cost issues

The need for action (abatement) is linked to the increasing burden of social costs[3] in the transport sector; a redeployment of funds into sustainable future-oriented policies is required. Transport on land is disproportionately supported, the European taxpayer pays the cost and deferred environmental costs (external costs as yet not incurred). The implementation of a "new" sustainable transport system fails on its own success so far. The interests of industry and business representatives have prevented a sustainable policy. A redirection is becoming more and more difficult.

The most important measure is to implement external costs for land transport and intermodal transport, e.g. from 100 km upwards. The social costs should reflect the circumstances (impact) of the whole transport. This should also be included in the following items, which are generally not yet considered (cf. Bac) in the external/social costs:[4]

- private additional costs due to road and rail congestion,
- congestion caused through road damage from heavy duty vehicles (HDV or HGV),
- land loss for the general public,
- depreciation of property by transport traffic (principle of proportionality),
- additional occupation of traffic area and general public area,
- scarcity rent of resources e.g. fuel and construction material (opportunity cost)
- additional accident costs due to injured and traffic deaths.

2.3. Fuel alternatives and their abatement costs

The EU relies on a number of green alternatives to traditional fuels, such as biofuels and electric batteries for road transport, and LNG for water-borne transport. Biofuels have to be critically reviewed in terms of their feedstock. Biofuel as an alternative fuel is not necessarily a better choice. The extension of biofuel production cannot be accomplished without emission; a LCA is necessary, in particular the calculation of a balance sheet in order to get well to tank result (WTT). The EU recommends that the use of biofuel should result in an overall GHG saving of 35%. Given the correct selection of raw materials, as in the case of ethanol, wood-based biofuels fulfil the EU's sustainable conditions in an excellent way, most important is the correct selection of the raw material as for ethanol (Czermanski, 2014).

[2] Prevent intermodal transport and promote unfavourable road freight traffic (heavy duty transport).
[3] Social cost=(external+private) costs cf. Fig. 5.
[4] Should be based on vehicle specific type class, which opened innovations in terms of reduction the environmental impact.

The emerging interest in LNG as a fuel, e.g. in the maritime sector, is controversial. Because of methane slip (leakage up to 5%), methane is 25 times more harmful in terms of GHG impact, even though the lifetime of methan is almost 12 years[5].

In general, the integration of fuels and technologies for heavy duty vehicles, aviation and marine applications is more challenging than for other energy-intensive sectors. The abatement costs are to be evaluated in detail and are very different.

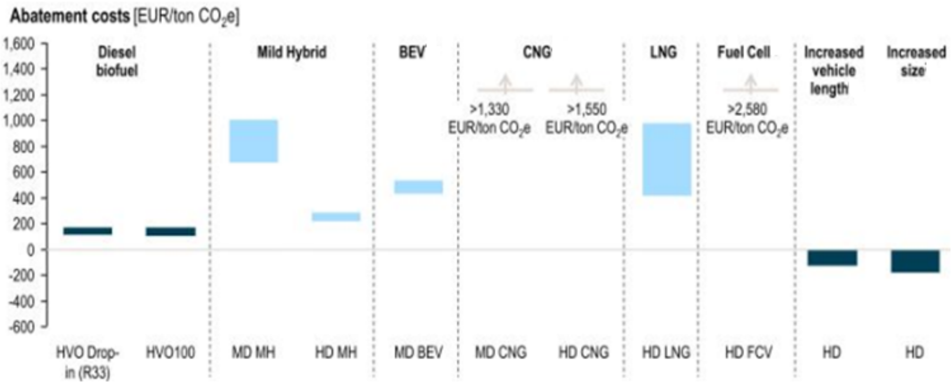


Fig. 8. GHG abatement costs for alternative fuel options (EUR/tons CO2)

Source: Schlick, Roland Berger 2016, Integrated Fuels and Vehicles Roadmap to 2030 refer on IKA CO2 study; with: BEV battery electric vehicle, CNG compressed natural gas, MD/HD medium duty/heavy duty.

Diesel biofuel for internal combustion engines (ICE) as a new standard fuel (renewable fuel) seems to be a cost-optimal solution in terms of abatement costs (Fig. 8), whereas for BEV and LNG trucks, the corresponding abatement costs are not competitive. Hydrogen-electric fuel cell powertrain (300 kW) on the road could be the future from 2020 on the way to zero emissions from energy creation to energy consumption.

Hybrid trucks with electric overhead wires (catenaries such as trolleybuses) are likely to be introduced. The first trial motorway is in operation in Sweden on a test track. The electrification of longer motorway sections would drive up infrastructure costs and resource depletion of scarce copper resources – the same can be said for the lithium battery. More likely is the introduction of battery electric vehicle (BAV) for smaller trucks (medium duty vehicle MD or urban eTruck) for a range up to 200 km and a battery capacity e.g. of 2x125 kWh (MAN project). The FH (full hybrid) vehicle can only be combined with gasoline engines because of diesel vibrations which are harmful for the battery (Note: gasoline engines have a 10-20% lower efficiency and therefore a higher CO2 impact).

5 https://earthscience.stackchange.com

Fuel footprint g/tkm WTT	9,9	
Ext1	1,08	c/tkm
Ext2	4,6	
Accd.	3	c/tkm
Sustainability Criteria	58,07	g/tkm
Economic Criteria	3,82	cent p.tkm
External costs etc.	8,68	
Freight capital cost Euro /t/d	0,00	Euro /t /d
Trip (day) km	1200	
Average speed km/h	50,00	
Detour Factor	1	
Number of Trips/vehicle:	1	
payload / Trip	20	
Transport Performance tkm/d	2,400E+04	
tons/d CO2	**1,39**	
Euro p.d	**3000**	
TQI-Solution		
tons/d CO2	**1,39**	
ETS Euro / t CO2	**0**	
ETS Costs p.d. Euro	**0**	
TQI =	**8,0**	tkm p.Euro

Fuel footprint g/tkm WTT	45,7	
Ext1	1,08	c/tkm
Ext2	3,2	
Accd.	3	c/tkm
Sustainability Criteria	54,17	g/tkm
Economic Criteria	7,03	cent p.tkm
External costs etc.	7,28	
Freight capital cost Euro /t/d	0,00	Euro /t /d
Trip (day) km	600	
Average speed km/h	25,00	
Detour Factor	1	
Number of Trips/vehicles	2,66	
payload / Trip	15	
Transport Performance tkm/d	2,394E+04	
tons/d CO2	**1,30**	
Euro p.d	**3426**	
TQI-Solution		
tons/d CO2	**1,30**	
ETS Euro / t CO2	**0**	
ETS Costs p.d. Euro	**0**	
TQI =	**7,0**	tkm p.Euro

Fig. 9. Transport comparison (HDV) with diesel drive system (left) and BEV (right)

Source: own calculation, all costs such as capital, operating and external costs were taken into account, with: BEV battery electric vehicle, TQI (tkm/EUR) take into account economic and CO2 footprint (in the example, the CO2 certificate price is zero), cf. https://link.springer.com/chapter/10.1007/978-3-319-51427-7_1?no-access=true

A comparative calculation (Fig. 9) has revealed that BEV is not a better solution in regard to sustainable criteria. Electrically powered trucks (BEV) have a lower performance than corresponding diesel-powered vehicles, more than two BEV are needed (2.66). The transport quality index (TQI) is more than 10% smaller for a BEV. The difference in the CO2 impact is small (1.3<1.38 ts p.d.), because the battery (200 kg CO2 p. kWh) production and electric power generation (500 g/kWh) footprints are decisive factors in this context.

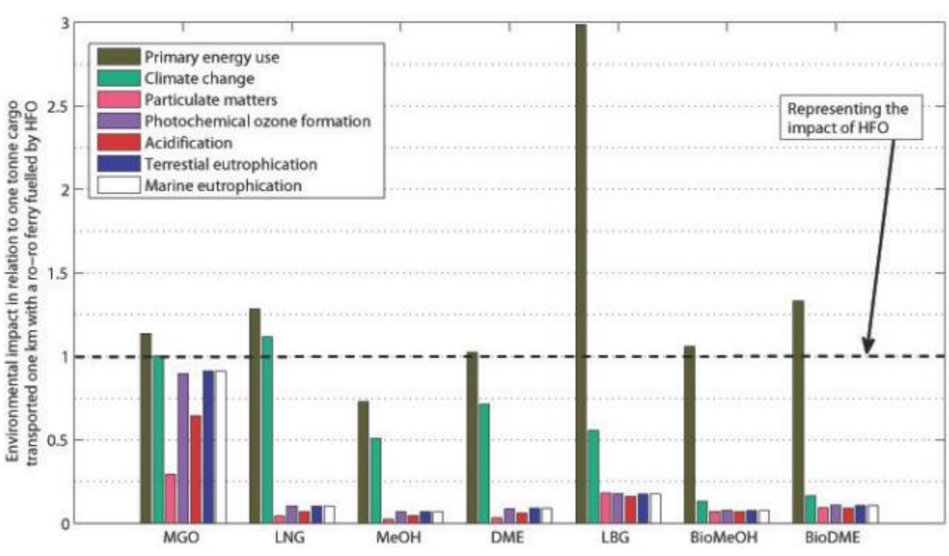


Fig. 10. Environmental footprint of Methanol, MGO, LNG etc.

Source: Workshop:Wellcome to the final EffShip Seminar Paper, 2013, Sweden, p. 7.

Methanol (cf. Faberi) as a future fuel could be a solution in many aspects, may also be produced nearly climate neutral from renewable electricity (generation of H2) and CO2 as feedstock (Figure 11). The current production is energy-intensive (Figure 10) and natural gas serve as feedstock in the syngas process (converting natural gas to methanol), which is connected with high costs and therefore not competitive in comparison to common fossil fuel.

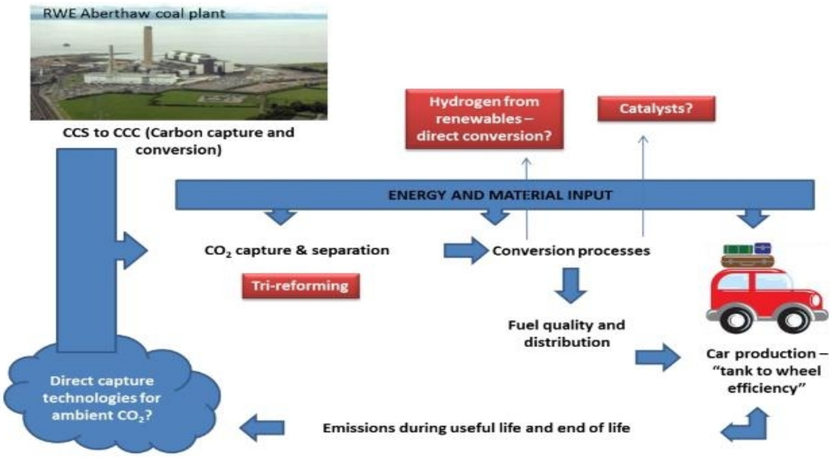


Fig. 11. Carbon neutral (almost) production of methanol

Source: Faberi, Methanol: a future transport fuel based on hydrogen and carbon dioxide, Methanol Production and use from life-cycle perspective, E.Ipinazar Tecnalia, STOA-EU Parliament, Brussels, 2013.

Carbon capture from coal-fired power generation could be advantageous in two respects, i.e. eliminating the carbon emissions and producing a nearly climate-neutral fuel (methanol). Today's extra costs would be a good investment in the future, especially in the event of an increase in the cost of certificate for CO2 in the energy sector. Then the production of methanol would be more economically interesting.

Conclussions

In the transport sector, long-term solutions are required, as a switchover to CO2-lower fuels such as LNG etc. would not bring about a decisive change. Heavy battery-powered trucks are not a solution, because the payload of the vehicle is greatly reduced and valuable basic materials for battery production are limited and would find a more useful application in urban transport systems, in particular in order to sustainably protect environmental pollution in urban areas. In shipping, the use of battery-powered ships is to be excluded because the energy requirement is far too high (this excludes small vessels at short distances). In this context, bio-fuel or methanol is by far the most sustainable fuel in terms of CO2 emissions, especially when renewable energies are used in the production of the respective fuel.

In all considerations, today's decisions must be considered in the long term. The European plan (TEN-T) to build a comprehensive transport network with motorways and rail networks is to be questioned, if the environmental burdens and the agreed reductions are not clarified at the same time. So far, the energy issue with low CO2 impact is unresolved, assumed efficiency gains are not expected to be achieved because this is physically not possible if the current strategies are to be maintained.

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REDUKCJA EMISJI SPALIN W TRANSPORCIE ŁADUNKÓW A CENY PALIW

Streszczenie

Obecnie największym źródłem emisji gazów cieplarnianych jest przemysł i transport. Udział źródeł odnawialnych w strukturze energetycznej całego świata wciąż jest na niskim poziomie. Jednakże spośród dostępnych i używanych paliw wyróżnia się te, które cechują się znacznie niższą emisją spalin. W tym kontekście pod znakiem zapytania stoi produkcja i stosowanie biopaliw, których spalanie powoduje znacznie większą emisję aniżeli spalanie gazu. Pojazdy zasilane gazen CNG lub LNG wpiusują się w tym kontekście jako najczystsze paliwa, szczególnie pod względem CO2. Doświadczenia stosowania LNG w transporcie lądowym przenoszone są do sektora żeglugowego i stanowią istotny element przyszłych technologii napędów statków, szczególnie wobec zaostrzających się limitów zawartości SOx oraz NOx w spalinach statkowych.

Głównym celem artykułu jest wykazanie istotnych różnic oddziaływania na środowisko przez sektor transportu ze względu na różne źródła energii. Od tego zależeć będzie sprawność systemu transportowego w przyszłości w kontekście wdrażania procesu internalizacji kosztów zewnętrznych i obciążania nimi podmioty generujące emisje GHG. Stosowane i wdrażane nowe technologie powinny w szczególności jako pierwsze brać pod uwagę redukcję CO2.

Słowa kluczowe: transport ładunków, redukcja emisji CO2, koszty zewnętrzne

Klasyfikacja JEL: R40

Eugen Ferdinand Spangenberg
Maritime Consulting GmbH
Steinstrasse 25, 24118 Kiel, Germany
Spangenberg-uni.gda@directbox.com