Klimarådet.

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Paths to climate-neutral heavy duty trucks

Future potentials for alternative fuels in heavy road freight transport

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Who is the Danish Council on Climate Change?

The Danish Council on Climate Change provides recommendations on climate initiatives in the transition to a low-carbon society. They are based on independent professional analyses, centered on the overall objective of how we can make a cost-efficient transition. The objective is a future with very low emissions of greenhouse gasses while maintaining social welfare and development.

Introduction, conclusions and recommendations

The Danish Climate Act has set a goal that Denmark must have reduced its greenhouse gas emissions by 70 percent by the year 2030 relative to 1990. With the current policies, this leaves emission reductions by a minimum of 12 million tonnes of Carbon Dioxide Equivalents (CO_2e) in 2030. This calls for an active response from all sectors of society, including the transport sector. As things stand, transport by heavy duty trucks will be responsible for 13 percent of the transport sector's total emissions in 2030, as transport by heavy duty trucks will emit 1.5 million tonnes of CO_2 in Denmark.

Emissions by heavy duty trucks will not be significantly lower in 2030

At present, heavy duty trucks on Danish roads emit approximately 1.7 million tonnes of CO_2. With current Danish climate policy, emissions from heavy duty trucks will be reduced by a mere 0.2 million tonnes of CO_2 between now and 2030. This was the conclusion of the Danish Energy Agency's most recent climate forecast from April 2021. The reduction will be achieved primarily by means of an expected switch to more energy-efficient diesel vehicles and increased blending of green fuels in fossil diesel. The impact of both of these measures is however negated in part by an increase in heavy duty trucks traffic and by the fact that neither measure will be able to entirely eliminate emissions from heavy duty trucks. Therefore, it is necessary to switch from diesel to alternative, low-carbon fuels. However, the Danish climate forecast does not anticipate a substantial transition to greener fuels. This lack of progress calls for immediate political action if heavy duty trucks are to contribute to achieving the emissions reduction target by 2030 and if Denmark is to chart a course towards achieving climate-neutral heavy duty transport by no later than 2050.

…and the most recent political initiatives will only provide few emissions reductions

In December 2020, a majority of parties in the Danish Parliament signed a green road transport agreement. A key element of this agreement was that the biofuel blending mandate was replaced by a carbon intensity reduction requirement for fuel suppliers. This requirement will gradually increase to 7 percent in 2030 with a view to reducing emissions from fossil fuels. This measure was taken into account by the climate forecast and, as previously mentioned, together with projected technological advances, will contribute to a reduction of emissions from heavy duty trucks totalling 0.2 million tonnes of CO_2 by 2030. This amounts to a 12 percent reduction relative to today, and a modest 18 percent reduction of emissions since 1990.

It was also agreed that, by 2025 at the latest, distance-based road charges will be introduced for heavy duty trucks weighing over 12 tonnes. The Danish government expects emissions to be reduced by an additional 0.2 million tonnes of CO_2 by 2030 if the road charges are differentiated according to CO_2 emissions. This initiative has yet to be finalised and thus the potential effect has not been included in the climate forecast.

More stringent and specific mechanisms are required if road freight transport in Denmark is to contribute to achieving the target of a 70 percent reduction in CO_2 emissions by 2030 to the same extent as other sectors. It is of course possible that the Danish government will decide that this particular area of society will not have to reduce its carbon footprint as much as other areas between now and 2030 given that the technological solutions available to the heavy duty trucks are less developed than those in many other sectors. However, this would in turn necessitate that other areas of society achieve greater emission reductions than is presently the case. This is something the government should take into consideration when developing the strategy for heavy duty road transport, which is expected to be published in 2022. Yet, irrespective of the 2030 targets, it is necessary for the road freight transport sector to work towards becoming fossil fuel free by 2050 at the latest, and this will require political initiative and planning here and now. Therefore, the Danish Council on Climate Change (the DCCC) has chosen to focus on ways of reducing emissions in this part of the transport sector.

Battery-electric trucks for distribution are coming and likely to prove profitable within a decade

Today, there is no clear-cut dominating technology for decarbonising heavy duty truck transport. One reason for this is that the road freight sector is highly heterogenous, with different heavy duty trucks that vary greatly in terms of their daily mileage and their energy consumption. Nonetheless, there appears to be a clear way forward for one particular branch of the sector. A significant proportion of trucks carry out local and regional logistics services, for example distribution transport in and around major cities. This entails running short trips with a

typical daily mileage totalling only a few hundred kilometres. Battery-electric trucks that use overnight charging could be used for these types of operations, as they would be able to complete such a daily schedule without any major technical or practical obstacles in most cases. The DCCC's calculations indicate, albeit with a degree of uncertainty, that it will be possible for this branch of the freight sector to achieve a reduction of around 0.07 to 0.17 million tonnes of CO_2 by 2030. Moreover, a significant proportion of local distribution transport is carried out in urban areas where the low levels of noise pollution and lack of air pollution associated with battery-electric trucks – compared with trucks with internal combustion engines – will provide major health benefits.

Our analysis revealed that heavy duty truck manufacturers are already beginning to focus on producing battery-electric trucks for short-haul transport, and that these trucks will soon be competitive on the commercial market. The transition to battery-electric vehicles is further supported by a number of studies that anticipate that electricity stored in batteries will become the most economical alternative to diesel powered trucks in the future.[1] The cost of batteries is expected to decrease significantly, and when it comes to shorter trips, the limited range of battery-electric vehicles will not be an issue. As such, it is reasonable to conclude that in the future, distribution transport can, should and will be carried out by battery-electric trucks.

The DCCC's analysis focuses on alternative fuels for long-haul transport

Given the potential of short-haul transport transitioning to battery-electric trucks, the DCCC focused its analysis on the branch of the road freight transport sector engaged in long-haul transport. Long-haul road freight is one of the sectors the with the greatest level of uncertainty regarding future solutions to reduce emissions. Long-haul road freight transport is typically carried out by the largest trucks with an annual mileage of over 100,000 km. These vehicles are also responsible for the biggest share of the total haulage of heavy duty trucks, and consequently, the largest share of emissions. As such, this is the area in which the greatest reduction in CO_2 emissions can potentially be achieved.

In broad terms, emissions can be reduced in the following ways:

- Fewer kilometres driven, as a result of e.g.
  1. changes in consumer behaviour resulting in a reduction of the amount of goods transported
  2. logistical improvements that reduce the distance a given quantity of goods needs to be transported
  3. transition to other, more climate-friendly forms of transport such as rail freight.

- Fewer emissions per kilometre driven, as a result of e.g.
  1. more energy efficient internal combustion engines
  2. improved aerodynamics, tyres with low rolling resistance etc.
  3. switching to alternative and greener fuels.

The first five approaches to emissions reduction listed above are relevant options for reducing emissions, but most studies indicate a limited emissions reduction potential.[2] For instance, it can prove challenging to significantly reduce the scale of freight transport in practice given that it is correlated with material wealth, and limiting the mobility of goods can have major socio-economic consequences. Similarly, a considerable reduction in diesel consumption pr. km has already been factored into the climate forecast's 2030 emissions estimates for road freight transport, and there is a limit to how much more can be achieved with respect to this parameter by Danish efforts alone. Only a transition to CO_2-neutral technologies can make the freight sector fossil fuel free. If the sector's goal is to become climate neutral it will be necessary to make a clean break with diesel. Therefore, the present analysis focuses on alternative fuels.

The purpose of the DCCC's analysis is first and foremost to provide a technological overview of the potential for alternatives to diesel powered trucks. This includes looking at what technology developments we can expect to see heading towards 2030. The analysis identifies possible alternative fuels that may replace diesel, and maps the technological, functional and economic advantages and disadvantages of each of these fuels. The analysis also takes into consideration the plans and goals of the biggest heavy duty truck manufacturers. The intention is to identify the direction of technological developments at this relatively early stage. The analysis then turns its attention to what strategy politicians should adopt in response to the situation in the sector and to the uncertainty

surrounding future technologies. Finally, the analysis highlights the short-term political initiatives that could be deemed as sensible initiatives regardless of how the technology race unfolds in the future.

Obstacles for the green transition of long-haul transportation

There are at present no easy or obvious routes to replacing the fossil fuel diesel used in heavy duty trucks that carry out long-haul transport. The transition of this part of the heavy road freight transport sector in Denmark faces four main challenges:

- Climate-friendly alternatives to fossil fuel are still at a very early stage in their development process, and some are far from being market mature. For cars and short-haul goods transport, battery-electric vehicles seem like they will become the dominant renewable technology; however, there is no clear frontrunner when it comes to a technology that can handle long-haul trips. Denmark is unable to exert any real influence on the technologies that will be available as the development of these technologies is in the hands of heavy duty truck manufacturers abroad. Uncertainty surrounding the availability of technologies in the future also means that investment in supporting infrastructure may prove to be in vain if a different technology than expected ultimately gains dominance.

- Long-haul heavy road freight transport crosses international borders as part of a competitive European logistics market. This means that Danish solutions will need to match those offered by other countries. Denmark thereby only has very limited ability to chart its own course in the sector.

- It is by no means a given that there is a one-size-fits-all solution for all areas of the heavy road freight transport sector. The needs of the sector vary in terms of distances covered, vehicle sizes and functionality, and there are a wide range of requirements with regard to what a fuel must deliver. The direction technological developments suggest that different solutions will have different characteristics, not least in terms of their range and flexibility.

- Systemic limitations might also arise when attempting to scale up some of the alternative fuels being considered. One example of this is the use of biomethane, where the input for producing biomethane is very limited. Another example of this could be the raw materials required to manufacture batteries, which would in turn increase the cost of battery-electric trucks.

These four challenges and the DCCC's analysis underscore that it is difficult to identify viable measures that will help achieve a long-term green transition and simultaneously bring about a radical reduction of CO_2 emissions from heavy road freight transport well before the year 2030. The dilemma we face, then, is what and how much Denmark can expect the heavy road freight transport sector to contribute towards achieving the 70 percent target if the chosen initiatives aimed at reducing emissions between now and 2030 also need to be sustainable and capable of bringing about carbon neutrality by 2050 at the latest.

A sector strategy should form the basis of political climate action within the road freight transport sector

The DCCC recommends that the Danish Government, at the earliest opportunity, creates an in-depth sector strategy for the heavy road freight transport sector. In its climate action plan *Klimaprogram 2021,* the Danish Government announced that it would publish a strategy on the rollout of infrastructure that will contribute to greener heavy freight transport on Danish roads.[3] The government has thereby already turned its attention to laying the strategic foundations for a green transition of the road freight sector. It is however crucial that this strategy has a broad focus and can effectively form part of an overall climate strategy for the entire transport sector. The strategy should set the level of emission reductions that the government expects to achieve in the road freight transport sector by 2030, without necessarily specifying the exact measures that will be taken. The strategy should also focus on long-term objectives and the transition to road freight transport based on zero emission technologies. This means that the transition to alternative fuels should be the focal point of the intiative with regard to both the 2030 goal and the ongoing green transition, even if other reduction methods, such as logistics optimisation, are also worthy of consideration. The strategy will serve to guide the decisions made by public authorities, hauliers and suppliers of infrastructure for energy supply.

Infrastructure for the distribution of alternative fuels ought to be a key element of the future strategy. An expansion of the necessary infrastructure requires state intervention to provide power, coordination, planning, practical knowledge and a legislative framework. The state does not necessarily have to own or build the infrastructure, but the strategy needs to identify the need for infrastructure and provide the framework for the sufficient expansion of said infrastructure. Naturally, this is no simple matter for a sector with considerable uncertainty regarding which of the competing technologies will come out on top. Thus, the strategy needs to be very clear in stating when and based on what future available information, pivotal decisions will be taken. A failure to make decisions can easily result in unnecessarily prolonging of the use of fossil fuels.

The sector strategy should also carefully weigh the short-term reductions that can be achieved between now and 2025 and 2030 against the sector's long-term contribution to climate neutrality by 2050. This balancing act should consider whether short-term decisions will tie the sector to technologies which may later prove to be inexpedient. The degree to which one becomes bound by these decisions will rest on, among other things, an assessment of the life span of the trucks and the adaptability of the energy system in question.

Long-haul heavy goods transportation will probably also need to be powered by green electricity

The sector strategy should address the various alternatives to diesel for heavy duty trucks. These include: hydrogen, biomethane, electricity via batteries or electric road systems, as well as various forms of liquid biofuels and electrofuels. A number of these fuels can become attractive socioeconomic alternatives to diesel if emissions of diesel are valued at DKK 1,500 per tonne CO_2e.

As previously mentioned, there is much to suggest that short-haul trips will be carried out by battery-electric trucks. When it comes to long-haul transport, however, the choice of technology is less clear-cut. Nevertheless, the DCCC's analysis suggests that, as with short-haul transport, trucks operating long-haul transport will also be powered by electricity derived from renewable energy sources. Electricity can be sourced directly from batteries, be delivered to driving vehicles through electric road systems, or be used indirectly through hydrogen produced through electrolysis. A hydrogen truck uses a fuel cell to turn hydrogen back into electricity that can power the vehicle's electric motor. There is scope for scaling up electricity-based solutions across Europe, while biofuels, in contrast, face challenges when it comes to scalability: the volume of biofuel that it is possible to produce is constrained by the limited availability of biomass.

Electrification of heavy duty trucks can be achieved in several ways, but all options will require substantial production of green energy

Direct electrification comes out on top in the DCCC's calculations for large heavy duty trucks with high mileage requirements when one factors in the total socioeconomic operational costs per kilometre over the trucks life span. This applies both to battery-electric trucks and to electric road systems. At present, range and charging time pose considerable challenges to using batteries for long-haul transportation, but major progress is currently being made in both areas. As such, battery-electric trucks are expected to become an attractive alternative to diesel by around 2030.

Hydrogen produced using green electricity is, as mentioned, an indirect way of electrifying heavy duty trucks. The hydrogen solution is more costly than batteries, even when the DCCC's calculations take into account an assumed decrease in the price of hydrogen. A key factor here is that the process of converting electricity into hydrogen and back to electricity is considerably less energy efficient than the direct process from electricity to batteries and back to electricity. As such, abundant, cheap electricity is a prerequisite for the hydrogen solution. However, the range of a hydrogen truck is less limited than battery-electric trucks. Given this, hydrogen appears to offer particular advantages for long-haul transport whereas battery-electric trucks could face challenges if battery technology fails to develop sufficiently in terms of longer ranges and shorter charging times. Hydrogen in particular may have a role to play in a future scenario where a pan-European electric road system fails to materialise. A number of heavy duty truck manufacturers are currently investing in hydrogen technology, and the European Commission has also done its bit by introducing the requirement that Member States must establish a minimum number of hydrogen refuelling stations by 2030. In this light, it is too early to say how batteries, electric road systems and hydrogen will share the task of powering long-haul road freight transport. This uncertainty is something a future sector

strategy needs to be attentive to, and it will be necessary to set criteria for what market developments will need to be in place before Denmark in earnest begins investing in hydrogen technology.

Another form of indirect electrification is using hydrogen to generate carbon-based electrofuels such as e-diesel. Besides being easier to store, the advantage is that current diesel trucks can run on them with no or only minor modifications. Nonetheless, the DCCC's calculations indicate that, even by 2030, the use of electrofuels by heavy road freight transport will in socioeconomic terms prove to be the more costly option compared to other alternative fuels. The higher cost comes from carbon-based electrofuels being considerably less energy-efficient when compared to batteries and hydrogen due to the fact that using them in internal combustion engines is less energy-efficient than a combination of fuel cells and electric motors. Consequently, these electrofuels will require a considerably greater expansion of renewable energy production in order to meet the same transport requirements. Furthermore, the savings achieved by utilising existing, conventional heavy duty trucks becomes less significant viewed over the entire lifetime of the vehicle. All things considered, it is difficult to view electrofuels as a particularly attractive route to a green transition for the majority of the road freight transport sector.

Electrofuels will almost certainly play a key role in other parts of the transport sector such as shipping and aviation where it is more difficult to identify viable alternative fuels. However, road freight should not be used as the main offtaker for electrofuels in the short term in the event that a political decision is made to upscale the production of electrofuels at a pace that outstrips the demand by the shipping and aviation sectors. This is because road freight has cheaper alternatives in the form of batteries, electric road systems and hydrogen. But given that diesel-driven trucks will be driving on Danish roads for many years to come, the heavy road freight transport sector can potentially step in to purchase any surplus production of carbon-based electrofuels for shorter periods of time in case of insufficient demand by shipping and aviation.

Electricity will be the primary source of energy irrespective of whether the heavy duty trucks of the future use electric road systems, batteries, hydrogen or other electrofuels. The DCCC therefore recommends that the government incorporates a significant demand for electricity by the heavy road freight transport sector in its long-term plans for renewable electricity generation capacity, for example offshore wind energy. On the face of it, there is relatively little risk associated with expanding electricity generation, transmission and distribution to meet the demands of an electrified future in which heavy duty trucks will require considerable quantities of electricity. How much electricity trucks will need depends on which technology becomes dominant as the tecnologies, as mentioned, have different levels of energy consumption. This underscores how the sector strategy for heavy road freight transport needs to be closely coordinated with the government's strategic work in other sectors.

The Danish government should contribute to expanding charging infrastructure

This analysis points to battery-electric trucks playing a major role despite the degree of uncertainty surrounding future technological developments within long-haul road freight transport. The DCCC therefore recommends that the Danish Government plans for battery-electric trucks handling a significant proportion of road freight transport and accordingly supports the expansion of charging infrastructure. This recommendation is further based on the expectation that battery-electric trucks will dominate the short-haul road freight market. While depot charging will likely be the primary charger for many of these vehicles, there will probably also be a need for public charging facilities in order to guarantee operational flexibility. Specifically, the government needs to integrate facilities for charging larger vehicles into its plans for charging stations for private cars along the road network as a whole. Such an initiative would also assist in the implementation of the upcoming revisions to the EU Directive on Alternative Fuels Infrastructure, which propose a requirement that Member States establish charging points for heavy duty trucks. Timely planning can help ensure economies of scale in the rollout and optimum proportioning of the grid.

Electrification of major sections of the road network, i.e. the establishment of electric road systems, will mitigate the range limits of battery-electric vehicles, and thereby allow these vehicles to reach their destinations with the help of overhead lines combined with a smaller on-board battery. This model looks economically promising on paper. However, electric road systems present at least three challenges. Firstly, electric road systems only exist on trial routes at present. Secondly, electric road systems pose particular practical challenges. For instance, a fallen overhead line can impact an entire stretch of road. Thirdly, the sound economics of electric road systems is conditional upon high utilisation rates as well as a multiple country roll out. This last challenge underscores the

fact that electric road systems require a coordinated effort on the part of multiple international partners as part of a pan-European system in order to become a viable alternative to diesel. As such it would be advisable for the Danish government to push for prompt clarification by the EU regarding the prospect of pan-European investment in electric road systems. The upcoming revision of the EU Directive on Alternative Fuels Infrastructure could be a venue for such a discussion.

Scarcity of biomass resources poses an obstacle to biofuels

Production of biomethane in the form of upgraded biogas is currently highly subsidised, and according to the DCCC's calculations, biomethane would prove more costly in socioeconomic terms than battery-electric trucks. Perhaps even more importantly, gas-powered trucks could potentially suffer from the limited European supply of renewable gas. Denmark certainly has considerable potential to produce biogas, which also forms a key source of energy in our long-term energy plans. The DCCC's review of relevant literature indicates however that there are far from sufficient biomass resources in Europe to render gas-powered heavy road freight transport a viable option. Moreover, other sectors of the economy also need to transition to renewable gas. It is primarily access to these resources long-term, and the degree to which biogas is subsidised in the short term, that will determine supply availability. It is therefore the conclusion of the DCCC that a major European investment in transitioning the heavy road freight transport sector to biomethane could end up being a dead end that results in increased consumption of natural gas. In light of this, it would be hazardous for a sector strategy to give biomethane a pivotal role in the long-term green transition.

The lack of short-term emissions reduction options begs the question whether gas-powered trucks could serve as a transitional technology that could contribute to meeting the 70 percent target by 2030. The answer is that the net impact on Denmark's total CO_2 emissions as a result of an increased use of biomethane in heavy duty trucks would be very modest, because the total supply of biomethane will in all likelihood not be impacted given that biomethane production is driven by subsidies. Accordingly, in order to achieve a reduction in CO_2 emissions, biomethane production must be scaled up beyond the already considerable ramping up that has been factored into the climate forecast for the period from now until 2030.

The DCCC therefore recommends that Denmark does not actively seek to promote the use of gas-powered trucks in the form of e.g. subsidies for gas-powered trucks or infrastructure or special purchase requirements. The gas consumption of such vehicles, even if it is comprised of pure biomethane, will effectively displace the use of biomethane in favour of natural gas somewhere else. As a consequence, the net impact of gas-powered trucks would in practice amount to the same as a switch from diesel to natural gas. With this in mind, the resultant benefit to the climate would at best be modest, given that it is debatable whether there are any real carbon reductions to be gained from a transition from diesel to natural gas-powered trucks.

Finally, biomass can also serve as a source of energy for liquid biofuels such as HVO diesel. Many kinds of biofuel are practical because, like e-diesel, they utilise the same filling station infrastructure as fossil diesel and provide practically the same performance. The problem with this type of fuel is that in many cases they are not necessarily particularly climate-friendly. Especially in the case of first generation biofuels, where the life cycle emissions can be high. Second generation biofuels meanwhile, in common with biomethane, would be vulnerable to a scarcity of sustainable biomass resources if their use is expanded. Lastly, fierce competition for biomass resources could drive up the price of biofuels, making sustainable biofuels a potentially expensive solution.

The future use of biofuels in Denmark will be driven by the CO_2 intensity reduction requirement passed by the Danish parliament in December 2020. This requirement is an effective instrument to ensure emissions reductions in the short term because it reduces the emissions of the existing fleet of vehicles. In the short term, reductions will presumably be achieved by blending biofuels into fossil fuels and, as mentioned, this gives cause for concern as to the sustainability of the biofuels currently available on the market. The CO_2 intensity reduction requirements can help ensure that Denmark meets the requirements set by the EU directive on the use of renewable energy for transport in Europe. However, current EU requirements should not dictate the direction of the long-term green transition, given that electricity, for example, cannot be used to meet these requirements and, as such, the requirements provide no impetus for the adoption of battery-electric vehicles.

The Danish Council on Climate Change's conclusions regarding technologies for future heavy road freight transport

- For delivery trucks and other *short-haul transport*, battery-electric trucks seem to be the most beneficial solution to replace diesel based on expected improvements to battery technology.
- For *long-haul transport*, it is much more difficult to select a clear winning alternative to diesel at this point time. However, the Danish Council on Climate Change concludes that electrification represents the most attractive solutions viewed from a socioeconomic perspective. Specifically, direct electrification in the form of battery-electric trucks, potentially in combination with electric road systems, or indirectly through the use of hydrogen as an energy carrier:
    - *Battery-electric trucks* appear to be the least costly option from a socioeconomically point of view in 2030, but their short range and long charging time may prove a challenge to hauliers if advances in battery technology fail to provide the hoped-for benefits.
    - If *electric road systems* are rolled out extensively across Europe they will help mitigate the limited range of current battery technology and with a high utilisation rate, they can become socioeconomically as cost efficient as battery-electric trucks. However, electric road systems will require considerable political coordination between Member States and sizeable initial capital investments.
    - *Hydrogen* provides practically the same level of flexibility as diesel and is another potential solution to the short range of battery-electric vehicles. However, as things stand, hydrogen would prove to be more costly than batteries and electric road systems, mainly because it provides three times lower energy efficiency than electric vehicles.
- *Carbon-based electrofuels* such as e-methane and e-diesel appear to be considerably more costly than other green alternatives. These fuels probably have a major role to play in shipping and aviation, but they are not an ideal solution for heavy duty trucks.
- European *biomethane* production capacity falls far short of demand from the heavy road freight sector when one takes into account that other sectors will also need to use biomethane. As such, biomethane will not render road freight transport carbon neutral in the long term. In the short term, the climate change impact of Danish biomethane-powered trucks would in real terms result in an increased use of natural gas in place of diesel, which would at best bring about only a modest reduction in CO_2 emissions.
- *Liquid biofuels* face similar challenges in terms of scalability due to the risk of shortages of sustainable biomass. This could mean increased costs in the future in the event that stricter sustainability requirements are introduced.

Technology-neutral taxation should be the main tool in the transition of heavy duty trucks

The lack of a single clear winner when it comes to technological solutions for long-haul transportation strengthens the argument for technology-neutral regulation. Regulation should ideally serve to promote greener, alternative fuels without giving any one fuel an advantage over others. This minimises the risk of promoting the wrong technology. The broader, long-term green transition of road freight transport should therefore be incentivised through the use of uniform taxation that provides the same incentive to all climate-friendly, alternative fuels and simultaneously ensures carbon pricing is consistent across the board in all sectors of society.

Therefore, the DCCC recommends that a greenhouse gas tax be introduced as a key mechanism to stimulate the green transition of the heavy road freight sector and all other sectors in general. The DCCC has previously highlighted the need for a general tax on greenhouse gasses of around DKK 1,500 per tonne CO_2e in 2030, and this should also apply to diesel and other fossil fuels used in road freight transport. This would help promote the

optimum socioeconomic transition to alternative fuels, and not least the timing of this transition. The size of such a general tax should take account of the allowance price in the EU's emissions trading system as well as the potential inclusion of road transport in a separate emissions trading system from 2026.

The fact that greenhouse gas emissions are not the only externality created by road transport complicates the implementation of a greenhouse gas tax. Externalities such as road accidents, congestion, noise pollution, air pollution and infrastructure wear and tear are considerable and must be taken into account when regulating road transport. These externalities primarily vary according to distances travelled and driving patterns. Accordingly, the greenhouse gas tax should be coordinated with the introduction of the 2025 road pricing charges for heavy duty trucks over 12 tonnes, as announced in the 2020 Green Transport Policy Agreement. If the aforementioned externalities are addressed through distance-based taxation, we will be able to achieve a more socioeconomically cost effective taxation of the transport sector than today. These externalities constitute a considerable burden on society and, as such, the proposed road pricing charges for heavy duty truck transport should be equally substantial, in particular in urban areas where the external effects of heavy duty trucks are considerable. The DCCC urges that the development of road pricing form part of a coordinated taxation reform in which the tax on diesel is determined on the basis of its CO_2 content, while road pricing charges tackle the remaining externalities. A differentiation of road pricing charges according to CO_2 emissions, as proposed in the Green Transport Policy Agreement, should therefore be a temporary measure which needs to be abolished once the general greenhouse gas tax is fully phased in. The CO_2 differentiation of the road pricing system should therefore be viewed as a push to get the green transition of trucks started in this early phase of the transition. To the extent that it can be done, road pricing charges should be differentiated according to time and place so that it is most expensive to drive at times of greatest congestion.

A tax reform where diesel is taxed at a rate of DKK 1,500 per tonne of CO_2 in 2030 and road pricing charges address the remaining externalities, will increase the price of fossil diesel by around DKK 0.75 per litre excl. VAT compared to today's prices. This is a cost increase of just under 10 percent and diesel will therefore not become substantially more expensive. Introducing road pricing will increase costs for all road freight transport no matter the fuel type. Road pricing should not be differentiated based on fuel type as trucks cause the same level of external effects on society regardless of the type of fuel they use. Since trucks on the different types of fuel causes roughly the same level of external effects on society it should not be differentiated according to what fuel is used. The DCCC's calculations nonetheless indicate that the proposed reform is probably sufficient to render a number of alternative fuel technologies competitive by 2030 and thereby support a transition to climate-friendly energy. On the other hand, the tax reform, which should include road pricing charges, will make it considerably more costly to drive on Danish roads. If we are to take proper account of the wide range of externalities, the tax per driven kilometre should probably be in the region of DKK 5 per kilometre on average, although it is difficult to put a precise figure on this. The price for driving in urban areas should be considerably higher, and the price for driving in rural areas should be lower.

There is in the very near term scope for raising the tax on diesel

A major tax reform is not necessarily something that can be done overnight. For instance, as mentioned, the most recent Green Transport Policy Agreement expects that it will take four to five years to implement road pricing charges. Parallel to this, a reform of Danish CO_2 taxation is awaiting the response of the expert group on green tax reform. However, within the sphere of transport, it has been debated whether the taxation of petrol, diesel and gas used in the transport sector should be raised immediately in order to align it with the increase in the German CO_2 tax.[4] Germany has, by means of a national quota system, raised the tax on fossil diesel by DKK 0.5 per litre in 2021, and the tax will increase incrementally to DKK 0.6 by 2025. Additionally, there was an extensive cross-border fossil diesel trade on the Danish side of the border equivalent to 0.7 million tonnes of CO_2 in 2019, meaning vehicles are filling up at petrol stations in Denmark instead of Germany.

This cross-border trade in Denmark poses a challenge to achieving the 2025 and 2030 Danish climate change targets. If the extensive cross-border trade in Denmark continues, or indeed increases, it will be necessary to achieve considerably greater emissions reductions in other sectors in order to meet the targets, which will prove costly for Denmark. With this in mind, the DCCC considers it appropriate to raise the Danish tax on diesel in order to avoid an increase in cross-border trade. The tax increase should consider Danish CO_2 intensity reduction

requirements as well as the interplay between taxation of the road freight sector and of private cars. A more thorough analysis is therefore required in order to assess how large a hike in taxation is necessary before net cross-border trade is zero. The foremost argument for higher taxation should however be that heavy duty truck transport is generally undertaxed relative to the amount of externalities it generates, and this state of affairs alone speaks in favour of increasing the price of diesel, as long as there is no distance-based road pricing.

A higher Danish tax on diesel will first and foremost reduce Danish greenhouse gas emissions, since it will push cross-border trade back to the German side of the border. For instance, in a response to the Danish Parliament, the Danish Ministry of Taxation concluded that an increase of DKK 0.53 per litre of diesel incl. VAT would immediately reduce emissions by 0.5 million tonnes of CO_2.[5] The majority of this reduction would be achieved by virtue of the fact that the emissions would be passed on to other Member States and the impact in terms of global climate change mitigation would initially be modest. However, the Member States in question have emissions reduction obligations of their own, including national limits on levels of emissions in the non-traded sectors, and increased diesel sales would then place further limitations on emissions in other sectors of the respective states. A Danish increase in taxation that reduces cross-border trade will result in a more accurate and perhaps fairer division of emissions between neighbouring countries.**The Danish Council on Climate Change's recommendations for political action on emissions reduction within the heavy road freight transport sector**

- The Danish government should – as it announced in its climate action plan *Klimaprogram 2021* – create a strategy for the transport sector with a focus on expansion of the necessary energy infrastructure. This strategy should in particular plan for the possibility that at least a significant share of heavy duty truck transport is likely to run on electricity as its primary energy source. As such, the government should:
    - plan for an increased demand for electricity from heavy road freight transport in its plans for renewable energy generation such as offshore wind energy, and in its plans for proportioning of the electrical grid.
    - push for a prompt clarification by the EU regarding the prospective of pan-European investment in electric road systems. The upcoming revision of the EU Directive on Alternative Fuels Infrastructure could be a suitable venue to seek such a clarification.
    - incorporate charging infrastructure for heavy duty trucks into its plans for charging stations for private cars along the national road network.
    - for the time being, regard the European Commission's proposal for minimum requirements for filling station facilities for hydrogen as adequate. Hydrogen may have a key role to play in long-haul road transport, but at this stage it is still too soon to decide on an extensive network of hydrogen filling stations in Denmark. Uncertainty regarding the role of hydrogen is high and any investment therefore carries the risk of little or no return.
- Denmark should make the consumption of diesel and gas by heavy duty road transport subject to a general greenhouse gas tax, a tax which likewise should be introduced in all other sectors. The Danish Council on Climate Change has previously proposed a general tax on greenhouse gasses of DKK 1,500 per tonne by 2030. Such a level of greenhouse gas taxation can and should be the main driver in the transition to alternative fuels. In tandem with this the government should continue to place a focus on developing and introducing road pricing charges which are differentiated according to time and place in order to ensure more accurate taxation of externalities such as road accidents, congestion, noise pollution, air pollution and infrastructure wear and tear than is achieved by the current energy tax.
- Denmark should not actively seek to promote the use of gas-powered trucks by, for instance, subsidising gas-powered vehicles and gas infrastructure. Among other things, this means phasing out gas from grant schemes for heavy goods transport.

- Denmark should immediately raise the tax on diesel as a precursor for a larger tax reform. A higher tax rate will bring the cost of road transport more in line with the actual socioeconomic burden it places on
- society. Parallel to this, in view of Germany's CO_2 tax and the current cross-border trade on the Danish side of the border, increasing the Danish diesel tax rate would be an appropriate measure, which would ensure that cross-border trade more accurately reflects the use of fossil fuels in the two countries. This would reduce emissions from heavy road freight transport and at the same time ensure that they fall more closely into line with emissions from Danish territory.