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THE HIGHWAY TO PARIS: SAFEGUARDING THE CLIMATE BY DECARBONISING FREIGHT TRANSPORT

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Climate Action Tracker

KEY MESSAGES

- To be compatible with the Paris Agreement's long-term goal, freight trucks need to be almost fully decarbonised by around 2050.
- To achieve this goal, governments need to set up policy strategies for decarbonising freight vehicles and to incentivise modal shift.
- A carbon-free power sector is essential for decarbonising road freight transport—either through electric or fuel cell trucks driven by renewables-based fuels such as hydrogen, biofuels, or synthetic fuels.
- Trucks can contribute to a decarbonised electricity system by providing storage and flexibiity.
- Biofuels, if produced sustainably, are one of the few GHG emissions reduction options for road freight available immediately.
- By 2030, the freight sector would need to achieve mass market deployment of electric and fuel cell trucks.
- Commercial electric and fuel cell trucks are emerging, but countries need to urgently ramp up incentives for deployment and support renewables- based hydrogen or other fuels.
- Results for the EU show that there is potential to reduce all emissions from heavy road transport by 30% below 2015 levels by 2030 (not only for new trucks).
- Zero carbon road freight would bring significantbenefits including improved air quality, energy security, electricity storage and economic development.
- A rapid transformation towards zero carbon freight transport options could occur much faster than assumed by many analysts.

INTRODUCTION

Decarbonising the transport sector, which accounted for 28% of global CO2 emissions in 2014,[1] is crucial for the transition to a low-carbon economy in line with the Paris Agreement (Sterl et al., 2016).

To meet the Paris Agreement's long-term temperature goal, global GHG emissions need to peak urgently, start declining and reach net-zero in the second half of the century, with fossil fuel-related CO2 emissions going below zero by around 2050 (Luderer et al., 2013; Rogelj, McCollum, Reisinger, Meinshausen, & Riahi, 2013; Schleussner et al., 2016).

About 40% of well-to-wheel CO_2 emissions from the global transport sector were attributed to freight transport in 2014.[1] Heavy road transport activity in particular has, historically, been closely related to GDP and is expected to increase about threefold from 2010 levels by 2050 (Sims et al., 2014).

An analysis of Nationally Determined Contributions (NDCs) shows that governments pay much less attention to freight transport than passenger transport (PPMC, 2016), despite its significant contribution to transport emissions.

Zero emissions technologies for passenger vehicles, in particular electric vehicles (EVs), are already advanced and their market share is increasing. This is not the case for freight transport, where zero emissions technologies are in an earlier state of development.

However, a renewed wave of interest for low-carbon and zero carbon freight has recently emerged. One example is Tesla announcing its electric semi-trucks in November 2017.[2] This new truck, the production of which will begin in 2019, will be able to travel 500 miles (800 km) on a single charge (twice as much as regular trucks[3]) and charges 80% in 30 minutes using Tesla's new "Megachargers." The announced prices were also significantly lower than the expectations of many experts (Arcus, 2017) and the additional cost paid for the electric truck over a diesel truck could be recouped in around two years (Ferris, 2018).

1 Authors estimate based on (IEA, 2017a)

2 https://www.tesla.com/semi

3 https://www.theverge.com/2018/4/13/17234040/volvo-fl-electric-commercial-semi-trucks
http://www.emoss.nl/en/electric-vehicles/full-electric-truck/

NEW CLIMATE INSTITUTE
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In the USA the Nikola company has introduced to the market a renewable 'green' hydrogen based fuel cell based electric semi-trailer technology that is claimed to be cost-competitive with present diesel powered trucks and has teamed up with the one of the largest brewing companies in the USA, Anheuser-Busch, to roll this out[20].

Other examples come from Mercedes, who have announced mass production of their 2018 electric truck by 2021,[4] and Swedish startup Einride who are piloting an automated electric truck in 2018 (van Rooij 2018). Other major companies asked the EU commission to introduce mandatory targets in the freight transport sector[5].

This memo explores technology innovation options and necessary mid-term steps (up to 2030) to put overland freight transport, which today accounts for more than 70% of total freight CO_2 emissions,[6] on a pathway consistent with the Paris Agreement's long term goal.

We have divided this memo into three sections that explore the following themes:

1. We outline a Paris Agreement-consistent pathway for heavy road transport, and the date by which we need zero emissions trucks in use.
2. We outline technological options for decarbonising freight: modal shift and efficiency, electric trucks, biofuels, and hydrogen or renewable-based synthetic fuel trucks.
3. We explore freight sector emissions in the EU as a case study: how much freight transport can we avoid, move to other modes of transport, or make more efficient by 2030? By how much can we increase the share of low-carbon technologies by 2030 and by mid century?

A PARIS AGREEMENT COMPATIBLE PATHWAY TO ZERO EMISSIONS TRUCKS

Integrated Assessment Models provide pathways in line with the Paris Agreement's long term goal[7]. In these models, power sector emissions reach zero before 2050 and then turn negative, thus leading to overall emissions reaching zero by 2050. At the same time, global transport sector emissions are reduced by a third compared to 2010.

However those models do not provide detailed information for the freight sector, nor do they fully incorporate options in this area.

As an approximation to a Paris-compatible emissions pathway for the freight sector, we refer to a scenario consistent with a 50% chance of limiting warming to 1.75 °C (B2DS scenario) that was published in the IEA Energy Technology Perspectives (ETP) 2017 report (IEA, 2017a). While the definition of the B2DS scenario is not consistent with the Paris Agreement's 1.5 °C temperature limit, its CO_2 emissions trajectory for the global transport sector is in line with the least-cost 1.5°C-consistent emissions pathways (>50% chance by 2100) from integrated assessment models (Rogelj et al., 2015).[8] The IEA foresees deeper emission cuts in advanced economies, like the EU, where total transport emissions should be reduced by 90% by 2050 below 2014 levels, and even emissions from heavy road transport should go below zero by 2055[9].

We conclude that, to be consistent with the Paris Agreement, and taking into account recent technological developments and options not explored in the scenarios, full decarbonisation of overland freight should be targeted to around 2050, especially in advanced economies. This would help to reduce the need for negative CO_2 emissions.

In the following sections, we explore technological and other options to significantly reduce emissions in the short/medium term.

MODAL SHIFT AND EFFICIENCY

MODAL SHIFT

At a global level, the IEA'sB2DS scenario suggests a peaking of well-to-wheel CO_2 emissions from overland freight transport by 2030. Modal shift can significantly contribute to achieving this milestone.

To transport an equivalent amount of cargo, the amount of energy required by freight *trains* is

4 http://media.daimler.com/marsMediaSite/en/instance/ko/All-electric-Mercedes-Benz-trucks-for-the-heavy-duty-distribution-sector-Sustainable-fully-electric-and-quiet-Mercedes-Benz-eActros-to-roll-out-to-customers-in-2018.xhtml?oid=33451264

5 https://www.transportenvironment.org/press/ikea-unilever-carrefour-and-nestlé-among-companies-logistics-groups-and-hauliers-asking

6 Authors estimate based on (IEA, 2017a). Includes international shipping.

7 With at least a 50% chance of limiting warming to 1.5 °C

8 The direct CO2 emissions projections in the ETP 2017's B2DS scenario are on the lower side of the 15th-85th percentile range for 2030 and is in line with the median for 2050 reported in Rogelj et al 2015.

9 Including (net-negative) emissions from electricity consumption in th efreight sector.

typically much lower than that required by *trucks*.[10] Shifting transport from road to rail will result in an avoidance of emissions, in particular when the rail system is electrified and the power sector increasingly decarbonised. However growing demand for "just-in-time delivery" and subsequent shift from rail to road could hamper modal-shift efforts (ETP 2017, McKinnon 2016). Not all types of cargo transport are suitable for being shifted to rail. Most door-to-door transport will require at least some "last-mile" transport by road. Railway transport is also constrained by the fact that the railway grid must usually be shared with passenger trains with a regular and fixed timing, so unlike a cargo truck, a cargo train can only travel at certain times.[11]

A complete shift from road to rail transport thus appears neither realistic nor reasonable. Rather, we need to consider "multimodality" where various modes are used to achieve an optimal use of resources.

EFFICIENCY AND DEMAND REDUCTION

Peaking global freight emissions around 2030 would also require substantial energy efficiency improvements. A recent IEA study shows that energy efficiency of newly-sold trucks could be improved by 35% within the next 20 years (ETP 2017). However, progress on efficiency standards in the freight sector has been much slower than for passenger vehicles. Only four countries (Canada, China, Japan and the United States) have introduced efficiency standards for heavy-duty freight vehicles (OECD/IEA & IRENA, 2017). The introduction of such standards in other G20 countries, facilitated through international collaboration, would yield important climate, local air pollution and health benefits (CAT 2015).

The reduction of freight transport demand also has significant potential: the full implementation of a suite of measures, including those with low and high implementation barriers, could result, globally, in a 26% reduction of vehicle activity compared to a reference scenario by 2060 on a global level (IEA, 2017a). This would first require basic data collection as well as the development of key performance indicators (IEA, 2017a)(Sims et al., 2014).

We have shown that modal shift, demand reduction and energy efficiency improvements can reduce emissions in the short/medium term. However, these measures are highly insufficient to meet the Paris Agreement in the long term.

TECHNOLOGICAL INNOVATION: MANY WAYS TO ZERO EMISSIONS TRUCKS

To fully decarbonise the transport sector by mid century, we ultimately need to move the remaining road freight to low-carbon vehicles.

Given typical vehicle lifetimes, deployment of low-carbon technologies should start at scale by around 2030. The two options that are most often discussed (IEA, 2017a; OECD/IEA & IRENA, 2017) and analysed for zero emissions trucks are electric vehicles or—because of the current range limitations for electric vehicles—biofuel trucks. A third option is with fuels produced with hydrogen or renewables- based liquid fuels. Apart from biofuels, all these options, including fuel cell powered trucks, rely directly or indirectly on electricity from renewable energy and therefore rely on a decarbonised power sector to lead the way to zero emissions heavy transport on roads.

ELECTRIC TRUCKS

Electrification of freight trucks is an attractive option for decarbonising the freight sector, provided the consumed electricity is also zero-emissions. There are a number of signs that large-scale electrification of freight trucks is feasible in the next decades:

- An increasing number of freight owners are involved in developing and using electric trucks systems. This can be seen in UPS pilot electric truck projects, and logistic companies such as EMOSS which offer a variety of electric trucks with ranges from 150–250 km.[12] The German Post office is also developing its own e-truck fleet.[13] The US brewing company Anheuser-Busch is aiming to reduce its freight emissions to zero by 2025 using electric and fuel cell trucks, with renewable sourced electrictity[21].
- A recent study on the advances in lithium-ion batteries shows, in a conservative development scenario, that EVs will become cost-competitive with internal combustion engines by 2020, much earlier than

10 The ICCT Global Transportation Roadmap Model (ICCT, 2012) suggests an energy intensity of 0.15 MJ/tkm for freight rail, whereas a truck carrying a typical load of 8–9 tons (suggested as average load factor for the EU) would require around 1.3 MJ/tkm.

11 Also, not all countries have an adequate railway system, or a railway system at all, in place. In Europe, island nations such as Malta, Cyprus or Iceland are good examples of the latter.

12 http://www.emoss.nl/en/electric-vehicles/full-electric-truck/

13 https://qz.com/1158107/the-german-postal-service-has-built-its-own-electric-trucks/

http://www.dpdhl.com/en/media_relations/specials/e-mobility.html previously thought (Kittner et al. 2017). The Tesla Semi suggests that this may also be the case for trucks.[14]

- There is a significant push to develop electric vehicle charging infrastructure, some of which could also be used for electric heavy duty vehicle (HDV)s, resulting in a cohesive, targeted decarbonisation strategy for the whole transport sector.

There are two main options for electrifying freight trucks: battery-electric trucks and electric road system (ERS) ("e-highway") (IEA, 2017b):

- The power transfer in ERS operates like a tram receiving power from overhead lines (IEA, 2017b). These types of systems are technologically mature but require significant investment to develop the infrastructure (whose utility would be limited to the freight vehicles).
- Battery-powered electric trucks had not been considered as a major mid to long-term option due to concerns over the range, but this is changing. As described above, the newly-announced Tesla truck claims a significantly improved range of 500 miles (800 Km)—this would cover the majority of freight transport distance in the EU (Figure 3) as well as in the United States.[16] Several existing electric trucks on the market (with ranges up to 200 miles or 300 Km) are sufficient for many freight transport requirements. Using range-extended powertrains on these trucks is a solution where additional range is required.[17] Some components of the charging infrastructure required for passenger electric vehicles can also be used for trucks (ICCT 2017).

It is essential that e-truck and battery technologies reach an intermediate or advanced phase of technological learning in the near future to achieve mass deployment by 2030 and contribute to full decarbonisation by 2050. To realise this, countries need to urgently ramp up R&D and investment, including through incentives for private investment.

Based on IEA ETP 2017 beyond 2°C scenario, the share of electric trucks in global new truck sales will increase to 30% by 2030[18] following a logistic growth curve. This assumption is in line with the benchmark required for passgenger vehicles under a 1.5°C pathway (Kuramochi et al., 2018), and would lead to a roughly 5% share in total in-use stock by 2030.

Globally, e-trucks can significantly contribute to halving global freight emissions by 2050. In avanced economies like the EU28, heavy road emissions could be reduced up to 90% below 2015 by mid century (IEA/ETP 2017) and then going below zero in the second half of the century.

BIOFUELS

Biofuels are viewed as an important transition fuel in decarbonising the transport sector, and a possible option in the long term—particularly where direct electrification might not be viable (yet). This could be the case for freight transport on roads, aviation and maritime transport.

Box 1: Three generations of Biofuels

Several types of biofuels

The IEA classifies biofuels into two categories: conventional and advanced biofuels (International Energy Agency, 2012).

Conventional biofuels include sugar and starch based ethanol and oil crop-based biodiesel.

Advanced biofuels are produced from non-food crop feedstocks or from waste and residues. An additional option under development is biofuel derived from algae.[19]

The emissions reduction potential of biofuels depends on their source. There is a general consensus in studies that biofuels have lower GHG emissions per km travelled than fossil fuels, although for some biofuels indirect emissions can lead to greater total emissions than petroleum products (Sims et al., 2014).

There are two main concerns around biofuel production: long-term sustainability and carbon neutrality.

The sustainability concern relates to growing feedstock for crop-based biofuels which requires a significant amount of land. This has the following implications:

1. All crop-based biofuels require agricultural land which can lead to unwanted negative impacts on land use and, potentially, food security; this is not an issue for waste and residues or algae.

14 Assumes 2015 average gasoline prices in the United States.

16 "U.S. Department of Transportation estimates that more than half the freight (by weight) in the U.S. is driven less than 100 miles (160 kilometers), while 71% travels less than 250 miles (400 kilometers)." (https://static1.squarespace.com/static/585c3439be65942f022bbf9b/t/59f279b3652deaab9520fba6/1509063126843/RethinkX+Report_102517.pdf)

17 https://www.wrightspeed.com/

18 We assume hybrid trucks running 50% electric.

19 http://biofuel.org.uk/third-generation-biofuels.html

2. The land requirement may also lead to deforestation.
3. Evaluating the impact of biofuels on other resources is important. For instance, sugarcane plantations are water-intensive and, other than being key contributors to water stress, may lead to biodiversity losses. (Hoekstra & Mekonnen, 2016).

The carbon neutrality concern encompasses all types of biofuels. For example, the carbon neutrality of any crop-based biofuels (premised on the sequestration potential of the feedstock) does not take into account the emissions associated with land use change, which are usually underestimated by the literature and vary considerably depending on the biofuel production route ((Valin et al., 2015) and (Plevin et al., 2010)). On the other hand, the use of algae biofuels requires a high concentration of nitrogen and phosphorous, as well as water for some routes. The emissions associated with the production of nitrogen and phosphorous are significant, and reduce the mitigation potential of these fuels. (Maity et al., 2014).

The IEA envisages that more biofuels will be consumed in the transportation sector than gasoline by 2050 (OECD/IEA & IRENA, 2017) Biofuels are one of the few viable GHG emissions reduction options for road freight in the short- to mid-term, *if they are produced sustainably.*

Biofuels production, if carefully and sustainably managed, could also lead to significant co-benefits, inlcuding enhanced energy security, economic development and poverty alleviation (Peskett et.al, 2007).

'GREEN' HYDROGEN

Although the IEA ETP 2017 projects electric trucks to be the dominant low-carbon freight truck technology, enabled by electric highways, others see a more viable future in hydrogen-powered fuel cell trucks to ensure long range freight transport. For example Anheuser-Busch ("A-B"), one of the largest brewers, aims for 800 Hydrogen-Fuel-Cell EV trucks ("FCEV") to come online by 2020[20]. Instead of batteries, hydrogen-powered trucks use hydrogen tanks as energy storage and fuel cells to produce electricity. The USA Manufacturer Nikola is reported to have 9,000 orders already for its renewable hydrogen based fuel cell trucks and has offered them to the market on a lease basis cost competitive per mile with present diesel semi-trailers trucks[21]. Hydrogen can be generated in many ways[22], but the main process for *zero* hydrogen production is via electrolysis using renewable electricity. As suggested by the IPCC[24], hydrogen is also interesting because it could store excess electricity generated from intermittent renewable energy sources (such as solar and wind) in peak hours and release it back to the grid later (also referred to as Power to Gas/Power, P2G/P2P). The P2P via electrolysis process, however, would lead to significant energy losses of around 60-70%.[25] Current cost reductions in solar and wind power, and the cost of electrolysers, enable lower cost production of green hydrogen at larger scale from renewable energy. Assessed costs for hydrogen from electrolysis vary depending on the region (IEA, Renewable Energy in Industry, page 28).

A key challenge and uncertainty for the use of hydrogen in freight transport lies in the future cost reduction of fuel cell technologies (IEA, 2017a). Hydrogen would also require investments to equip existing gasoline stations with hydrogen storage tanks - or build a separate (lower density) charging network. Innovative market solutions are however already emerging in the USA with the Nikola company announcing plans to roll out 700 renewable hydrogen refuelling stations in that country by 2028[21].

Hydrogen fuel cell HDVs not only provide a pathway to decarbonising the freight sector, but also offer the same co-benefits as electricification:

- Increased air quality and noise reduction from the operation of the trucks. (Pallas, Chatagnon, & Lelong, 2014)
- Potential for vehicles to balance the grid (Vehicle-to-grid strategies) (Zhao, Noori, & Tatari, 2016)

RENEWABLES-BASED SYNFUELS

Synfuels are an additoinal option for decarbonisation of the freight transport sector. Synthetic fuels such as methanol (CH_3OH), dimethyl ether (DME), or based on methane (CH_4) and other hydrocarbons are already being developed (Varone & Ferrari, 2015). However, as the IEA points out, it is more efficient to use electricity directly or via a more effective storage

20 https://reneweconomy.com.au/budweiser-switches-hydrogen-trucks-carlton-united-41031/

21 https://www.forbes.com/sites/sebastianblanco/2018/05/03/anheuser-busch-800-nikola-hydrogen-trucks/ -27987c814d4c

22 Hydrogen can be also produced as a side product of the chemical industry, stream reforming (via fossil fuels), or via biological production (e.g. from algae).

24 The IPCC identified that"some forms of RE [Renewable Energy] are primarily used to produce electricity, the ultimate contribution of RE to the overall energy supply may be dictated by the future electrification of transport or by using RE to produce other energy carriers" (Edenhofer, Pichs-Madruga, & Sokona, 2014).

25 http://energystorage.org/energy-storage/technologies/hydrogen-energy-storage

technology such as batteries. Synfuels are therefore most useful when ease of portability is the primary concern, as is the case in the transport sector. Synthetic gas may entail comparative advantages when existing gas infrastructures (e.g. pipelines) are already locally available.

Competitiveness of RE PtL (power to liquids) depends on locating the synfuel production in areas with the best complementing solar and wind sites, creating a significant potential for synfuels to be exported. For countries with the appropriate solar and wind potential the following are suggested areas of focus:

- Funding H2tL (hydrogen to liquids) and electrolyser improvements
- Implementing higher carbon prices to make the technology more competitive
- Utilising CO_2 produced from other sources (carbon capture and use or CCU) to generate the synthetic hydrocarbons

Box 2: Summary of co-benefits from various technological options

Technology	Co-benefit
Sustainable Biofuels[26]	• Poverty alleviation • Economic development
Electric Trucks	• Improved air quality • Noise reduction • Grid balancing
Renewables based Hydrogen	• Improved air quality • Storage of excess electricity • Can use existing infrastructure
Synfuels	• Storage of excess electricity • Can use existing infrastructure (depending on the type of synfuel).

DECARBONISING THE EU FREIGHT SECTOR – A CASE STUDY

This section explores the GHG emissions reduction potential in the EU freight transport sector. Figure 3 presents the potential per area.

MODAL SHIFT

Compared to global estimates, the EU, as a developed economy, needs to significantly reduce freight emissions: by more than 30% below 2014 levels by 2030 and 90% by 2050, according to the B2DS.

Most overland freight transport in the EU, nearly 80% of the total amount of tonne-kilometres, is on the road. Trains make up most of the rest – nearly 20% (European Commission, 2016).

In this context, it is instructive to look at "best practice" examples of countries that transport relatively high shares of domestic cargo by train. In the EU, the highest share[27] is found in Latvia (80%), Lithuania (68%), Estonia (55%), and Slovakia, Austria and Switzerland (35%–40%) (Cloodt, 2012). However, the Baltic states have a very low share of *passenger* rail transport, with the share of total inland passenger transport ranging from less than 1% for Lithuania to 4% for Latvia, compared to an EU average of 7.7% (Eurostat, 2017b).

This is likely no coincidence: mountainous countries in the EU make driving generally less efficient, more expensive and more time-consuming than in low-lying countries (Nordregio, 2004). Switzerland and Austria are also known for having implemented specific policies—e.g. heavy vehicle fees, restrictions on truck weight and dimensions, driving bans at certain times—to incentivise train traffic over road traffic (European Court of Auditors, 2016).

These examples show that, in theory, there is a potential to increase the share of rail freight if regulatory measures are taken to incentivise railway transport over road traffic.

In Figure 3, we show the estimated effect on emissions from freight transport if the entire European Union achieved a "modal shift scenario", where railways transport 30% of freight traffic by 2030 (a share inspired by Slovakia, Austria and Switzerland), without reducing rail passenger traffic. The potential identified here is also consistent with that for the long-term reported in den Boer et al. (31–36%) (den Boer, Van Essen, Brouwer, Pastori, & Moizo, 2011).

26 Conditional on the implementation of transparent, sustainable practices highlighted in the section: Biofuels.

27 Note that this data is based on *territoriality*, not on *nationality*, meaning that the emissions are counted where they are emitted, and not where the trucks are registered.

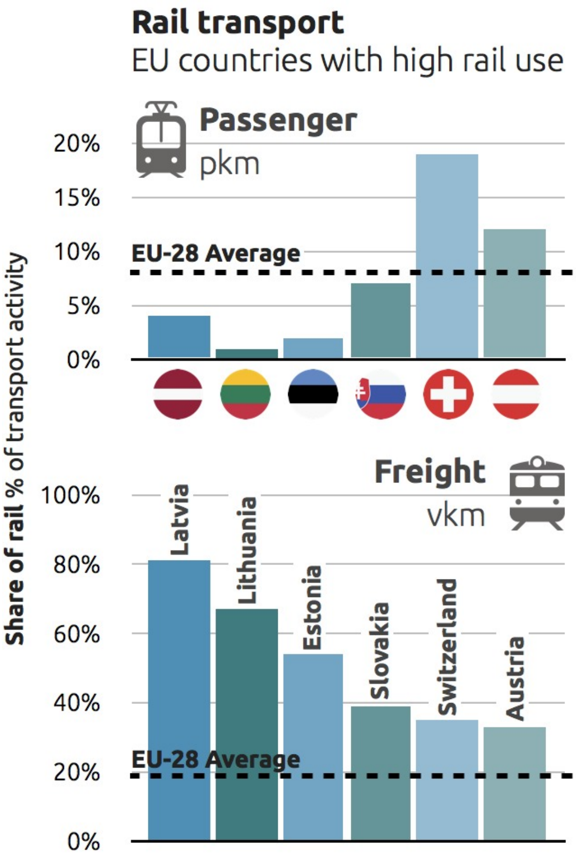

Figure 1: The share of railways in transport activity (pkm or vkm) for EU countries with high shares of rail cargo. Slovakia, Austria and Switzerland obtain much higher shares of rail freight transport than the EU average, while having at least the same share of rail in passenger transport. Data from *(Eurostat, 2017a, 2017b)*. Dotted lines show EU-28 averages.

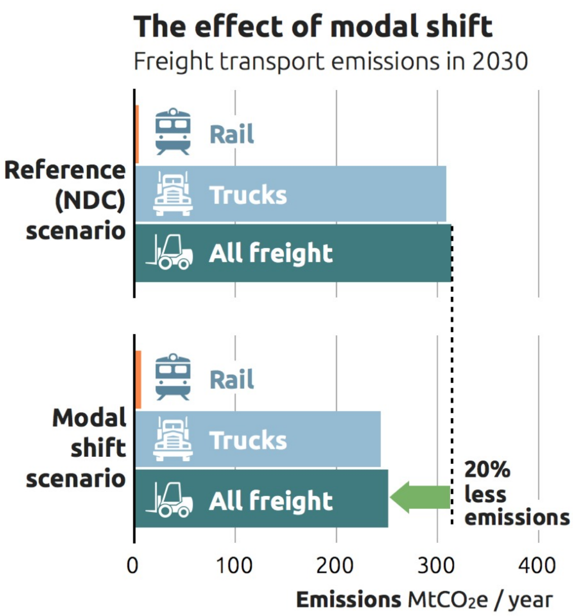

Figure 2: The estimated emissions from overland freight transport in the EU (direct and electricity-related emissions) under current policies in 2030 (left) and under a modal shift of rail traffic (right) similar to the current one of Austria, Switzerland and Slovakia.

Such a modal shift can reduce overall emissions from freight transport in the EU by roughly 20% compared to a reference scenario roughly consistent with the NDC target (or a 24% reduction compared to 2015 levels).

However, realising this theoretical potential would be very challenging. Due to structural inelasticity, which confines shorter distance freight to road transport, as well as inadequacies in rail infrastructure and service quality, a substantial reversal of recent freight modal split is considered difficult to achieve (Sims et al., 2014). This is why we present the emissions reduction potential of modal shift after all other options in Figure 3.

EFFICIENCY

The European Union is working towards the implementation of fuel economy regulations for heavy duty trucks by 2020. This is in addition to high fuel tax rates and the deployment of road tolls introduced by individual member states. Opportunities for further efficiency improvements have been identified in: aerodynamics, rolling resistance, weight reduction, transmission and drive train, engine efficiency and hybridisation (IEA, 2017a).

When the future stock-average annual energy efficiency improvement rates up to 2030 are 50% larger than in the reference scenario, roughly in line with the Global Fuel Economy Intitiative's target (GFEI, 2017; IEA, 2017a), freight transport CO_2 emissions can be reduced by 9% by 2030 from the reference scenario (Figure 3). The impact is significant, but also shows that energy efficiency alone is not enough to achieve reductions consistent with the Paris long-term goal.

TECHNOLOGICAL INNOVATION: MANY WAYS TO ZERO EMISSIONS TRUCKS

On top of energy efficiency, biofuels could lead to significant emission reductions if produced sustainably. Policies that wil enable the short and long term potential of biofuels to be realised include:

1. The adoption and enhancement of blending targets in the Renewable Energy Directive (European Parliament and the Council of the European Union, 2009).
2. Adoption of directives which seek to transparently resolve the potential conflict between the volume of biofuels required and sustainable, ethical practices. Such directives have already been adopted by the European Commission (European Parliament 2015).

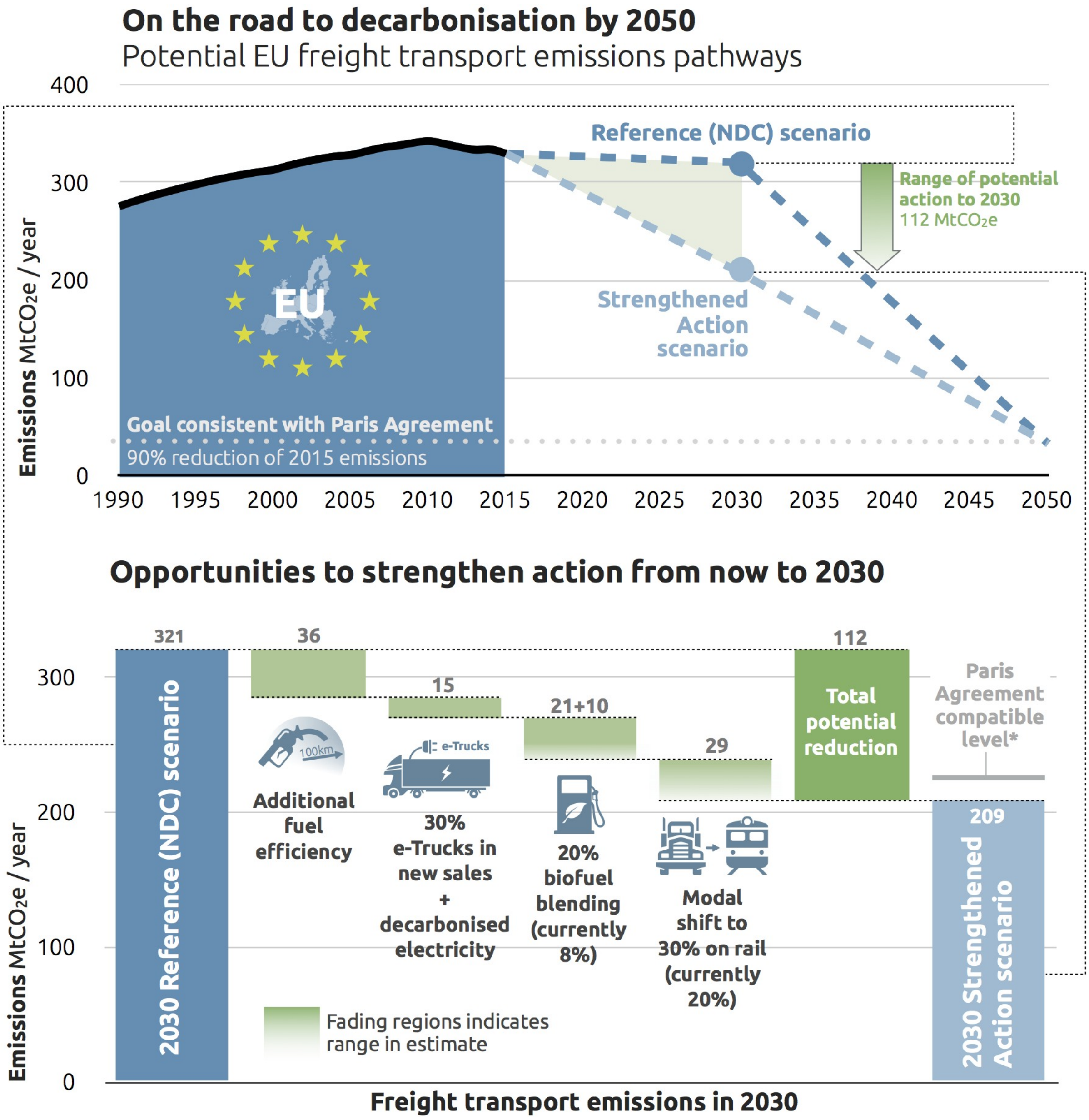

Figure 3: CO_2 emissions reductions for freight transport (road and rail) in 2030 per mitigation option (unit: $MtCO_2$/yr on well-to-wheel basis, but excluding emissions from fossil fuel processing).

For biofuel blending, the range represents range of reduction potentials depending on the the type of biofuel used, with well-to-wheel CO_2 emission factors 60–90% lower than for conventional fossil fuels.

The entire potential for modal shift is also presented in shades due to its high uncertainty.

* : This indicative emission level is estimated by the authors based on the Beyond 2 °C Scenario (B2DS) in the IEA Energy Technology Perspectives 2017 (IEA, 2017a).

3. The Renewable Energy Directive II which will phase out conventional biofuels but will set targets for advanced biofuels (under discussion in the EU Trilogue which should conclude later in 2018).
4. Supporting research into advanced biofuels.

With existing technologies, a 20% biofuel blending is feasible for diesel fuel with existing fleets and fuelling infrastructure (IEA, 2017b). Assuming a 8% biofuel share in 2030 in the reference scenario and a well-to-wheel CO_2 emission factor of 60% lower than that of conventional fossil fuels, this would reduce emissions by up to 6% on top of strengthened energy efficiency and e-truck deployment by 2030 (Figure 3). If trucks are supplied with near-carbon neutral biofuel (90% lower emission factor), the additional emissions reduction impact would increase to 9%.

In the EU28, a policy package of support for fast uptake of e-trucks (30% of new sales by 2030) combined with a 90% share of zero emissions electricity[29] can lead to a further 5% of emissions reductions on top of strengthened energy efficiency by 2030 (Figure 3).

In the long term, the IEA/ETP estimates a significant emissions reduction potential in the freight sector of the EU. By 2050 electric trucks would cover about three quarters of the entire truck fleet by 2050, following a logistic curve.

On top of that, additional policies should be aimed at developing hydrogen and synfuels infrastructures. Like batteries, these would also contribute to flexible power system management.

If combined, all these mitigation options can lead to a 90% reduction in the EU freight emissions by 2050. It is important to bear in mind that zero carbon hydrogen, synfuels and electric trucks all rely on decarbonised electricity, which reiterates the need for a carbon-free power sector by 2050 (Climate Action Tracker 2016).

CONCLUSION

To achieve the Paris Agreeement's long term goal, we need significant advancements in technologies that allow *full* decarbonisation, i.e. electrification, hydrogen or synthetic fuels. These need to be deployed in addition to options which are already readily available today, including efficiency and demand reduction measures, modal shifts and biofuel blending. This needs to take place in conjunction with a decarbonised renewable energy-based power sector.

Under a Paris Agreement compatible pathway, full decarbonisation of global freight emissions should be targeted to around 2050, especially in advanced economies. A decarbonised transport sector would entail significant co-benefits including air quality improvements, grid balancing, electricity storage and economic development.

Our analysis shows that there is a range of technological options for zero emissions trucks, but there are technical, economic, policy and logistical challenges in introducing these fast enough.

In particular, countries need to ramp up investments in electrifying the sector, as well as provide incentives for private investments and mandatory sales targets for manufacturers. At the same time countries need to support Research and Development investments into other promising options for decarbonising the freight transport sector.

In the EU case study we have shown that, with all these advancements, there is potential for the EU to reduce emissions from heavy road transport by 30% below 2015 levels by 2030. To achieve this the EU must strengthen policies in all of these areas. This would lead to a reduction of 35% of emissions from freight transport compared to the emissions expected under the current EU NDC submitted under the Paris Agreement.

An important conclusion from this memo is that with the right incentives there are strong grounds for optimism that rapid changes can be expected in the sector, including overturning conventional technology assumptions. The USA example outlined here shows a commercial market for fuel cell electric trucks based around renewable hydrogen beginning to develop, based in part on one company's desire to move its entire value chain to renewal based electricity by the mid-2020s. Such moves are indicative of the potential for a rapid transformation in this area towards zero carbon freight transport options that could occur much faster than assumed by many analysts.

29 By 2030, we assume a 25–30% share of electricity generated by nuclear power plants and a 60–65% share of renewables (in line with the IEA/ETP 2017 Beyond 2°C scenario).

ANNEX A: METHODOLOGY

In this brief, the reference scenario developed for quantifying the mitigation impact of different options for the EU case study is roughly in line with achieving the NDC, i.e. 40% reduction by 2030 from 1990 levels, based on the IEA ETP 2017's Reference Technology Scenario[30]. Details of the reference scenario are presented in Annexes A and B. Under the reference scenario, well-to-wheel CO2 emissions from overland freight transport decreases slightly from the current level up to 2030.

The calculations in this analysis were performed using a prototype of the PROSPECTS model, under development by the Climate Action Tracker[31]. The prototype used for this study contained simplified modules for the power, cement and steel sectors, interlinked such that electricity-related emissions could be allocated to the end-use sectors in industry. Logic charts for the calculations in these sectoral modules are shown in Figure 4 and Figure 5. As indicated in the legend, some of these metrics are necessary as input data to run the calculations; the data sources used are given in Annex B.

With regard to the GHG emission factor for biofuels, based on an assessment on ILUC for the European Commission,Valin et al. (Valin et al., 2015) we assumed the default value to be 60% lower than the conventional fossil fuel counterparts and also presented the results with a 90% lower emission factor. Valin et al. have shown that Land Use Change effects differ significantly for various types of biofuel. The EU consumption of biodiesel produced from vegetable oils has a very large Land Use Change emission impact, which is mainly caused by the considerable emission effect of peatland drainage for palm oil plantations.

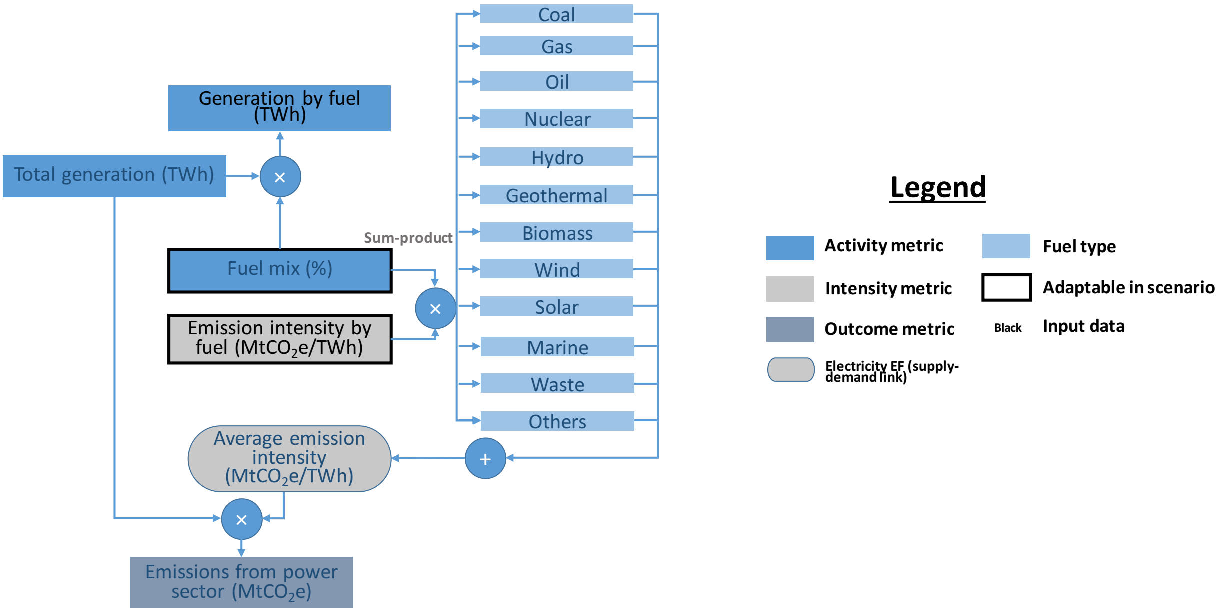

Figure 4: Flowchart showing the logic of the power sector in the present analysis (Zhang, 2017). *EF = Emission factor.*

30 This scenario takes into account the current commitment by countries to limit emissions including nationally determined contributions under the Paris Agreement (IEA, 2017a).

31 PROSPECTS stands for *Policy-Related Overall and Sectoral Projections of Emission Curves and Time Series*. The aim of the model is to estimate historical emissions time series across all economic sectors, coupling energy supply and demand, and allow for user-defined scenarios of activity/intensity indicators for emissions projections. A full documentation of the PROSPECTS approach is expected to be published in 2018.

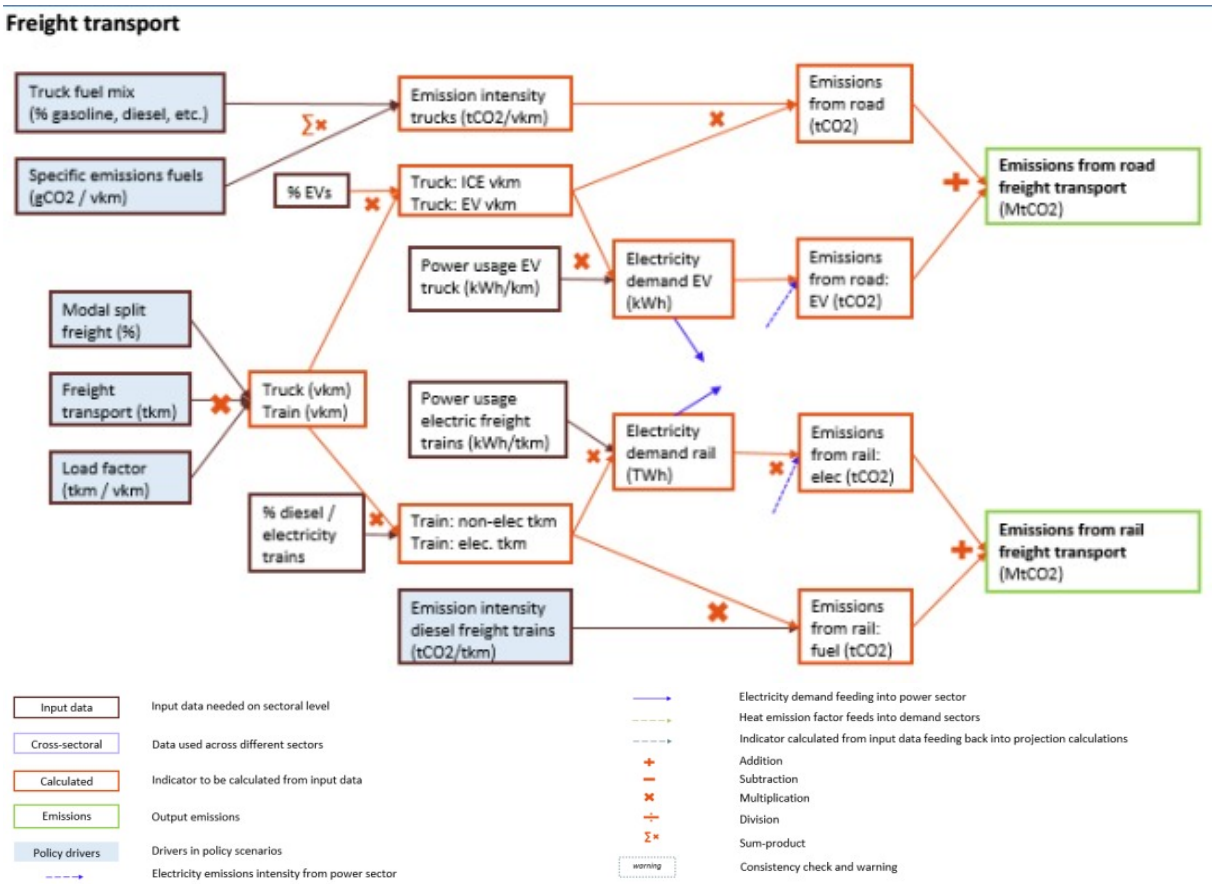

Figure 5: Flowchart showing the logic of the freight transport sector in the present analysis (Zhang, 2017).

ANNEX B: SCENARIO ASSUMPTIONS

Lever	Metric	Reference (NDC) scenario (Figure 2 and 3)	+ Strengthened energy efficiency (Figure 3)	+ E-trucks w/ decarbonised electricity (Figure 3)	+ biofuels (Figure 3)	+ Modal shift (Figure 3)	Modal shift only scenario (Figure 2)	Affects which emissions?
Freight transport activity	t-km/capita	Hisotircal data taken from (European Commission, 2016). Future growth rates taken from IEA ETP 2017's Reference Technology Scenario (RTS). Historical and future average load factors (tonne-km / vehicle-km) are calibrated so that the calculated CO_2 emissions are consistent with those from IEA ETP 2017.						*Direct energy-related* *Electricity-related*
Modal shift	% share (t-km basis)	Fixed at 2015 shares (80% road, 20% rail)				30% rail by 2030		*Direct energy-related* *Electricity-related*
Share of electrified freight trucks	Share in new sales	Zero in 2030		30% by 2030 (5% in total in-use stock)			Zero in 2030	*Direct energy-related* *Electricity-related*
Energy intensity of electrified transport (per vehicle-km)	Change from 2015 levels	Assumed no change from 2015 levels						*Electricity-related*
Energy intensity of non-electrified trucks (per vehicle-km)	Change from 2015 levels	Future improvement rates taken from IEA ETP 2017's RTS	Future annual improvement rates double from RTS, roughly consistent with the GFEI target				Future improvement rates taken from IEA ETP 2017's RTS	*Direct energy-related*
Fuel mix for non-electrified truck transport	% share	Extrapolation of historical trends (2000-2015) up to 2030, resulting in a biofuel share of 8% in 2030			20% biofuel blending		Extrapolation of historical trends (2000-2015) up to 2030	*Direct energy-related*
Electricity mix	% share (43% fossil fuels in 2015)	Based on IEA WEO2 2016's New Policies Scenario (34% fossil fuels, 66% renewables and nuclear in 2030)		11% gas, 89% renewables and nuclear by 2030			Based on IEA WEO2 2016's New Policies Scenario (34% fossil fuels, 66% renewables and nuclear in 2030)	*Electricity-related*

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