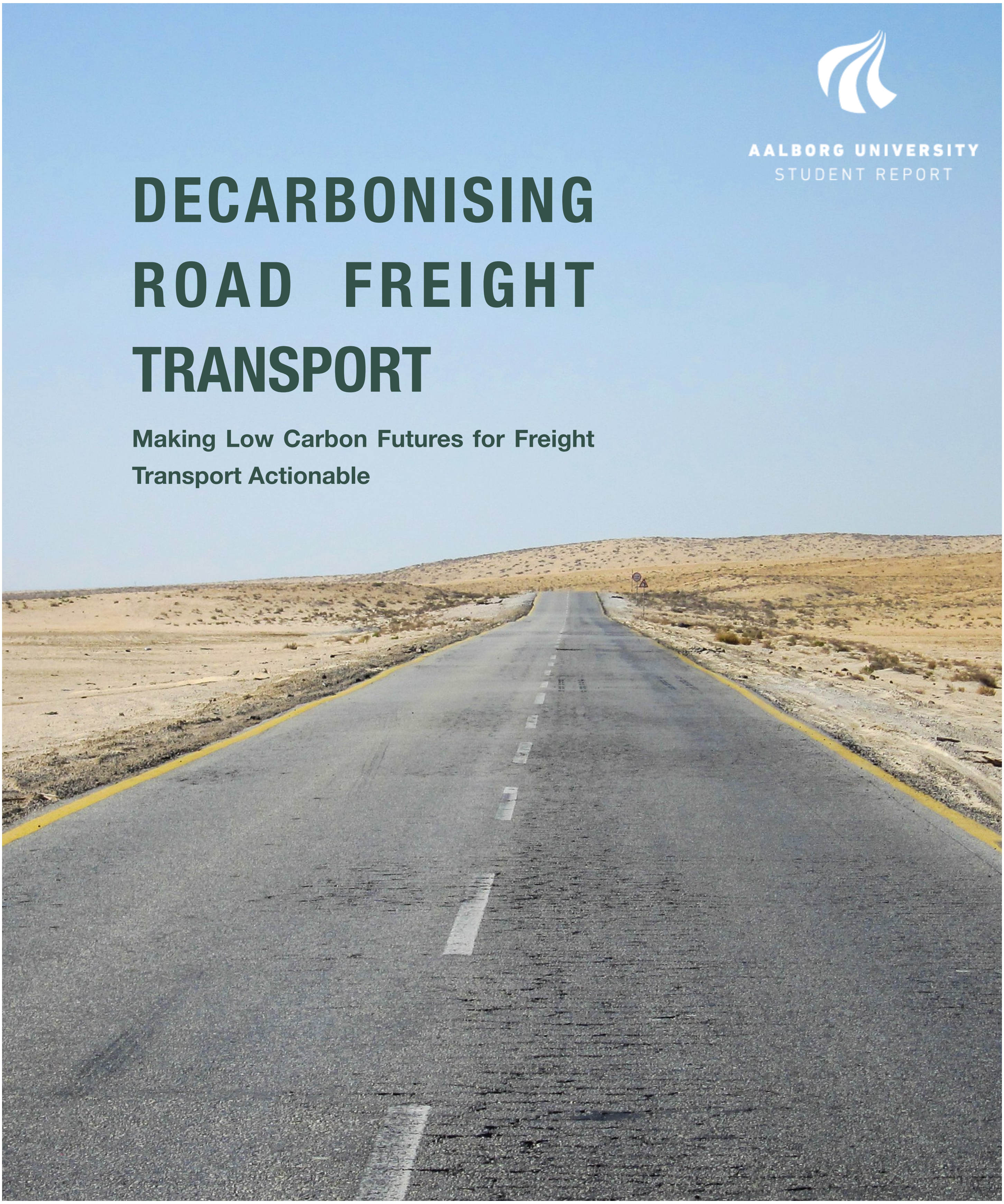
AALBORG UNIVERSITY
STUDENT REPORT

DECARBONISING ROAD FREIGHT TRANSPORT

Making Low Carbon Futures for Freight Transport Actionable



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DANSK RESUMÉ

Dette kandidatspeciale behandler emnet ’Dekarbonisering af godstransport’ i et dansk perspektiv. Dekarbonisering af godstransport er en kompleks men presserende udfordring i en tid, hvor der er stort fokus på at nedbringe CO2 udledning verden over for at leve op til Paris aftalen vedtaget i 2015. Transportsektoren står for 26% af det samlede CO2 udslip i Danmark, og på nuværende tidspunkt er der stort fokus på især elektrificering af persontransport. Men dekarbonisering af godstransport har ikke modtaget så meget fokus, og der ligger et stort potentiale her. Der er ellers ikke mangel på nye innovative løsninger. Men små og store lastbiler kører stadig på benzin og diesel, hvilket kan forklares af et ekstremt fastlåst socio-teknisk system.

Formålet med specialet er at belyse, hvordan man kan gøre denne udfordring så håndgribelig, at en fragmenteret skare af nøgleinteressenter kan samarbejde om at skabe en ny ønskværdig fremtid for godstransport. For at undersøge dette, har jeg samarbejdet med den danske grønne tænketank CONCITO, der i øjeblikket arbejder med et stort projekt under samme navn ’Dekarbonisering af Godstransporten’. På baggrund af en systemanalyse af den danske sektor for godstransport, er en designintervention blevet formet og testet i et praktisk set-up med relevante nøgleaktører. Designinterventionen tog form som en workshop, og ved hjælp af udvalgte fremtidsobjekter var hensigten at skabe indikatorer for hvilken retning, der kunne være interessant at gå samt skabe grobund for at mobilisere nøgleaktører rundt om disse retninger. Workshoppen var succesfuld i den forstand at det var en god dag med engagement og gode diskussioner, men vi havde ikke succes med at mobilisere aktører rundt om de nye retninger, der blev repræsenteret af vores fremtidsobjekter.

På baggrund af dette arbejde, fremhæver jeg tre ting i min konklusion. Først og fremmest, er jeg blevet bekræftet i kompleksiteten af det system der tilsammen skaber godstransportindustrien i Danmark. Den enkelte aktør har begrænset rum for manøvrere, og fælles løsninger er nødvendige for at skabe nye reaktionsveje til forandring. Men dette er svært, og aktørerne efterlyser mere fokus på problemet fra politisk hold i stedet for at tage ansvar og handle selv. Dernæst, blev det tydeliggjort, at der mangler en fælles vision for dekarbonisering af godstransport industrien. Det er svært for aktørerne at samle sig om nye retninger, hvis banen ikke er kridtet godt op for forandring. Måske burde visionskabelsen være næste skridt, hvis man virkelig vil have succes med dette. Sidst men ikke mindst, var retningerne der blev præsenteret til workshoppen ikke klare nok, og dette er en læring i forhold til design af fremtidsobjekter; jo mere tydelig man kan gøre repræsentere nye potentiale retninger, jo nemmere er det for folk at kunne forstå og samle sig omkring. Derfor foreslår jeg, at fremtidigt arbejde skal fokusere på at skabe en stærkere vision for arbejdet for godstransport i Danmark samt benytte sig af mere klare fremtidsobjekter til at facilitere dialogen blandt de relevante nøgleaktører.

Alt i alt. Når man kigger på udfordringen, er det ikke underligt at vi ikke kom længere med en enkelt workshop. Systemet er så fastlåst, at det vil kræve vedholdende arbejde over en længere periode for at opnå den ønskede mobilisering af aktører, som det kræves for at skabe en nye alternative fremtider til det eksisterende karbon paradigme, der hersker i dag.

Samarbejdet med CONCITO har været helt essentielt for at få dette kandidatspeciale afviklet. Men samarbejdet, størrelsen og vigtigheden af projektet har også begrænset mine muligheder for indflydelse på design af workshoppen.

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"Every vehicle engaged in Company business including dump wagons and pole wagons will be operated by electricity by the first of the year."

— EDISON ROUND TABLE, 31 OCTOBER 1921 (MOM AND KIRSCH 2001, P. 489)

TOWARDS A CARBON-FREE FUTURE

"Every vehicle engaged in Company business including dump wagons and pole wagons will be operated by electricity by the first of the year" (Mom and Kirsch 2001, p. 489). If it was not for the mention of pole wagons, this might have been a bold statement from a contemporary entrepreneur in the automobile industry. But it was soon to be a hundred years ago this was said about the transition from horse-drawn carriages to trucks.

In the meantime, our society grew to be locked-in on fossil fuels, not only for transportation but as our primary source of energy (Unruh, 2000). Our appetite for the burning of fossil fuels had lead to increasing accumulations of carbon in the atmosphere, which is now changing the climate by trapping heat radiation just as in a greenhouse (IPCC, 2018). Since the Kyoto protocol, there has been a broad political recognition of the problem on an international level (UNFCCC, 1998) which has grown with the Paris Agreement (United Nations, 2015) and recently Denmark have committed to becoming a "climate-neutral" country no later than 2050 (Danish Ministry of Energy, Utilities and Climate, 2018a).

The transport sector has historically been hard to decarbonise, which can be seen from the sector is the only large-scale sector in Denmark where emissions have increased since the Kyoto-protocol base year of 1990 (Energistyrelsen, 2018). A transition towards a low carbon future is likely underway for the part of the transport sector covering mobilisation of people (as this function increasingly is being electrified), but the transportation of freight have often been overlooked and are seen as harder to decarbonise as there is no silver bullet (McKinnon, 2018). In Denmark, the dominant part of freight is transported by road (Nordic Council of Ministers, 2018), which is the main focus of this work.

I have used the Multi-Level Perspective to understand the current lock-in on fossil fuels in the freight transport system in Denmark, as the perspective has been shown in the literature to be a suited tool to analyses of transitions in transport systems (Geels, 2018). The perspective opens up for the stable transport regime with incremental progressions (e.g. optimisation of vehicle fuel efficiency), the competing and collaborative developments of niche innovations (e.g. new advancements in battery electric vehicles or liquid electrofuels produced from electricity), and the large-scale landscape changes that is beyond the influence of any one actor (such as climate change).

History has shown that the future is not settled and the pathways that seem obvious at present are not destined to be taken. Before the First World War, the electrical truck was believed to be both a suitable and economic successor to horse-drawn urban freight distribution, but in the aftermath of the war, the whole system of freight transportation changed in favour of the internal combustion engine (Mom and Kirsch, 2001). Though new technological innovations are created and landscape developments put pressures on the system, it is not these dynamics alone, which is forming the future. People are also involved in making the future through the practices they do that have lasting effects for the future.

Future-making practices, where people, deliberately or unknowingly, engage in making the future take place when ideas and anticipations of the future shapes actions in the present (Granjoua, Walkerb and Salazar, 2017). The future-making practices create a connection between the present and the future through many shapes such as policy planning, regulation, climate models, the behaviour of different social groups, images of desirable futures and technological research (Knappe et al., 2019). The Transition Management approach attempts to govern sustainable development by harnessing future-making practices under collective long-term visions of desirable futures (Loorbach, 2010). Shared visions that extend into the future can direct distinctive future pathways towards the same goal, without restricting the room for learning and experimenting with different innovations (Frantzeskaki et al., 2018).

In an object-centric perspective, it is not only the practices of people that govern how the future is made, but it is also the underpinning objects (Esguerra, 2019). A future-making object is an intrinsic part of future-making practices, and the two cannot be separated. It is the prototypes that came before we had battery-electric vehicles on the roads, it is the publications from knowledge institutions on energy and climate outlook that advise, and it is the legislative proposal on vehicle emissions from government agencies that informs the haulier which trucks to invest in when the fleet is renewed. Or they can be carefully created forecasts for the freight demand 20 years from now, or parliament hearings were politicians, researchers and the public meets and pushes their boundaries of knowledge or formulations of new synergies between transport and energy systems that do not yet exist. The object-centric perspective sees objects as socio-material creations as "objects are hybrids, not disembodied ideas or norms, which have both a knowledge and a material component" (Esguerra, 2019, p. 2). A central part to the object-centric perspective is that "the world is changed by remaking the configurations of elements that constitute it" (Allan, 2018, p. 859). As future objects attempt to depict or engage with the future, the design of these objects makes up an active part of creating the possible pathways that can be taken, and which will not be considered.

Research question

Over the last few years, the attention in decarbonising road transportation has gone from focusing primarily on personal mobility to also including hauling of freight. Actors in the industry are also showing interest in how the future of their business is going to look like, and consumers are increasingly aware of their CO2 footprint. So how come that so little progress is seen in reducing carbon emissions from road freight? It is not because there is a lack of innovative new solutions. We see truck manufactures demonstrate vehicles propelled by an assortment of different energy source and cargo bike delivering goods around our cities. But still, it seems like there is a technological deadlock that keeps the trucks and vans running on gasoline and diesel. I will try an unfold the freight transport sector in an attempt to shed light on its dependency on fossil energy and current internal dynamics in the system and the forces that act upon it. I will build on this knowledge to asses how actors in the freight transport sector engage in the making the future and how we can transition towards a desirable system by making it possible for actors to engage in making a desirable future. My research question is:

"How can low carbon futures be made actionable for regime actors in the freight transport system?"

I explore this research question in a case study made in collaboration with the Danish think tank CONCITO. Based on a thorough system analysis of the current regime within the freight transport system, I support them in building a design intervention with the aim of making low carbon futures more actionable for regime actors. The design intervention consists of a large scale workshop with relevant industry actors and future objects developed for the purpose of enriching discussions of potential solution pathways.

Case presentation

CONCITO is Denmark's Green think tank, established in 2008, which aims to curb emissions of climate gasses through partnerships between political institutions, companies and people (CONCITO, 2019).

During 2019 senior consultant Henrik Gudmundsson, carried out the CONCITO project 'Decarbonisation of freight transport' (CONCITO, 2019b), supported by Energifonden (2019) (For CONCITO's own project description, see appendix 1). The project investigated key trends for decarbonising the road freight transport sector towards 2030 and 2050, intending to create actor-driven inputs to pathways for Denmark towards a low carbon future. The first part of the project focused on the overall freight transport system and climate implication and the second half of the project looks at road freight transport in urban environments.

This thesis followed the first part of the project, which concluded with the workshop 'Climate plans and climate budgets - what does this mean for freight transport?' at May 14, and the publication of a report outlining recommendations for future efforts. At the workshop, key actors were presented to the current state of the transport system and promising future pathways. During the workshop, the actors collaborated on formulating inputs and identifying barriers to the different decarbonisation pathways, which served as input to the subsequent report.

Through the work up until the workshop, the dynamics in the transport system was sought to be clarified, and the climate implications were assessed through the newest available data. A broad range of proposed pathways for the future was also identified and evaluated. In the thesis, I have in parallel to the COCITO mapped out the system and used the perspective of future-making practices to see the pathways and workshop as examples of future-making objects.

I am very thankful to CONCITO, and especially H. Gudmundsson, as a large part of my knowledge on the transport system comes from the collaboration with him and actors connected to the project. In this thesis, I have used some of the content I have created for Gudmundsson to the CONCITO project as they depict elements of the system that is not evident elsewhere.

METHODOLOGY

The project flow diagram for the work process is depicted below. The boxes with sharp corners in the middle column indicate project tasks and the horizontal bands shows project phases that correspond to each part of this report. The method and knowledge input to each project task are indicated in the left column (boxes with full lines and round corners) and data inputs in the right (boxes with dotted lines). Thick arrows indicate progress between project tasks and thin arrows indicates inputs to project tasks.

The diagram depicts the work process as a linear sequence of events; only broken by the circle indicating a deliberate iterative process in the design phase. The narrative of the project process is a refined version of the way it really happened and a useful guide to explain the project methodology as below. I will elaborate on reasons for differences between the real project process and the more linear flow process.

Research scope and methodological considerations

The overall project scope is adopted from CONCITO's project 'Decarbonisation of freight transport' to define the scope of this thesis to decarbonisation of freight transport by road in Denmark. The second part of CONCITO's project also focused on the urban environment, but a specific focus on urban transport is omitted from the scope as I only followed the first part of CONCITO's project.

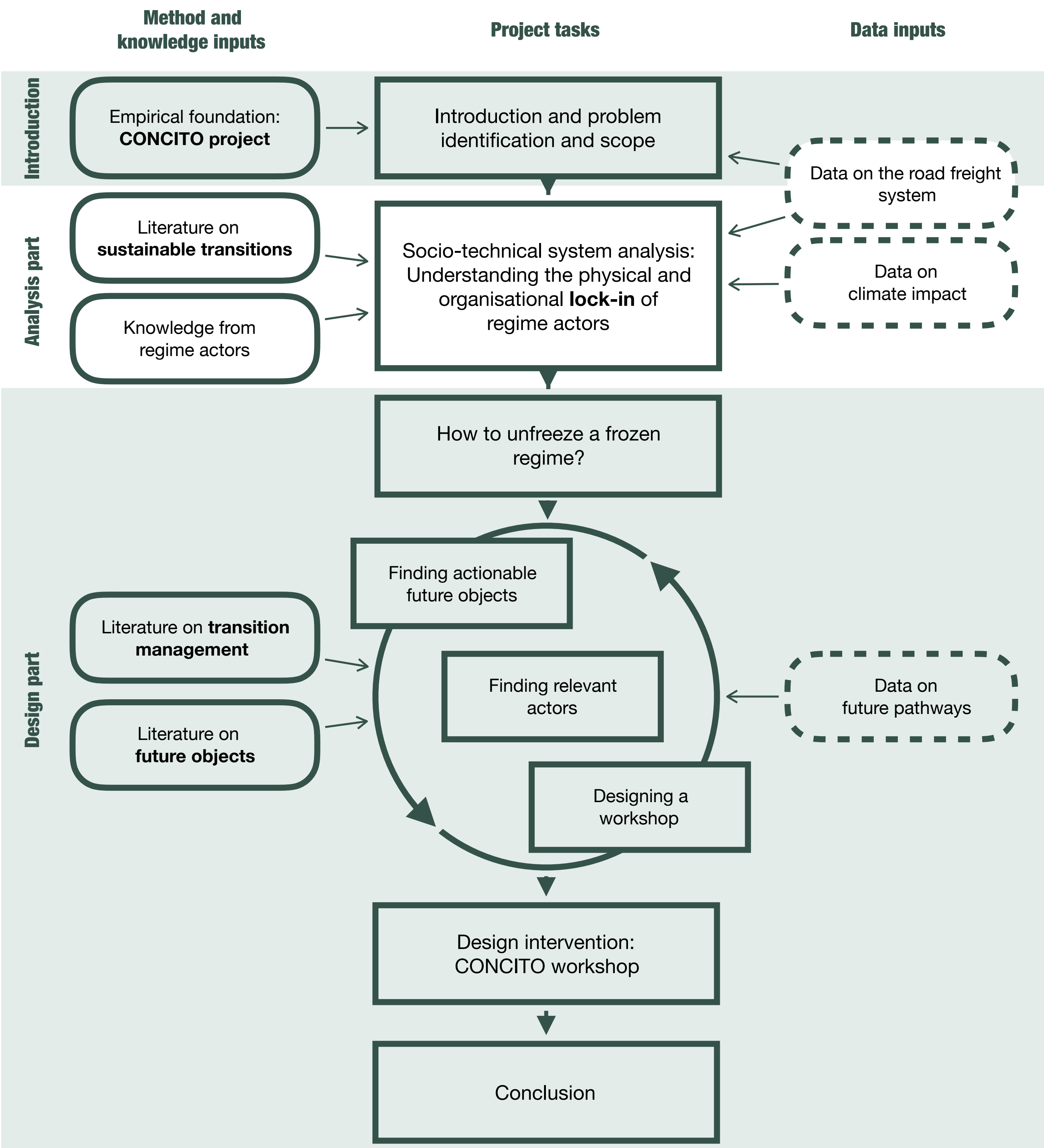


FIGURE 1: FLOW DIAGRAM FOR THE PROJECT PROCESS

(Own illustration)

I centred on the Danish national level as an early assessment of the decarbonisation of freight revealed that the most notable carbon abatement potential was not at the city level in specific but from extended stretches of hauling. It is not to say city logistics is not essential in terms of freight transport, but in the context of cities exist a subset of issues besides climate change (e.g. air pollution, traffic congestion, noise levels or optimisation of societal function and liveability), that are also important and deserves attention if the focus was mainly on the city scope.

I started the work by also looking into other modes of transportation (e.g. rail and waterways) but defined the scope only to road traffic as I found the potential for -, and the actor support to-, a modal shift in Denmark to be weak. It is necessary to state that modal shift can be a viable part of a decarbonised transport system, and thus is not entirely excluded from the later analyses.

Analysis part

Decarbonisation of freight transport was approach as a socio-technical challenge by drawing on the literature of sustainable transitions. Large societal functions, such as freight transport by road, tend to become fixed in their tracks and only incremental changes happen. If we are to get out of freight transport's lock-in on fossil fuels, more radical transitions has to take place. I used the Multi-Level Perspective to conceptualise the dynamics in the current systems with knowledge from literature, statistics, new publications and system actors. The perspective shed light on the interconnectedness of the regime and why the regime elements are locked together. It also showed how the regime is making some progression through incremental innovations as a response to the pressure from climate change and mapped out the radical niches innovations that have the potential to make radical changes the regime.

To frame the system in a decarbonisation context, I used the latest national data on climate gas emissions. I used data from on the national inventory on climate gasses to investigate which freight transport practices that contribute to the most substantial parts of the emissions in Denmark.

What really happened deviates from the more linear representation of progress as I needed a tool to sort out the many solutions paths I came about during my work. The solution paths are shown in the flow diagram to be a review and assessment of future objects, but this was done alongside the conceptualisation of the system, as sustainable solutions to decarbonisation can either visible in the epistemic practices of carbon budget or to reach a zero-emission society.

Design part

Transition management literature was reviewed to discuss the governance of desirable futures. The notion of future-making practices was used to encompass the things we do when we engage in making the paths for the future. Future objects were defined as socio-material objects that take part in creating the future. As "the solution is less to make subjects believe new things than it is to rearrange the elements to destabilise political traps, realign interested actors, make new possibilities seem more obvious or introduce new forces" (Allan 2018, p. 859).

Key future objects were organised, restructured and produced. CONCITO's workshop on decarbonisation served as a design interaction as it was a future object itself and used future objects as part of the agenda. This was an iterative process where each project task produced or identified future objects that acts inter-connectedly.

PART 1: ANALYSIS

Conceptualising decarbonisation of road freight

“One sometimes gets the idea that the change that really matters is truly dramatic change, the overturning of big systems. (...) Yet we should take care here. Our concern should be solving societal problems not tilting at ‘systems”

(MEADOWCROFT 2009, P. 337).

A short history: the beginning of trucks running on fossil fuels

In the last decades of the nineteenth century, the industrial revolution led to urbanisation, which again led to an exponential increase in horse-drawn transport (Geels, 2005). This was not without its problems, and aside from the cost for companies to be attending to an increasing fold of horses, new problems emerged such as congestion (as city streets were not designed for the increased traffic load); safety issues (from the intensified mix of humans, animals and vehicles on the roads leading to more accidents) and the concern for pollution (at that time in the form of horse manure which went hand-in-hand with the growing culture awareness of proper hygiene); though the causes were different at that time, the problems can be compared with what we deal with today. All in all, the need for solutions beyond the horse was pressurising the incumbent regime of the time.

At the turn of the century, a wide range of transportation modes came into the urban landscape; especially bicycles, electric trams and automobiles. The electric tram was dominant in for urban personal mobility in the USA at first, only to be overtaken by the automobile from 1920. For commercial fleets, the internal combustion engine and battery electric truck was first competing technologies, but developed in the first decade of 1900 into specific spheres; electric trucks was believed to be the better option in cities as substitutes to horses and combustion engines were favoured in rural areas (Mom and Kirsch, 2001).

Along came World War 1, and European countries began to make subsidies to purchases of trucks living up to military standards where the more extended range and increased speed of the internal combustion engine were better suited to the front line. Production of combustion engine trucks surged which increased production dramatically in The United States. The quality of ICE trucks rose with increasing returns to scale, as did the customer expectations of versatility in terms of speed and driving range. At the same time, small commercial fleets saw electric trucks as too large an investment as the upfront cost was higher than for internal combustion engine trucks. As transportation became more versatile than what the regime of horses had been able to provide, a cultural acceptance of a radical change in the transport system came into effect, and the need for the electric truck vanished. Mom and Kirsch sum up the learnings from this story:

> "It seems that the process of rational choice, often presumed by economic theory to occur when technologies compete, may be powerfully constrained by time, place, and especially intended application."
>
> Mom and Kirsch, 2001, p. 518

THEORY

The climate change debate has for many years be revolving around the nature and the scale of the climate challenge (Stoknes, 2015), but has during the past few years shifted to a discussion on the solutions for a decarbonised future (Hajer and Pelzer, 2018). The Danish Parliament has committed Denmark to be a net-zero emission country by 2050 following the Paris Agreement (United Nations, 2018), which implies a need for reconfiguration of the societal systems that are powered by fossil fuel.

Societal reconfigurations have been debated in literature through the lens of a range of different ontologies (Markard, Raven and Truffer, 2012; Geels, Berkhout & van Vuuren, 2016). Previously, technological substitution approaches were in favour, with the underlying assumption that new and better technical solutions succeed at the expense of the old and outdated, but this approach has been demonstrated to be too simplistic to explain the effects of continuous power plays between various elements in the system (Mom and Kirsch, 2001; Geels, 2005).

Mainstream economic theories based on a positivism ontology of rational decision-making have also been found inadequate (Unruh, 2000) as it does not explain the dynamics of the system arising from actors making non-rational decisions and interactions between actors (Geels, Berkhout and Vuuren, 2016).

Sustainable transitions

Sustainable transition theories that build on a socio-technical approach have been proposed and utilised in the literature as a way to explain and govern reconfigurations of societal systems (Markard, Raven and Truffer, 2012). The socio-technical ontology accounts for forces between the social and technical elements of society by interpreting the policy processes at play together with the physical structures of the system. In this way, the socio-technical approach can account for the dynamic nature of a societal system, and prevent pitfalls of becoming technology-blind or lessen the risks of dismissing unforeseen forces.

Socio-technical systems fulfil primary functions in the society, such as transportation, housing or food systems and are actively created by the actors embedded in the systems. The configuration of the systems can lead to path dependency, where many different elements, for example, the established rules of the political systems, cultural norms, the economy of scale, and so on, creates a lock-in that is not easily escaped. Due to the same dynamics, the selection environment of the system will favour those technical solutions that are consistent with the system path. In this way, our society has grown to become 'locked-in' on fossil fuels, a condition that is so ingrown in our technical and political institutions that it is possible without precedence (Unruh, 2000).

Despite these effects, socio-technical systems are not static, and transitions take place from time to time, whether it be as many incremental processes or as radical shifts. During the time of radical transitions, multiple technological innovations might co-exist to fill out the same societal function. Only later will some innovations become dominant and others will succumb - although the winner is not necessarily dictated by having the technological, economic or social upper hand.

The Multi-Level Perspective

The Multi-Level Perspective is used as a framework to explore these dynamics of socio-technical transitions and has been applied in studies of transport systems to a great extent (Geels, 2018). The perspective differentiates between three analytical levels of the socio-technical system; a niches level of radical innovation, a socio-technical regime as the structure for the existing system and a socio-technical landscape of external developments. The framework works well to conceptualise a socio-technical system, as the three layers offer an analytical approach to the mix of elements with social and technical character. As such, the multi-level perspective is most of all a descriptive tool with a socio-technical approach to show recent developments within societal functions to inform assessments about the future (Geels, Berkhout & van Vuuren, 2016).

An incumbent regime embodies the socio-technical system behind a societal function. It is the cluster of elements such as "technology, regulation, user practices and markets, cultural meaning, infrastructure, maintenance networks and supply networks" (Geels, 2005, p. 446) that provides the societal function. In this thesis, it is the societal function that makes it possible to transport freight by road in Denmark. The freight transport regime is made of many elements such as the fleet of trucks, the streets that they drive on and share with the system of personal mobility; It is also the industry norms and national and international regulations that govern transportation; it is consumer preferences and cultural norms around sending and receiving goods; and the established science and practices behind internal combustion engines. It is the interconnectedness of the elements that make established regimes resistance to change, but regimes are not static, nor do they shift radically by themselves. Regimes are 'dynamically stable' (ibid.) and incremental changes happen over time due to dynamics in internal structures, pressure from landscape developments and the emergence of niche innovations.

Niche-innovations are new technologies and social structures that can grow when protected from the selection pressure of the regime (Schot and Geels, 2008). Protected niche innovations compete or cooperate until dominant designs emerge that can enter market niches, which might expand to replace elements in the incumbent regime. This can be in the form of radical niche innovations that have the potential to completely restructure the regime by providing societal functions in novel ways, or by niche-innovations adapted to the selection environment of the regime (Smith and Raven, 2012).

The socio-technical landscape is out of reach for any one actor in the system, but landscape developments might affect the whole system. Examples count the landscape development of urbanisation that is changing where goods are delivered to as people increasingly are living in cities and climate change that is the hotbed for the current urge for a transition. These change in the landscape level put pressure on the regime by introducing forces that might not be tackled by any incremental improvement (Geels, 2018).

The Multi-Level Perspective can serve as a heuristic framework to analyse the dynamics in path-dependent regimes and the interplays from emerging innovations and landscape pressures (Geels, Berkhout & van Vuuren, 2016). As there can be a number of competing niches, and the arrangement and interaction of the niches can determine the outcome of a dominant design over a timespan of decades, it is important not just to look at one niche but to account for what Geels coins the "de-alignment" of the regime; where multiple market niches together provide the societal function (Geels, 2005). Expanding on this, it is also noteworthy to investigate the interactions between regimes. Drawing on Geels (2018, p. 88) there is three types of interactions; the competition (which for the freight transport system would be the modal shift between transport domains such as rail versus road), symbiosis (which is the separate spheres that positively interacts, such as electric vehicles that are linked to the electricity regime), and integration (where new integrated systems arises, such as goods being delivered to convenience stores forming an integrated last-mile system of freight transport, grocery shopping and personal mobility).

This highlights that it is not necessarily disruptions from radical innovation that is needed to change a socio-technical system, but a gradual reconfiguration of the system is also essential. Continuous reconfiguration is where incremental changes in limited system elements such as regulatory improvements, cultural changes towards climate adaptability or replacement of components of in technical systems work together to change the system. In Meadowcroft's words "One sometimes gets the idea that the change that really matters is truly dramatic change, the overturning of big systems. (...) Yet we should take care here. Our concern should be solving societal problems not tilting at 'systems" (2009, p. 337).

METHOD: ANALYSING THE SYSTEM

The transport system was conceptualised through a socio-technical approach building on the multi-level perspective to understand the path-dependancy and lock-in of the incumbent freight transport regime. First, the regime structure was investigated where the physical architecture and social structures were considered. The multi-level perspective is heuristic in nature, and no one specific formula is given to analyse a system, but the perspective served as ordering the information and revealing the dynamics in the system.

The data collection was done through:

- Empirical data from workshops
- Interviews with industry actors
- An assessment of climate impacts
- An assessment of potential destabilisation mechanisms

Empirical data from actors: Workshops, panels and debates

Data on actors in and related to the freight sector have been gathered from discussions with Gudmundsson from CONCITO and workshops, panels and debates[1].

- Workshop: Decarbonising Urban Freight Transport. Held by Trivector, CONCITO, Nordic Innovation and The Capital Region of Denmark. 12 Marts 2019
- Inter-political climate debate: DTU 25 Marts 2019
- Consultation on Sustainable Transport in a Sustainable Energy System: The Danish Parliament and DTU: 10 April 2019
- Hydrogen Denmark. Yearly gathering: 10 April 2019
- Panel On Decarbonisation of Freight: CONCITO 02 April 2019

Interviews with industry actors

To support the empirical data, I relied on the CONCITO project 'Energy saving in freight transport chains' (Krawack, 2015) which contains in-depth analyses interviews with large scale buyers freight transport scale (IKEA, Sanistål and Top Toy), forwarding agents (DSV and Blue Water Shipping) and conveyors and hauliers (Anders Nielsen og CO, Dania Trucking and Kaj Madsen Fjelstrup). Though changes have happened since 2015, the work gives a comprehensive baseline of knowledge of the practices of industry actors.

Sustainability of road freight transport

Decarbonisation of the freight system can be supported by knowledge about where carbon emissions are coming from. The climate impact was assessed through the national emission inventory Danish Centre for Environment and Energy (2019; Winther, 2018), recent statistics from the freight transport system from The Danish Road Directorate (Clausen, 2018) and Statistics Denmark.

The data differs between the institutions as they use different methods of for accounting. The inventories from Danish Centre for Environment and Energy (DCE) includes both historical emissions and yearly mileage for vehicles in different weight classes and follows the United Nations Framework Convention on Climate Change and the Kyoto Protocol. This convention includes emissions from border-trading of diesel and gasoline products. To account for the climate impact from the driving patterns in Denmark I received a set of data from DCE that did not include border-trading (Winther, 2019)

[1] Further detail about the event can be provided upon request

The Danish Road Directorate uses data from national vehicle inspections and driving books. The scope for classifications of vehicles is also different. The data from the road directory shows a lower accumulated yearly emission than emissions data from DCE; this is due to DCE's rely on data from DTU's traffic model where trucks are assessed from 3.5 tonne, whereas the Danish Road Directory rely on vehicle and driving book inspection for Danish vehicles over 6 tonne.

Greenhouse gasses will be used in the assessment of larger domestic and international sectors, but the transport industry will be accounted for in CO2 as the current regime is dominated by fossil fuels where CO2 emissions constitute almost all emissions.

Destabilising mechanisms

To comprehend and navigate the many measures proposed for the decarbonisation of freight transport, I used a framework of five categories that organised the measures.

The domain of sustainable niche-innovation within the logistics is somewhat mixed at the time being. Some niches are but mere technical small scale niches with limited actor support. Other technical niches have already a large share of actor support without having entered the market yet. Some niches are available to the market, and for some, it is difficult to assess whether they are radical niches or just increments to 'dynamical stable' regime. I have deviated from the multi-level perspective as I have assessed all destabilising solution through the categories outlined below, and not through whether they are part of the regime or a niche. This was a deliberate choice to make the design work, which is described later in this report, easier for the relevant actors to relate to and have a constructive dialogue around.

Alan McKinnon's work 'Decarbonizing Logistics' (2018) analyses the main trends of decarbonising, and have identified Five Categories of Freight Decarbonisation Measure, that I chose as a framework for categorising decarbonisation methods.

The measure categories are:

FIGURE 2: MCKINNON'S FIVE CATEGORIES OF FREIGHT DECARBONISATION MEASURES
(Own illustration)

I populated each measure category with solutions paths found throughout the study, starting with the range of solutions McKinnon discusses and expanded with decarbonisation solutions discussed in publications by research institutes, NGOs, company statements, freight industry associations and governments (see appendix 2). To manage the plus 100 solutions found, of the five solution areas was further divided into intervention categories (e.g. under increase (asset utilisation) the solutions of 'consolidation of goods 'and 'standardising of loads' falls under the intervention 'vehicle loading', whereas 'pollution-routing' and changes in 'order lead time' falls under 'Logistics').

The aim was not to make an all-encompassing solution space but to present a solution space gathering and sorting a vast number of various interventions for further investigation.

Solutions for decarbonisation have been mapped out by the following sources discussing a range of decarbonisation solution paths.

ANALYSIS OF THE ROAD FREIGHT SYSTEM

Freight transport is a complex subject and the nature of transportation, that consist of so many physical elements to make a service that 'disappears' when the goods a delivered (Burchardt, 2017). Transport consist of large infrastructure installations such as harbours, roads, gas stations and smaller things as vehicles, container, pallets and more (ibid.).

The major part of freight transport in Denmark is by road, with a share of more than 85% of the freight per tonne-kilometre, which is the highest of the Nordic countries (Nordic Council of Ministers, 2018). The transport chains are often divided between many actors with different concerns, as transportation of goods is usually outsourced through shipping agents and conveyors (Statistics Denmark, 2019a), who again can use subcontractors, as illustrated in the figure below. Krawack (2015) divides the general responsibilities as; it is common to be the buyer of transportation that establishes the boundaries for the of delivery, the shipping agents carry out the coordination with subcontractors and optimising truck capacity and hauliers choose the vehicle and driving patterns. This is a highly fragmented organisation, and even if there was a demand for green transport, would hauliers have concerns on how to comply; as one participant at the Trivector workshop expressed: "we can not dedicate trucks to specific tasks; unless the transport job is very large".

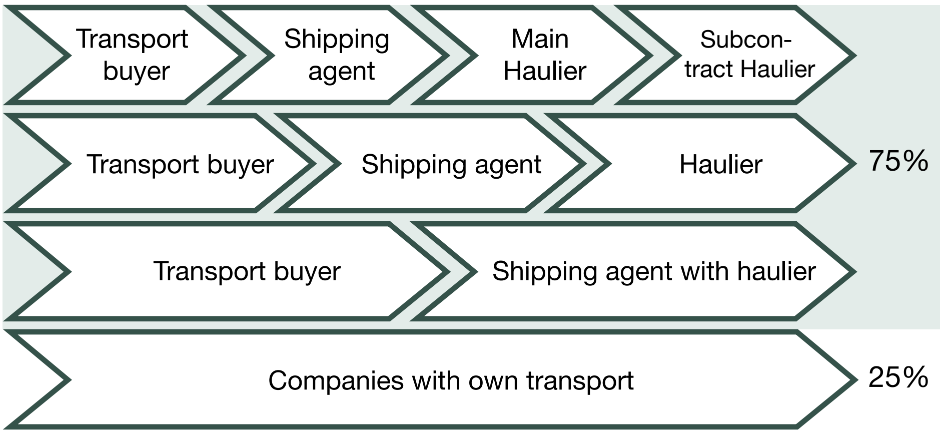


FIGURE 3: ORGANISATION OF DELIVERY CHAINS

Percentages depicts share between hired freight transport and transport for own account in total travelled kilometres for Danish road vehicles over 6 tonnes. Own illustration based on Krawack (2015) with data from Statistics Denmark (2019a)

Transport buyers have in general minimal focus on the reduction of carbon emissions from freight transport due to company management's focus on cost (Krawack, 2015), so they are often not demanding CO2 accounting when buying transport. A standard for CO2 accounting on transport (DS/EN 16258) have been established and are used by hauliers, but the customers are not asking for the inventories. Even the hauliers are in doubt of the most substantial emissions are and where to take measures; "where is the most significant consumption [of energy]" (participant from shipping company at Trivector, 2019) The share of CO2 emissions from transport are usually not the dominant part of a companies CO2 emission and thus have a tendency to remain in the dark.

This creates a vacuum where there is no incentive to reduce carbon emission, beyond the emissions that comes from fuel efficiency improvements. There is an extended system of more than 2,000 gas-stations in Denmark but only 2 % of them are offering alternative fuels such as gas of hydrogen (Drivkraft Danmark, 2019).

The transport sector is not against taxes and regulation, just as long as the regulations are equal to all players on the market, as expressed by industry organisations at the workshops. On the other hand, local rules (city-level, regions or country specific) are seen as very cumbersome to handle and are preferred avoided (Krawack, 2015). There was also found to be an urge to encourage fuel savings by increasing taxation on the more polluting options instead of reducing taxation for fuel savings.

A part of the truck freight that comes into Denmark is in direct transit between Germany, and Norway or Sweden due to Denmarks central geographical location (Dagnæs, 2016). For this type of freight, there are no Danish actors directly in the transport chain, but only as supporting functions to the supply chain as fuel providers, road maintenance and so on. In the same way, are we were dependent on the fuels in the neighbouring countries as Denmark cannot be an 'island' state with a specific fuel.

There is also a shift of Danish Hauliers having increasing subsidiaries in eastern Europe with and trucks driven by foreign labour (ITD, 2017). This pushes the prices level down, and it has been seen that it can be cheaper to send two vehicles registered outside of Denmark with foreign labour instead of one larger truck.

The road freight regime shares elements naturally with other regimes such as the road systems and large parts of refuelling infrastructure. It also overlaps with regimes of different modes of transportation, such as at harbours or road-to-rail logistics. Increasingly, the transport regime is beginning to be overlapping with the agriculture domain as regulation ensures biofuel is mixed in diesel and gasoline products.

Fuel sales across borders

The Danish market for diesel fuels is heavily influenced by discount schemes from energy- and oil companies (Danish Ministry of Taxation 2012, p. 145), which makes it favourable for hauliers to buy fuel in Denmark before driving on to neighbouring countries (Danish Ministry of Taxation 2017). This results in more than a third of the diesel fuel sold at the Danish market is being used by trucks outside of Denmark (Danish Centre for Environment and Energy 2019; Winther 2019). To buy fuel in one country, and export it in the vehicle fuel tank, to be used in other countries is called border trading, which is included in the accounting of national CO2 emissions under the Kyoto protocol (Danish Centre for Environment and Energy 2019). The border trading of diesel fuel therefor has significant implication for the Danish carbon emissions for transport, especially for trucks.

The main share of international border crossing to and from Denmark by truck is at the city of Padborg at the border to Germany (Clausen, 2018). Favourable trade agreements between oil companies and haulage contractors on the Danish side have been established as volume discounts from the vast quantities of diesel fuel being bought (Sørensen, 2019). This makes trucking companies fill their tanks on the Danish side of the border (ibid.), in spite of the net retail price of diesel oil in Germany is lower than in Denmark (Danish Ministry of Taxation, 2017). Even without the discounts, the retail price of diesel is higher in Sweden due to lower taxation in Denmark, making freight hauliers naturally inclined to fill their fuel tanks in Denmark before driving on to Sweden.

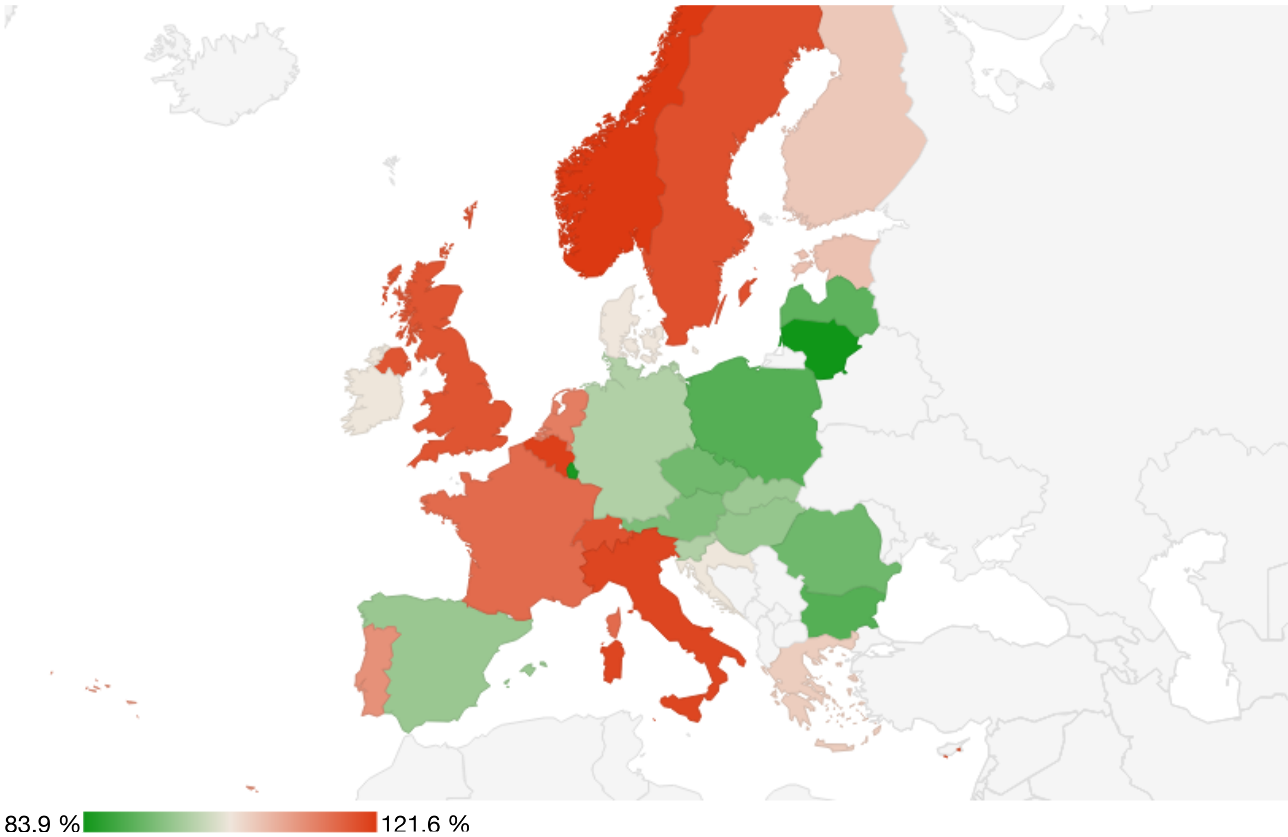


FIGURE 4: AVERAGE FUEL PRICES (WITHOUT INDIVIDUAL DISCOUNTS) AT THE PUMP
EU states and Schengen countries compared to the Danish level (Denmark: 100%) in week 21, 2019. Price does NOT include individual company trade agreements. Countries marked red are more expensive, countries marked green are less costly than Denmark. Darker colours indicate larger deviation. Own illustration with data from the Global Industry Association for Road Transport (2019); (Map data: Google, Sheets, 2019)

The relative size of the discounts have not been uncovered in this study (a good example of the protectionism is found in an article from more than a decade ago covering the subject, ending with the quote: "A large haulier recounts a discount of DKK 1.20 (0.16 €) per litre, against the fact that we do not mention his name; because it can cost him dearly to get into disrepute, he fears." (Berlingske, 2006). Thus, it has not been possible to estimate the extent of the discounts schemes or compare with price conditions in other countries.

The average price in week 21, 2019, of diesel fuel at the pump in Denmark compared to EU states, and countries in the Schengen area are depicted below. The average price at the pump is including general discounts but excludes individual discounts made by hauliers discussed above. The figure illustrates that it is cheaper to tank fuel in Denmark before driving north to Sweden or Norway. It also shows that hauliers that get a substantial discount in Denmark, that makes it cheaper to refuel in Denmark than in Germany, can benefit from first refuelling again in Luxembourg when westbound or Poland when going east. This makes Denmark a geographical hot spot for border trading with huge incentives for companies to refuel in Denmark, as well as possible substantial revenues for oil companies and the treasury through fuel taxes.

Government policies

The Danish Parliament has through the Energy Agreement of June 29th 2018 (The Ministry of Energy, Utilities and Climate, 2018a) sat the climate goal of being net zero emission no later than 2050 to stay in agreement with the Paris Agreement. The political focus of decarbonisation transportation has widely been on personal mobility over freight transportation (Nordic Council of Ministers, 2018). The energy agreement holds no specific targets for the transport sector, but funds have been assigned from 2020-2024 to underpin green solutions in the sector, and it is announced that Denmark will work towards tightening the EU commissions targets for light vehicles and introduce 'ambitious' CO2-requirements for heavy-duty vehicles. The Energy Agreement also establishes funding for an expansion of biogas and green gasses, among others for transportation.

Denmark is through EU committed to a target of 10 % renewable fuel used in the transport sector in 2020, which the Danish government will achieve by increasing the biofuel mixing requirements (Danish Ministry of Energy, Utilities and Climate, 2018b).

At EU level, there is an overall target to reduce emissions compared to 1990 level with 40 % in 2030. This is in EU context distributed at reduction compared to 2005-levels of 43 % in the quota sectors and 30 % in the non-quota sectors (which in general is transport, agriculture, housing and environment). The Danish obligation is 39 % reduction for the non-quota sector, which is estimated to and aggregated reduction of 32-37 million tonne CO2e over the period of 2021-2030 (Danish Ministry of Energy, Utilities and Climate, 2018b). The government assessed that the most substantial part of the accumulated reduction should come from LULUCF credits (through land management to increase uptake of CO2 in land and forest) and annulations of CO2-quotas; so-called 'flexibility mechanisms' which has been granted to Denmark due to the higher than average 2030 reduction target and danish agricultural systems effects on the national greenhouse gas emissions.

The latest class regulation on trucks of EURONORMS is exclusively regulating particles pollution, not climate gasses. For person cars, CO2 regulations are already in place, and new regulation is currently being introduced for trucks. The EU Commission has set targets for cars and vans as fleet-wide average emissions target from 2020. The first legislative proposal for CO2 emissions standards for heavy-duty vehicles was presented by the commission in 2018, as a target for a 15 % and 30 % reduction in 2025 and 2030 respectively, compared to 2019-levels (European Commission, 2018).

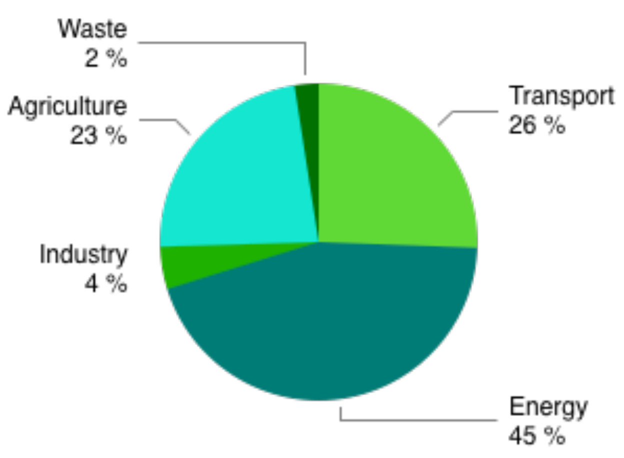
The carbon footprint of road freight transport

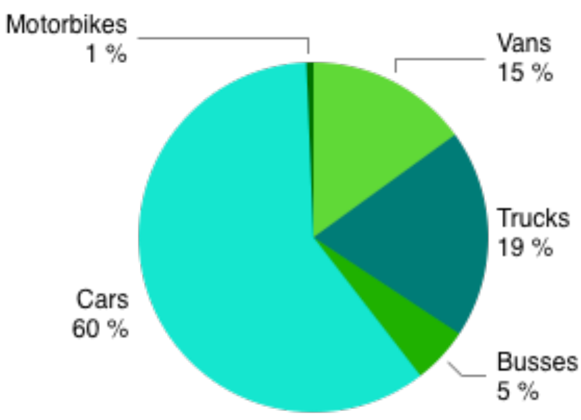
In the following, I will break down the carbon emissions from freight transport by road, by first looking at the overall domestic emissions and then piece by piece look at the different source.

Freight transport on road is usually carried out by vans (Light Commercial Vehicle) or trucks (Heavy Duty Trucks). All truck driving is considered to be freight hauling. Vans might be used for freight transport, but is also used for a range of other activities, such as service cars in company fleets and the share of transport performance that can be allocated to freight is unknown. Busses, passenger cars and 2-wheelers as motorcycles and mopeds might be used for small scale freight distribution, but the share is considered negligible.

In 2017, Denmark emitted 50.6 million tonne CO2 equivalents (Danish Centre for Environment and Energy, 2019). The total emissions have decreased with 31.7 % from 74,1 million tonnes in the year of 1990. In the same period, the transport sector has risen with 22.8 % to 13.2 million tonnes making it the only large scale sector to increase. More than half of domestic transport emissions came from private cars and motorcycles in 2017, and a third from light- and heavy-duty trucks (Winther, 2019). It is the heavy duty trucks that are found to be the hardest to decarbonise (Drivkraft Danmark, 2019).

It is worth noting that countries total GHG inventories usually account for direct energy use and territorial emissions only, and as the above numbers also are presented in this way sectors as international flights, shipping and carbon footprints from the production of imported goods are excluded. To set things in a context, the emissions from Danish operated ships, planes and vehicles were in 2016 34.6, 2.8 and 1.2 million tCO2 respectively.





GRAPH 1: GREENHOUSE GAS FROM NATIONAL SECTORS AND CO2 FROM ROAD TRANSPORT

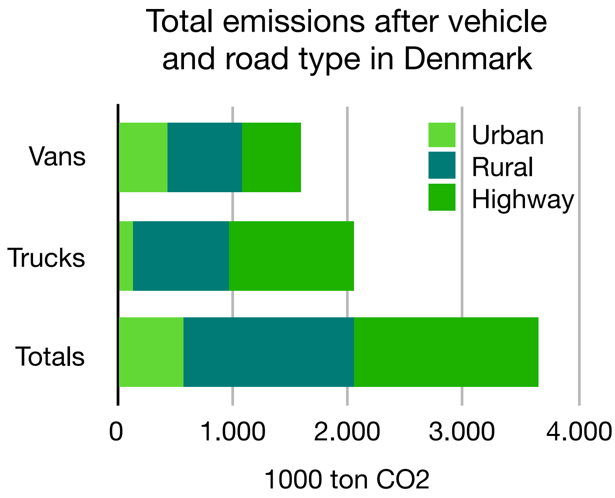
Left: Greenhouse gasses at Danish territory 2017 (Own illustration data from Danish Centre for Environment and Energy, 2019)

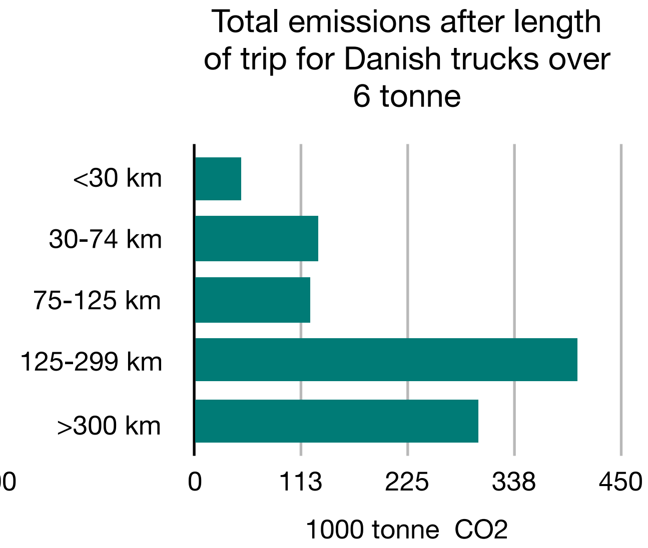
Right: CO2 emissions from road transport in Denmark 2017 (Own illustration with data from Winther, 2019)

The carbon footprint from road-, trip, and vehicle type and weight category

When looking into emission data, it becomes apparent where the vehicles are emitting the most. Trucks in urban environments only contribute marginally, but vans have almost the same total emission on all road types. For all freight transport, emissions at motorways dominate, followed by emissions in rural areas. It is also the total emission from hauling over longer stretches at each trip that have the most substantial emissions (note, there is a difference between the aggregated yearly emissions from each institutes accounting method).

Heavy trucks (over 40 tonnes) are dominating the emissions from trucks. This shows that to decarbonise freight, it is important to look at the heavy-duty vehicle driving at rural roads and motorways. Vans over 1.3 tonnes also contribute with quite a share.

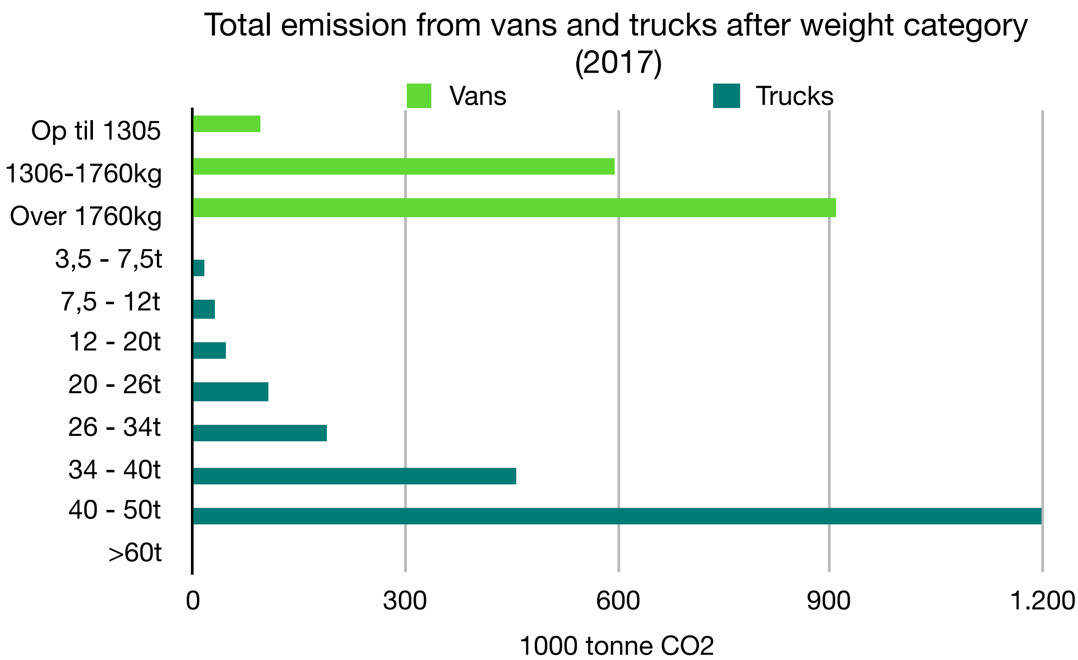




GRAPH 2: EMISSIONS AFTER ROAD TYPE AND TRIP LENGTHS

Left: Emissions after vehicle and road type in Denmark in 2017 (own illustration with data from Winther, 2019)

Right: Total emissions after length of trip for trucks + 6 tonnes in 2017 (own illustration. Calculation with data from Winther, 2019; Clausen)



GRAPH 3: TOTAL EMISSION FROM VANS AND TRUCKS AFTER WEIGHT CATEGORY

Emissions in 2017 (Own illustration with data from Winter, 2019)

Destabilising mechanisms

Destabilising: Landscape developments: Climate Change

Climate change is an increasing concern both in public and political discussions. Since the Kyoto agreement, there has been an international acknowledge of climate change, but change is not taking place in the speed of constituting a transition. The Danish government wants to be trend-setting for climate improvements and has committed Denmark to be “climate neutral” nation by 2050 (Danish Ministry of Energy, Utilities and Climate, 2018b), thus not emitting more greenhouse gasses that are being absorbed.

Freight transport has received less attention than the energy sector, which has seen the most significant reduction in the last decades (Danish Centre for Environment and Energy, 2019) and in the transport sector, there has been a focus on personal mobility over freight (Nordic Council of Ministers, 2018).

The growing awareness of climate change has made frontrunner companies volunteering to set emission targets in line with 1.5 C warming in initiatives such as the Science Based Targets (2019).

Destabilising: Radical and Incremental developments

Reduction of transport demand

Measures to reduce transport demand is not commonly debated among regime actors in transport, but there are several external movements in the society that can shape future demand (McKinnon, 2018). Together with increasing cultural climate awareness have been a broader acceptance and inclusion of dematerialisation in a society where actors in the full life-cycle of any goods may participate in the recycling of materials, waste minimisation or a broader acceptance of digitalisation or circular and sharing economies.

Financial crisis

In the year following the financial crisis in 2008, employment in the freight transport sector, the amount of goods being hauled and total driven distance drastically decreased (ITD, 2017). Whereas the transport performance more than recovered in the following decade, the total mileage driven is still lower, indicating a better utilisation of weight utilisation in hauling (ibid.). The financial crises have left fewer hauling companies, and it is indicated that the utilisation of assets in the freight transport industry has been improved in the wake of the crises.

Urbanisation and the information society

The ratio of people living in cities contra on rural areas have steadily changed in favour of cities, and more than half of the population are now living in urban areas worldwide and the same trend for Denmark. This makes changes to both the transportation of consumer goods but also the building materials for expanding cities with new buildings and extending infrastructure. By this follows a need for hauling of freight via highways to urban areas, and then distributions in the more dense city environments.

Internet shopping has become an integral way of consumer shopping. This has in part increased the number of packages being sent and moved some consumer goods from store warehouses to direct deliveries or to postal offices and pick up places and increased the private international import of goods. In the wake of this, new ways of goods transport have also emerged, such as home delivery of groceries and prepared meals. On the overall road network, the effect of e-commerce is assessed to be marginal, though some road stretches are more affected (e.g. west of Copenhagen) (Nielsen et al., 2017).

It has also been observed that there is a move towards resellers having business concepts including smaller storage space and higher turnover rate, calling for frequent freight transport (Krawack, 2015)

Optimise modality

In Denmark, the dominant transport mode is road, with a share of 85 %, due to the country's limited size and relative short hauling distances that disfavours rail and waterways (Nordic Council of Ministers, 2018). There has been a push towards more freight transport by rail, both domestically and on an European level and Europe Commission stated in 2011 that "30% of road freight over 300 km should shift to other modes such as rail or waterborne transport by 2030" (European Commission, 2011, p.9) and the European organisation Transport and Environment (2017) have argued for strengthening the rail freight network in the union.

IKEA has tried to implement rail as a transport mode in their freight delivery chain, but without any success and the as switching mode away from trucks was seen too cumbersome for (Krawack, 2015), as there is a series of disadvantages of less flexibility in time, planning, packaging and delivery points.

Urban city logistics have seen a surge of a shift towards delivery by bike, both for fast delivery of smaller packages and fast food (e.g. By-Expressen, 2019 or Wolt, 2019). Cargo bikes have the advantages of zero pollutions, less impacted by congesting compared to cars and lesser restrictions on parking. This trend is also being seen from 2- and 3-wheelers with electric motors to supply smaller goods and personal transportation between hospitals in the capital region (Madsen, 2019).

Increasing asset utilisation

There is a range of opportunities arising from new types of collaboration within freight chains though IT (International Energy Agency, 2016). An example is online load matching (where shipping agents and hauliers in the transport chain can coordinate supply and demand for vehicles). Predictive analytics are also emerging or and the focus on re-timing delivery schedules. This involves the customers, either in anticipating their needs or rearranging order lead time to prevent 'Just-in-Time' deliveries. Having demands of quick order lead times, even then it might not be of importance leads to increased emissions (McKinnon, 2018).

Other measures are vehicle and pollution routing (optimising for lowest emissions, as opposed to distance or time) and optimisation of vehicle loading as IKEA is doing (Krawack, 2015). Also 'backhauling' (where empty vehicles are filled with new goods in the return trip) or 'crowd-shipping' (where every-day drivers use the left-over capacity to carry goods instead of dedicated vehicles) and telematics (data from digital monitoring of vehicle fleets).

There is a trend for concentration and consolidation in the transport sector which can be seen as a decreased total number of trucking companies, that each instead are beginning to transport more goods (ITD, 2016). There is also a preference for larger but fewer trucks in the fleet (Winther, 2018). Laws for size restrictions of trucks restricts operators from choosing larger vehicles, although this could mean higher efficiency per load. Larger trucks might take some of the modal shares from rails and is seen as more dangerous and are being opposed by some (Nordic Council of Ministers, 2018).

Improve energy efficiency

The automobile and truck manufacturing industry has adhered to the reliance on the internal combustion engine for many years. The focus has been elsewhere than decarbonisation (Geels, 2018), and environmental improvements has come with motor efficiency improvements and vehicle optimisation of fuel consumption (such as aerodynamic improvements), driven by the demand from economic incentives of customers, and class specifications such as the Euronorm, which is regulating air pollution but not climate gases.

Improve energy efficiency holds an assortment of measures such as driver training, increasing fuel efficiency through light-weighting of vehicles, aerodynamic improvements to vehicles and trailers and idling reduction technologies leads to lower fuel consumption which goes hand-in-hand with lower carbon emissions and decreasing fuel expenditures. Therefore, many of these solutions have already been taken up by the industry. This is indicated by the Danish Transport and Logistics Association publication “49 ways to save fuel” (2009) and by industry organisations at the workshop “Decarbonising Urban Freight Transport” (Trivector, 2019). This trend is likely to continue with proposed CO2 Vehicle Standards on trucks from the European Union. There is also solution paths as autonomous trucks and platooning which seeks improvements through to automation.

Large industry organisations believe that the easy solutions to carbon abatement are already implemented as this equals reductions in fuel savings (participant at Trivector, 2019), but some of the solutions that might not lead to direct fuel savings, or have a higher capital cost are possibly still left (McKinnon, 2018).

Reduction of transport demand

Reducing carbon emission in the energy mix is already happening through mixing of biofuels into gasoline and diesel oil as part of the regulation. But it is still fossil fuels that are the predominant fuel type and only a fraction of the gas-stations in Denmark provides the opportunity to refill other fuels than gasoline and diesel (Drivkraft Danmark, 2019).

Hybrid heavy-duty vehicles are also emerging, as both electrical hybrids (vehicles having both an internal combustion engine and an electric motor) and hydraulic hybrids (vehicles with fluid systems to reuse breaking power). But hauliers are still baffled on which direction the technology is going. As expressed by a participant at the Trivector workshop from an industry organisation: “[we] do not know what to fill in, in 2020. What about 2030?”.

Battery electric trucks are shown in demonstrations from Volvo, Tesla, Mercedes-Benz and more. The niche of electrical trucks is receiving attention from the growth of battery-electric cars. Although companies are promising range and loading capacity for the trucks, these are not demonstrated on the market products yet.

Biofuels are already blended in fossil fuels to promote renewable fuel in transport as bioethanol and biodiesel (Drivkraft Danmark, 2019).

Electrification of road systems (also called electrified highways or eHighways), whether this may be by overhanging wires or inroad electric tracks. Electrical highways are being developed in small technical niches in Sweden and Germany. Siemens has created catenary systems for trucks (with overhanging power-lines as for trams) and tested on two-kilometre stretches with Scania trucks in both countries (Siemens, 2017). One demonstration project has also been carried out in the USA. The trucks that use eHighways are fitted with a pantograph on top of the driver's cap to conduct electric current from the power-lines to the drivetrain. The pantograph automatically extends only when the truck is driving at an eHighway and retracts when then truck moves away from the eHighway. There have also been made small scale tests in Sweden with inductive tracks are embedded into the road (Zhao et al., 2018). Inductive charging roads have the potential of also powering cars. When the vehicles are not on the eHighway, they can be driven by a battery, internal combustion engines or any other propellant.

Electrofuels is liquid fuels that can be made from renewable energy and CO2 harvested from industry, agriculture or the air. A primary energy product from renewable energy is hydrogen, which can be upgraded in carbon chains to liquid fuels such as DME that can be a successor to diesel oil. Electrofuels production is seen as an integral part of strategies towards smart energy systems as it can constitute a buffer solution to the variations in energy supply from renewables (Mathiesen et al., 2015).

CONCLUSION: THE FROZENNESS OF THE FUTURE

In this chapter, we have analysed the established freight transport system to see how dependent its future path is on fossil fuels. The multi-level perspective was used as a heuristic framework to shed light on the recent dynamics in the systems. We saw that the incumbent regime was rooted in a carbon economy and that the future pathways were dependent on fossil fuels mainly due to two intrinsic character trades of the regime.

Why the carbon regime is locked-in on fossil fuels

1. The physical architecture of the regime is dependant on carbon
2. The organisational structures limit each actors room for action

First, I will elaborate on the physical architecture as it is deeply rooted in a carbon economy, then I will make some concluding remarks on the restraint of actors from the organisation structure.

Most trucks run on diesel oil and the mileage range of diesel trucks have become a part of the practices for both hauliers and transport customers. A fully expanded infrastructure for refuelling is established with gas-stations throughout the country. The geographical placement of the country also makes Denmark dependable on the propellants used in our neighbouring countries. Favourable trade agreements between private partners keep an incitement for the sale of fossil fuels in Denmark due to significant state revenues from fuel taxation.

The organisational structure of freight transportation is creating a highly fragmented actor constellation. We saw that there easily could be many steps between a transport buyer to the haulier and freight transport have a lot of established supporting functions in the regime. This makes the actors interdependent, which makes it very hard for any one actor in the regime to act independently. In the actor constellation of freight transport, the actors become bound to demands on being cost-effective and the power to make actions deviating from this is distributed between many actors. Although, both suppliers and customers have a wish, or at least are not radical against, becoming greener, it does not reflect in the customer interest and ability for demanding and paying for greener transportation. These effects prevent any one actor from breaking apart from the established regime to navigate independently towards new future pathways. In this way is the room for manoeuvrability for any one actor is confined by the very regime they are a part of.

The landscape pressures have only limited effects in policies making incremental improvement. Niche innovations have a hard time against the high selection pressure from a regime structure being almost immune to change away from a carbon-dependent track. It is possible to act within incremental developments and radical innovations, but it is hard to resolve which actors can take proper actions as the regime is too fragmented and locked-in.

The analyses show that some mechanisms are in play that can move the stability of the system. Some of these are not very strong or will have decarbonisation effects in the system. Landscape developments of urbanisation or information society might make changes to the types of goods being transport and the destinations, but it is not decarbonising freight transport. New policies on national levels call for something to be done, but not what, and on a European Union level regulations seek to increase regime developments. But it will not be enough to curb the challenge of carbon. Some niches innovations are proposing to increase the integration of the electrical and transport sector.

PART 2: DESIGN

Making the future of freight into actionable design objects

“the world is changed by remaking the configurations of elements that constitute it”

ALLAN 2017, P. 859

HOW TO UNFREEZE A FROZEN REGIME

In the previous part, we saw how the freight transport system is stocked in its tracks. No regime actor alone has much room for manoeuvring as the system's technical dependency binds them to fossil fuels and the interdependence with other actors. To shift the system towards a low carbon future is indeed a wicked problem. In this chapter, I will look into theories that explain how to create leeway in a stocked system through alternative governance mechanisms.

This path-dependency of socio-technical regimes makes regime actors chose future pathways that lie in the same track that the regime is already on. If every actor responds to system dynamics in the same path that we want to escape, nothing is ever going to happen. Changing a system is about creating collective visions of how the system should look like in the future. With collective visions, systems actors can act in different pathways but towards the same goal.

Some future pathways are not frozen in the same track as the regime. These futures can be depicted through socio-material objects that connect our ideas, designs and calculations for tomorrow in a materiality that can be presented today. We call these entities 'future-making objects' as they help us take action that will make the future. Before regime actors can work deliberately towards new futures, an understanding needs to be in place of what the future encompasses. Thus, the future pathways that are acted upon, are depending on how (and how well) the futures are articulated through future-making objects. Future pathways that are being expressed vaguely articulated future-objects is hard to act on, but well defined future-making objects might invite actors to engage in contributing to the pathway actively.

First, I will discuss theories for governing transitions that opens up for participatory developments around common cultural goals and present an approach to future-making objects which can serve as the connection socio-technical material that links present practices to new future. These two theories informed a set of theoretical methods which I used as tools in a design intervention with regime actors held by CONCITO.

Then, I will explain the methods that equipped us to do the design intervention. First, the relevant future objects that exist in a Danish context was mapped out, and then, the actors we wanted to engage with the future pathways were found. These two things were combined in a design intervention hosted as a workshop where the regime actors were introduced to the future pathways to discuss the most interesting solutions.

Subsequently will follow an analysis of the event that defines the design intervention and the learning outcomes.

THEORY

We saw in the first part how the societal function of freight transport is a highly complex component of the climate challenge as the system is routed in a range of interacting elements and is locked-in on fossil fuels. There is no silver bullet to solve the challenge of decarbonisation of freight transport (McKinnon, 2018). Scholars have observed that neither government policies nor liberal market forces alone are enough to create the needed sustainable developments in industrialised societies; however, contributions from government and market forces are still required to shape sustainable development (Loorbach, 2010). Power structures have during the last decades shifted from central governments to a plethora of actors in networks (Geels, 2018) and policymaking has been spread from being centralised at government level to governance on both subnational, national and supranational levels (Frantzeskaki, 2018). In this way, the "governance" that makes our policies are being diversified and diffused.

Transition Management

In trying to handle these persistent problems and get away from a societal lock-in on fossil fuels, there has been uttered a need for governance activities that extends beyond the time scopes of current national governments, but into the decades to come. Loorbach has proposed Transition Management as a new culture in policymaking (2010). Transition management aims to manage ongoing policy processes towards sustainability through governance activities that create long term perspectives guiding short-term developments.

Policymaking alone will not be sufficient to tackle the problems of climate change, as the systems are too complex. As Loorbach puts it: "every action or solution will lead to changes in the societal structures, in turn transforming the problem itself" (2010, p. 164). In other words, the problem being manage changes at interaction. As contemporary governance in a socio-technical perspective is dispersed between many actors throughout society, has policymaking become situated within the same societal structures that it attempts to govern. To manage development in such a dynamic system, Loorbach's formulations of transition management first calls for envisioning shared long term principles that work as guidelines for cultural direction and common goals for our societal system to work towards. Without having common goals it becomes difficult to establish a shared direction for development between heterogeneous actors, and even more difficult as the system changes at interaction. Thus, long term principles are needed to enable diverse actors in different pathways scattered across time and space to work towards a desirable future, instead of counteracting each other.

Loorbach's suggestion is to have a small party of independent frontrunners (10-15 competent actors with different backgrounds) to debate and formulate a vision for a collective desired cultural direction on a strategic and long term time scale (for decades to come). Transition management has been used extensively within this scope in geographically limited projects such as city-planning (Frantzeskaki, 2018) and specific infrastructure projects (Bosman, Loorbach and van Raak, 2018).

It is essential that the long term principles can penetrate the various actor networks and institutions that are part of the current regime. Certain key actors are needed to fill out this function by translating the cultural meaning and guidelines to their respective networks, organisations and institutions. If the cultural guidelines are not too normative, networks that share the same collective visions can establish and explore distinctive transition pathways over extended periods while working towards the same desired future.

When experimenting with new opportunities within a transition path, only the innovations (which should be understood in the broadest sense, as it can be in a technical or institutional sense or as innovation in behavioural practices) that supports the cultural goals should be cultivated and explored. These innovations serve to mobilise actors in concrete projects and can lead to a shift in practices over shorter periods.

An integrated part of the processes should be a constant collective reflection upon the progress of change and the management of the transition itself. The reflection should be an institutionalised monitoring of the processes, but society also has a role to play through public opinion formation and information driven by media and the internet. A constant reflection upon, and monitoring, of the transition processes, ensures continuing experimentation that prevents new lock-ins and fosters a constructive debate to the articulations of cultural visions.

Making the future

When visions and pathways for the future are created they can have long term effects and become a part of how we are anticipating the future and thus, how the future is going to be like. Practices, whether they are implicit or explicit, where we engage with how the future is going to be, can under one label be called future practices (Esguerra, 2019) as they are the practices surrounding how the future is made. If the future practices are what we do, then future objects, are those socio-materials entities that are crucial to support future practices (Esguerra 2019). Without them, the disembodied practising of future-making would not take place. The socio-material objects consist of both knowledge (the socio-side) and a material component. On a global level, examples of well know future objects is IPCC's climate models predicting climate change. On a national level, the Danish Energy Agency's Energy and Climate Outlook can be mentioned. On an organisational level, NIKOLA's hydrogen fuel cell truck prototypes and how it is presented to the public.

As future objects are part of shaping the future, they become instruments of agency. A future object informs our knowledge and the epistemic practices we perform around the future (Jensen, Cashmore and Elle, 2017). In other words, the object changes how we think about, and thus, how we make the future. The objects can in Esguerra's taxonomy (2019), be divided into what political work the object does in three different types. I will first present the types, and then explain the political work each type does through case examples.

Future-making objects work in three different ways:

1. objects that stabilise the future so it can be acted upon
2. objects serving as infrastructure for actors to gain new insight on what the future can be
3. objects being references for something yet to come into existence in the future

The first type of future objects presents the future 'as if' it is known. This type of objects stabilises the future. One example is the Danish Energy Agency's 'Energy and Climate Outlook' (2018) where the future of our energy consumption and the resulting climate impacts are presented if we imagine a world were our policies froze and did not change from today. This work is commonly understood as de facto the future world if we do not introduce new policies, and it disqualifies a frozen policy future if Denmark is to reach the climate targets. But it is still just an imagined world as unforeseen events, or cultural changes might reform the picture. What if a culture landslide was on the verge to happen and in a few years from the cultural norm shifted to a determination on refraining from carbon energy?

Many forecasts that predict the world 'as-if' it was known are not coming true, but they are still part of the future making as they are part-taking in the epistemic processes that determine what is visible in an epistemic sense and what is not (Jensen, Cashmore and Elle, 2017). Do we look to mitigate climate change due to moral reasons for our grandchildren, or because we might gain socioeconomically from to switching to renewable energy as lower pollution leads to reduced healthcare bills, or do we look for innovation capacities in a societal system under pressure? How the future is presented, is shaping what we look for, which again forms the problems we engage in and the solutions that come into play.

Future objects of the second type are "[…] designed to create the very conditions for future making" (Esguerra 2019, p. 4), by being what Esguerra calls 'socio-technical infrastructure'. This type of future objects is bringing actors together around imagined futures to negotiate desired futures (Hajer and Pelzer 2018). Examples count workshops on desirable future scenarios and installations of technology or arts. What they do is to create an arena for actors around future pathways to discuss and articulate collective visions.

Such an arena has politic agenda, as the physical surroundings and the participants invited together creates the future-making process that happens. If we look to the works of Loorbach (2010) the visions, future paths and the inventions can be inspired and take form from these conditional meetings. Objects that aims to create the foundations for participation have also been criticised for steering the conversation "[…] as the efforts of dominant institutions to legitimise already made decisions" (Soneryd and Amelung 2016, p. 157). Thus, "power is at work when inviting participants, defining modes of communication, and setting frames within which actors create desirable futures." (Esguerra, 2019, p. 5)

Future objects of the third kind are not settled yet but are the 'epistemic things' that we are seeking but do not yet know precisely how it is looking like.

An example is the prospects of technology chains that are not yet existing, such as Ørsted's (a Danish Energy Company) bid to a tender for a Dutch offshore wind farm proposing to incorporating wind energy and electrolyses of hydrogen. Though the individual parts of the technology exist, it is not known how the physical architecture and the organisational structure is going to be. A future object of this kind can provoke debate or make a formation around it as an incentive for new actions which might help to stabilise the object.

Type of Future Object	Future-Object	The Future of the Object	How the object has agency
Type 1	Report from Danish Energy Agency: Denmark's Energy and Climate Outlook	A report showing predicted CO2 emissions until 2030, 'as if' the future was predictable	Actors can agree upon where future problems "will be" and can take action accordingly
Type 2	CONCITO workshop on May 14 for actors in freight transport	A design intervention where actors learns about future pathways and form opinions on how the future of freight could and should be	The actors will engage and participate in a conversation on making the future, and thus starting to form the future
Type 3	(The idea of) electrofuels for freight transport	We use liquid fuels made from electricity to substitute fossil fuel and a means to store renewable energy	Letting actors talk about an alternative fuel-type without knowing exactly how it is going to look like

TABLE 1: EXAMPLES OF THE THREE TYPES OF FUTURE OBJECT'S AGENCY

To conceptualise the difference between the three types of future objects, one can think about what the socio-material entity is, how the future object depicts the future and what agency the object has. The three different types are explained in this way in the table above.

As was seen from the Multi-Level Perspective and the early history of trucks, the mere scientific "fact" (e.g. of an electric truck being best suited as the successor to the horse-drawn wagons), does not render it valid for the future to come. Instead, future-making objects can show the pathways for the future that are currently existing, whether or not they are acted upon (Knappe et al., 2019). The future objects that take part in current discourse, those are the ones that have agency as it is these objects that inform future-making practices. We have also seen that it is often not from the lack of knowledge that techno-institutional lock-ins arise. As such, the solution is less to produce more knowledge, but realigning actors and make new possibilities and forces more visible and apparent (Allan, 2017).

Theoretical methods for unfreezing a frozen system

In this chapter, I have looked at governance theories and identified methods on how to unfreeze a frozen socio-technical system through long term visioning and future-making practices. Future-making practices are our actions in the present that changes the direction of the future. Then, I have shown how future-making objects are an inseparable part of the practices as they are the entities that make the futures actionable, and I have explained how these objects are used in anticipating the future.

Sustainable future-making practices are always in a tension-field between the incumbent regime of today and a low-carbon future of tomorrow, as the regime actors are deeply invested in the regime they are a part of. It is not possible to change the actors overnight. However, with the governance methods proposed, it might be possible to rearrange the elements of the system through a collective collaboration around certain future-making objects.

The regime analyses showed that a transition in the freight transport system towards a sustainable future is a significant challenge as the actors only have limited room for action and coordinating system governance is challenging as actors in the transport regime are scattered in many arenas. Therefore, it is a demanding task to gather all relevant key actors in the system at the same time. Although we have the tools for making an intervention that can help to unfreeze the system, it is worth noting that in regards to freight transport, it is a difficult challenge. Nevertheless, in the following, I will try upon up for the task.

METHOD: PREPARING THE DESIGN INTERVENTION

In this chapter, I will explain the methods used for preparing and creating a design intervention in the form of a workshop to bring actors related to the transport regime together around future objects. From the theory, we established methods to create openings in a frozen regime. The design intervention aimed to bring future-making objects together with regime actors to see how rearranging the elements in the system can unfreeze the system. To facilitate the workshop, we needed to be equipped with three different elements; relevant future-making objects, actors willing to participate in making the future and the socio-technical infrastructure to let the two meet. Gudmundsson from CONCITO facilitated the workshop, and I assisted to the best of my abilities.

Elements required to do the design intervention:

1) to find and analyse relevant future-making objects
2) identifying and involving relevant actors
3) creating a workshop; a setting to combine future-making objects and actors in an interactive event

Finding actionable future-making objects

Two different categories of future-making objects related to the decarbonisation challenge were used in the workshop. The two categories comprise what the future making objects are about, and the categories are not to be mistaken for the three different types of what future-making objects do, as presented in the theory section. There is a category of future objects that depict what the world will be like (this is in the form of forecasts like Denmark's Energy and Climate Outlook), and a category of future objects of those things we can do in the future (the decarbonisation measures we can choose to act on). The latter involves all the niche innovations and technical developments that can destabilise the regime.

First, I will elaborate on the future-making objects forecasts what the world will be like. This type of objects has shown that we need to act if we want to mitigate future climate impacts from excess carbon accumulation in the atmosphere. The latest Energy and Climate forecast from the Danish Energy Agency (2018b) depict what happens if Denmark's policies froze. The forecast shows that the climate target will not be reached if deliberate actions are not taken.

Then, the other category of future-making objects, the decarbonisation measures that can be acted upon, was reviewed. As the theory showed, epistemic visibility is important. This means that the solutions that are being discussed are part of the future-making practice. In this way, the choices for which measures are presented is a part of making the future and have to be considered carefully. I will later present how the workshop was designed to let the participants contribute with own inputs while the workshop at the same time was based in a specific set of pathways.

To find suitable decarbonisation measures, I created a solution space for decarbonisation from the range of many niche innovations and incremental developments in the regime found in the analyses part. All of the measures had a potential to affect carbon emissions; however, the size of the potential impact was important in the perspective of decarbonisation. Furthermore, the solution had to be assessed in a Danish context. This was to create a way of determining which solutions should receive focus at the workshop and if any measured should be excluded and to see if some solutions deserved an extra level of attention. At the same time, it works as a design process of familiarisation with a large number of decarbonisation measures.

I let the solution space deviate from the Multi-Level Perspective that distinguishes between radical innovations in niches and incremental technological developments at the regime level. This was because incremental developments of the regime that lead to low carbon futures are preferred to radical innovation that leads to regime transitions without substantially reducing carbon emissions. The text below will show a few examples (e.g. large scale adaptation of circular economy might lead to a restructuring of the regime as the distribution of goods would change, but it is not equivalent to making low carbon regime).

Future-making objects: forecasts

Denmark's Energy and Climate Outlook (2018)

The Danish Energy Agency has though their document 'Denmark's Energy and Climate Outlook' (2018b) shown how the future 'is going' to look like, considering a frozen policy scenario where no new policies are introduced, and no further measurements are implemented to make carbon reduction. This is hardly contested, and the document is the agreed upon future 'as-if' it is known what is going to happen in epistemic communities of freight and policy.

In the "frozen policy" scenario, the emissions will keep falling until 2020, before the cumulated emission curve is rising significantly towards 2030, primarily driven by the of large data centres that are going to be built in Denmark. Transportation has stagnated in the forecast, as the yearly increases in total vehicle driving distance are going to outpace the substantial improvements in energy efficiency (ibid, p. 37). The transportation sector is influenced by high degrees of uncertainty related to estimating road traffic, types of cars being sold and the differences in the actual emissions of vehicles to the standard emission figures being used in the model (ibid, p. 60).

Future-making objects: measures for decarbonisation

To sort through the vast number of incremental developments and radical innovations identified in the analyses part, I relied on that several knowledge institutions have attempted to rate decarbonising solutions on an effect contra effort basis. In this way, I identified interesting decarbonisation measures from multiple sources to be assessed in a Danish context.

Several knowledge institutions have rated decarbonisation measures in 'abatement - implementation' graphs, but each institute uses slightly different scales. McKinnon (2018), rates in his work decarbonisation solutions in a value-frame of **CO2 abatement potential contra ease of implementation**, the The Centre For Sustainable Road Freight Transport (a collaboration between Cambridge University and Heriot-Watt University, working together with a range of actors in the freight sector) have used a scale of **reduction of Greenhouse Gases against barriers to mainstream adoption** (see presentations from Cebon (2016) and Greening (2016) presented at a workshop hosted by International Energy Agency (2016)) and the NGO Smart Freight Center (nd.), have weighted **CO2 reductions to feasibility of adoption at scale**.

I translated the ratings from the four institutes for each of decarbonisation measure that had been ranked by estimating a combined score from 1 to 9 on a scale of **decarbonisation potential** and **ease of implementation**. In this way, I ranked 50% of the decarbonisation measures and 74 % of the intervention categories that were presented in the analysis chapter.

Then i created chart with four levels of decarbonisation measures: **Pathways to zero** (solutions that can lead to full decarbonisation), **Low Hanging Fruits** (measures that ought to be taken by now to keeping the carbon budget), **Possible Opportunities** (Feasible solutions, but with a limited carbon abatement potential) and **Low effort, Low effect** (solutions pathways that is easily implemented, but also with low effect). The charts can be found in appendix 3, and the method for ranking in appendix 4.

I reviewed the decarbonisation measures by using the charts and literature to asses which solutions had decarbonising potential in a Danish context and to deselect the solution that had low abatement potential. The review was split into each of McKinnon's five decarbonisation measure category and described below.

The lists of measures created are not to be seen as an ultimate catalogue of decarbonisation measures but was used as a living catalogue created during the project to navigate and understand the complex solution space. It is important to state that not every decarbonisation solution was or could be counted for nor that every solution on the list was ranked.

Reduction of transport demand demand was left out of all rankings. This is in line with with potential *rise* in demand during the coming decades which suggest we might at most hinder an increase in demand, not lower it. To reduce Transport Intensity, a wide range of actors, not directly related to the freight systems have to be engaged. It might be assumed that this will lead to decreased needs for moving freight around, but feedback effects might trigger increasing demands (e.g. circular economy leading to more physical goods being relocated not less).

Optimise modality with modal shift away from trucking was not surprisingly found to be a pathway to zero, although in the Danish context, modal shift towards rail or road is only expected to be feasible to a limited extend. Shift to lower emission types of road vehicles (such as bicycles), will contribute to decarbonisation, but it is not attainable on the large systemic level as substitutes for heavy duty trucks.

Although the Physical Internet might lead to carbon abatement, the approach did not appear in any of the major Danish or Nordic publications found during this study, and is therefore considered too vaguely defined to be viable solution in this study.

Improve asset utilisation by forming new actor collaborations around online load matching can lead to some decarbonisation that is worth pursuing. On the other hand, collaborations around solutions as 'back hauling' or 'crowd-shipping' is found to have limited effects on reducing carbon, indicating that the benefits are more of economical concern than environmental.
Intervention in the logistic domain may also lead to some decarbonisation with predictive analytics and re-timing delivery schedules. This involves the customers, in both anticipating their demands and rearrange what is considered the norm in terms of relaxing demands on order lead times. Vehicle and pollution routing are options that should always be considered and are relatively easy to implement as well as optimised vehicle loading. Lastly, better utilisation of the vehicles through telematics is worth diving into.

Increase energy efficiency is of interest in keeping a carbon budget more than reaching a zero emissions. These solutions might also thigh closely to economical reasoning. Both decreasing emissions through driver training, increasing fuel efficiency through light-weighting of vehicles, aerodynamic improvements of vehicles and trailers and idling reduction technologies leads to lower fuel consumption which goes hand-in-hand with lower carbon emissions and decreasing fuel expenditures. This trend is likely to continue with proposed CO2 Vehicle Standards on truck from from the European Union.

Solution paths as autonomous trucks and platooning that might might be a thing of the future, is not found to lead to notable carbon reductions, and have at the same time very large deviations between the rankings. This is interpreted as although theses solutions might be interesting in future freight transport systems the carbon abetment is too uncertain to receive focus in this study.

Switch to low carbon energy by exchanging fossil fuel with biomass or electricity is not surprisingly found to be a pathway to a fully decarbonised road freight system. Not presented in the rankings, but not out of the scope, are electrofuels of any type. Biofuels are seen as possible options, but with large fluctuations between anticipated ease of implementation and impact potential. Hybrid vehicles, both electrical hybrids and hydraulic hybrids are seen as possible opportunities for some carbon abatement. The blending of non-fossil fuels in fossil energy is not ranked, but found to be an important part of the current freight system due to current national regulations.

Expanding on Future-Making objects: eHighways

To frame the future object of eHighways in a Danish context the amount of the road network that has to be changed into eHighways was assessed for vehicles having an excess range of 100 km (return trip) from the highway. In the illustrations below, the parts of Denmark that lies beyond 50 km by road from the Euro Routes (left) and all motorways (right) are depicted to show the needed coverage of eHighways to support the major part of freight transport (corresponding to 1.2 % and 1.6 % of the road network respectively). The additional range of trucks suited for eHighways is not known, but the 100 km range was chosen as an appropriate distance for illustrative purposes.

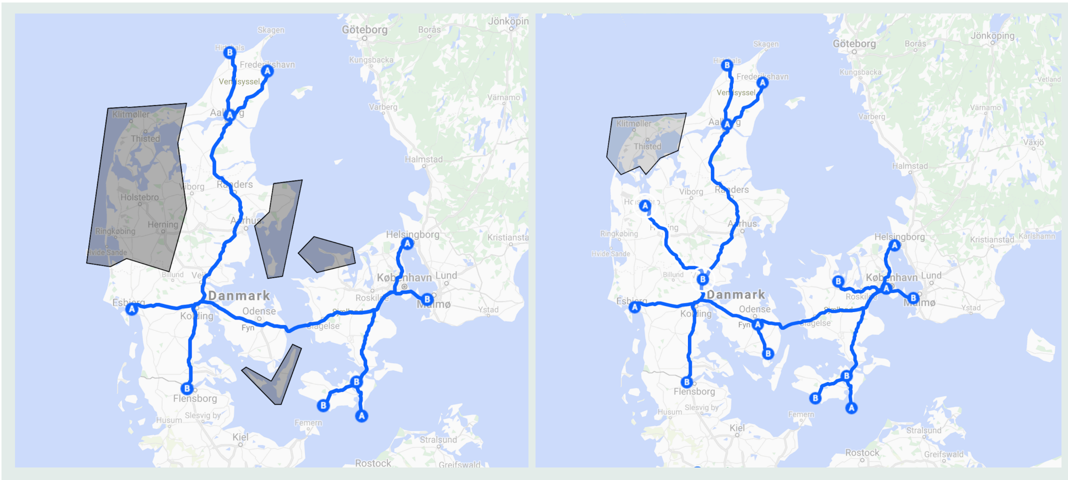


FIGURE 5: POTENTIAL COVERAGE WITH ELECTRIFIED MOTORWAYS IN DENMARK
Areas beyond 50 km driving range from the eHighways are greyed out (vehicle range of 100 km return trip).
Left: coverage if all European routes in Denmark were electrified. Right: coverage if all motorways were electrified.
(Map data: Google, GeoBasis-DE/BKG, 2019)

Finding the actors

The process of finding the actors was carried out by Henrik Gudmundsson from CONCITO with support from members several external numbers from CONCITO's network. I was not involved in the identification of actors.

As the design intervention was the first part of a larger project on decarbonisation of freight, it was designed to gather knowledge from many different epistemic communities. This opened up for the design intervention to work on different levels. First, a diverse set of system actors would be able to put future-making objects into different contexts and reduce the risk of important elements not being articulated. At the same time, as a design intervention can form an infrastructure for surprises the actors that participated might be informed by the event to take further action on decarbonisation pathways. Furthermore, the actors that are part of the first part of the project might be tempted to participate in the second part helping to create a red thread in the project. Finally, new actor constellations across established boundaries might rise around future-making objects. Nevertheless, too many actors can be harder to manage in a practical setting. A cap of 50 people was chosen to balance a range of epistemic communities and a manageable physical setting.

The actors were invited through the companies that are members of CONCITO'S network. These count COOP, EON, ITD, Postnord, Siemens, Teknologisk Institut, Det Økologiske Råd with more (CONCITO, 2019c). Furthermore, CONCITO's transportation network consisting of a core group of key actors helped to identify other relevant actors to participate. In this way, actors from transportation companies, industry association, government administration, consultancies and more were invited and attended the workshop.

Designing the workshop

The design intervention was created as an interactive workshop that combined participating regime actors and future objects. The overall goal was to see if we could get the actors to form collective articulations of future-objects. We wanted the actors to engage in collective thinking about which future-objects that were relevant in the context of a low carbon Denmark and how future-making practices might be created to support the objects. The knowledge gained from this workshop were to be used to inform the next phase of CONCITO's project.

The workshop was designed around two table discussion sessions. In the first one, we wanted the actors to meet in a broad debate about the future pathways that they saw relevant. In the next, the focus should be on qualifying future objects through barriers, criteria and indicators and then to identify possible initiative and instruments for further actions.

Table discussions were chosen to foster a debate among the participants. Alternatively, we could have formed the event around panel debates but decided not to do this as this would increase the expert focus and not the collective involvement of regime actors.

To frame the debates and to provide new knowledge to the participants, we chose to have expert presentations at the beginning and during the day.

Throughout the work, up till the workshop, we found that McKinnon's (2018) five categories of freight decarbonisation measures served as a suitable framework for discussing the many solution paths. This framework can help to promote a good debate as it divides the many measures into categories, which makes it easier to compare them to each other. Without any structure between the measures, it becomes more difficult to compare and contrast such different things as a deceleration of the freight sector, new logistic approaches or switching energy source. Not having a structure was observed to lead to 'technology-slippage' in discussions at the Trivector (2019) workshop; e.g. dialogue that starts to address logistics or behavioural practices but switches towards the topic of new types on energy mix.

McKinnon's categories were assessed, and it was apparent from the reviews of decarbonisation measures that 'Optimise modality' could be excluded from the workshop. The category 'Reduction of transport demand' was also expanded to include logistic management as it only held a few practical measures.

One category received extra attention as switching to lower carbon energy is widely debated and holds the potential as a radical transition towards low carbon freight transport. We divided the category into the three main groups of vehicle energy storage; which is electricity, liquid fuels and gas fuels. A total of six topics for the discussions was established.

Epistemic communities attending the workshop

Authorities and municipalities
Car manufacturers / importers
Carriers and hauliers
Consultancies
Electricity and energy
Energy Industry
Transport industry organisations
NGO
Retail trade
Scientific research
Technology institutes

Expert Presentations

The event was designed to support the table discussion through expert presentations. We chose the speakers to come from multiple countries to reflect the different national developments, and with various focuses.

We were lucky to have McKinnon accepting to be the keynote speaker, as he had inspired the project by his book 'Decarbonizing Logistics' (2018). McKinnon is professor of logistics at Kühne Logistics University in Hamburg. We had already used his framework for categorisation of decarbonisation measures extendedly throughout the work up till the event. He was invited to present his framework and decarbonisation measures in general.

R. Narkevičiūtė from The European Environment Agency was invited to shed light on the impacts of new emission regulations on greenhouse gas emissions from road freight transport in Europe.

H. Gudmundsson from CONCITO presented the status on freight transport in Denmark and the climate impacts and solution paths in a Danish context. This speech linked the transportation to a Danish context and included the review of the climate impacts from Denmark's freight transport sector, presented in the first part, to set focus on the basic facts about where emissions from freight transport are most significant.

PhD Candidate M. B. Simonsen from the Technical University of Denmark, Department of Technology, Management and Economics were invited to present possible future scenarios through the technical-economical model COMETS. The COMETS projects model Denmark's energy system towards 2050, including transport and optimises through a techno-economic perspective based on different inputs. The project was presented to show different futures scenarios.

Inge Vierth from VTI-Swedish National Road and Transport Research Institute was invited as to present how a research institute for freight transport has been established in Sweden, called TripleF: Fossil Free Freight,

Gunnar Ericsson from Trafik Analys (a traffic analysing institute in Sweden) was asked to present on the analysis of tax instrumentation in Sweden.

With the six presenters, we deemed that we both geographically and in terms of new future-objects had material to create surprises for the participating actors.

	Speaker	Topic covered
Session 1	Alan McKinnon (DE/UK) Kühne Logistics University	Forecast showing the need for decarbonisation Five Categories of Freight Decarbonisation Measures
	Rasa Narkevičiūtė (EU) European Environment Agency	Emissions from road transport in a Europerean context New regulations at EU-level
	Henrik Gudmundsson (DK) CONCITO	Climate impact in a danish context Roads to decarbonisation in a danish context
	Mikkel Bosack Simonsen (DK) DTU	Tool for the analysis of integrating the transport sector in the energy system.
	Table discussion #1: relevant future objects	
	Break	
Session 2	Inge Vierth (SE) VTI-Swedish National Road and Transport Research Institute	On Triple F: the Swedish Transport Administration's research and innovation initiative contributing to the transition to fossil free freight transport in Sweden.
	Gunnar Ericsson (SE) Trafik Analys	Taxation instruments in Sweden
	Table discussion #2: future-making practices	

TABLE 2: WORKSHOP SESSIONS AND PRESENTATIONS

The state of the freight transport system

Forecasts that disqualifies a frozen system

We needed a common ground for the actors in terms of the need to take measures within freight transport to mitigate climate impacts. This was done with the future-objects of climate forecast that is commonly acknowledged, such as the latest report from IPCC (2019).

Getting things in proportion

A part of Gudmundsson's presentation was designed to create a fundamental level of common knowledge in the diverse group of actors attending. One essential idea was despite the expertise of the represented actors; the nature of the problem was not well understood. We discovered this quite early in the process during the Trivecter's (2019) 'Decarbonisation of Urban Freight workshop' as key actors expressed a need for a better understanding of basic facts about where to engage with the problem; is there certain parts of the system that are responsible for disproportional high emissions? We met questions like; are the most substantial contribution from transport at motorways or in the urban areas? Are vans, light trucks or heavy trucks contribution to most pollution? Is carbon pollution mostly contributed to shorter or long trips?

From the questions raised by the actors before the workshop, we collected and interpreted data material. This work is carried out and presented in part one of this report as part of the system analyses. Key findings were presented at the workshop before the discussion sessions to give context to the workshop discussions.

Introducing future objects

We decided to introduce the future-objects through the expert presentations as we assumed a high of expertise from the actors invited to the workshop. Gudmundsson already knew several of the actors and deemed that there was no reason for extensive elaborations of the decarbonisation measures. On the other hand, we desired to spark the participating actors' attention to measures they would normally not consider. As we assumed that most of the measures were known to the invited actors and wanted to introduce the relevant future objects without being too normative about which future-objects should be discussed.

McKinnon's presentation was scheduled first, as he was asked to present the measures belonging to each of the decarbonisation measure categories presented in his book 'Decarbonising logistics' (2018). We got McKinnon to tailor his presentation to a local context by omitting the category 'optimise modality' from the scope as we have found these types of measures to be less relevant in Denmark.

Gudmundsson's presentation was created to close the gaps and focused on low carbon energy in three different forms; electricity, liquid and gas. Gudmundsson's presentation was to give a short overview of the potential energy forms, as we assumed that the participants had a relatively high level of knowledge of the different measures.

Presenter	reduce (transport demand)	optimise (modal shift)	increase (asset utilisation)	improve (energy efficiency)	switch (to low carbon energy)
McKinnon	Optimising Vehicle Routing	not assessed at the workshop	Improve vehicle utilisation: Supply Chain Deceleration and collaboration, Consolidating and High Capacity Trucks	new build and retrofits fuel economy standards vehicle operation	Switch to low carbon energy: biofuels, eHighways, electrofuels,
Gudmundsson	-	-	-	-	Electrification Liquid fuels Gas fuels

TABLE 3: TOPICS ADDRESSED IN MCKINNON AND GUDMUNDSSON'S PRESENTATIONS

Facilitating the discussions

We took a partially agnostic approach in the planning of the debates as we wanted to bring the actors together to collaborate around the future objects they found relevant. We made a structure where the participating actors was divided into six group of actors and each group was assigned one of the six topics.

The future objects of decarbonisation measures works on different organisational and technological levels, and some categories will be of more interest for certain groups of actors than others. The first three categories (reduce, optimise, and improve) work on a managerial and behaviour level, whereas the last two categories (increase and switch) are more oriented towards technology innovation and regulations. In this way, some communities will have a more substantial part to play (and interest) for measures in one category than other categories. For example, relaxing on delivery demands and just-in-time operations is requiring the customer to be part of the action, but increase the energy efficiency of the vehicles is usually the hauliers domain. We saw in the first part how freight transport chains are scattered between many actors, thus having a framework for the measures to structure the different actors around are essential.

We divided the attendants into six groups, each with one of the six categories as the predefined topic for the table. The actor constellations in each group were composed by Gudmundsson to gather relevant actors from various epistemic communities around each category of measures. This was done to promote fruitful discussion. The combination of topic and the epistemic communities of the actors at the table is outlined in the table below.

The table discussions were designed in two sessions. The first session was to take place after the first four presentations and should revolve around relevant solution paths and decarbonisation measures. The second discussion session was to take place after the last two presentations with the aim of identifying initiatives, criteria and barriers relating to the selected solution pathways. In the first discussion sessions, the groups were asked to identify three distinct pathways that they found interesting and relevant. In the second session, the groups were asked to conclude three initiative that could promote the relevant pathways, three criteria that could be used to asses the progress and three barriers to the pathway.

Each group was also assigned a chairman from one of the regime actors to initiate the conversation and one rapporteur to note the identified future objects and key future practices.

The program for the workshop was sent out to the actors beforehand, which also addressed the topics that were going to be discussed to prepare the actors for the content of the workshop. The background note also briefly outlined IPCC's forecasts for the global climate and the contribution to climate emissions from transportation and indicated this might result in future targets on transport at national and European level.

Table topic		Epistemic communities
Demand and logistics	#1 reduction of demand and other logistics factors, with a focus on looking for strong options	Authorities Carriers Consultancies Transort industry organisations NGO Scientific research
Increase asset utilisation	#2 improved utilization of vehicle capacity	Authorities and municipalities Carriers Consultancies Retail trade
Improve energy efficiency	#3 energy efficiency of vehicles, fleets and driving pattern	Carriers Consultancies Energy Industry Transort industry organisations
Changing energy supply: alternatives to diesel	#4 electrification; batteries and electrification of motorways (electric roads, overhead lines etc.)	Authorities Car manufacturers / importers Carriers Consultancies Energy Industry Scientific research
	#5 liquid alternatives to diesel; focus on advanced biofuel, hydrogen or electrofuels	Authorities Carriers Consultancies Energy Industry Retail trade
	#6 gaseous alternatives to diesel, with particular focus on Liquid Biogas (LBG)	Car manufacturers / importers Carriers Consultancies Energy Industry NGO

TABLE 4: DISCUSSION TOPIC AND EPISTEMIC COMMUNITIES OF PARTICIPANTS

ANALYSIS OF THE DESIGN INTERVENTION

The event took place on Tuesday 14 May 2019 at the second-floor conference room at Kosmopol in central Copenhagen. Breakfast and coffee were offered and conversation sprang from small clusters of people before everyone arrived. 41 persons signed up for the workshop, which was at the limit of the assessed capacity. Almost everyone arrived in due time and settled around the six tables placed in front of the speaker's stage. Each participant had been designated one table at their arrival for the later debates.

The workshop was split into two halves. In the first half, McKinnon held a keynote presentation on the need for decarbonisation and presented the future objects of decarbonisation measures. His speech was followed by presentations from the European Environment Agency, CONCITO and DTU and table discussions on the relevance of the future pathways. The second half was kicked off with two presentations on Swedish initiatives within freight transport followed by a second discussion session. The workshop was rounded off by summing up the learnings of the day. I will elaborate on the proceedings below.

FIGURE 6: CONCITO WORKSHOP 'DECARBONISATION OF FREIGHT'
May 14th 2019 (Picture by J. Schneider, 2019)

Alignment of actor perception of system challenges

The first step of the alignment of actors and the framing of the challenge was found in the program and background note send to the invitees to inform them of the event.

At the workshop, McKinnon started his keynote presentation by pointing towards a need for systemic change before he elaborated on various decarbonisation measures. First, he used IPCC's latest report (2018) as a call for a rapid global decrease of carbon emissions, and to inform the attendees on the concept of the carbon budget. McKinnon's point was that a low-carbon society in itself is an insufficient goal; the decarbonisation profile on the way towards decarbonisation have a significant impact on the accumulated emissions. "Implementation time [of decarbonisation measures] is now critical" as he expressed. He used this to emphasise the importance of managerial, behavioural and operational measures as opposed to a focus solely on technical solutions and stated that "there is a tendency to underestimate the contribution from the management options".

Narkevičiūtė from the European Environment Agency followed with the historical emissions trend for vans and heavy-duty vehicles at EU level, and the Agencies forecast of growing emissions from the freight sector due to increasing freight activity.

Gudmundsson put the numbers into perspective by showing the emission estimates for freight in Denmark by road type (urban, rural or highway), vehicle weight class and trip distances. Furthermore, he clarified the total available carbon budget and substantial emissions reduction needed if we are to get a zero-emissions freight transport system by 2050.

The attending actors might already have had a proposition to act on climate change. The presentations clarified the picture. Where the debate five years ago might have been on if we should do something, the discussion at the event was on when something is going to be done. Essentially, the touch points with participants prior to the workshop as well as all of the expert speakers at the workshop were selected to frame the challenge and align participants towards a common perception of system challenges. Based on the discussions at the tables, it seemed like the framing of the system challenge was successful as all of the tables were engaged in talking about the measures. However, the challenge of keeping a carbon budget was not discussed, meaning that some of the solutions that could to be of interest in keeping the carbon budget attracted less attention.

Presentation of future objects

In this context, the decarbonisation measures were future objects, which we wanted the actors to collaborate around and hopefully act upon. It was primarily McKinnon who presented the future-objects of measures for decarbonisation at the event by showing powerpoint slides made for the purpose. The slides were based on his book 'Decarbonizating Logistics' (2018). He elaborated on a range of different measures within each of the decarbonisation measure categories.

The slides were simple presentations tied to accepted background knowledge about each measure. The future objects also represented the most notable conflicts in relation to actor constellations as well as key prerequisites for the implementation of the measure.

Gudmundsson elaborated on the switch to low carbon energy in a Danish context. For eHighways, he showcased the percentage of the road network that needs electrification to cover Denmark. He also shed light on the innovational potential of electrofuels and the use of biofuels as Liquified Biogas for heavy-duty vehicles in Denmark. This was done in a presentation supported by powerpoint slides.

Table discussions on future-objects

The discussions took place based on the six topics each of the attendance had been assigned to. About eight participants were placed at six tables, each with its topic, and every group got handed out a paper brief on the subjects to discuss. The participants were encouraged to shape the debate around the table topic, but they were not restricted from discussing other matters.

Every group had an assigned moderator and a rapporteur (I assisted as the latter at the 'improve energy efficiency' table). Two discussion sessions were initiated during the event. The first was on which future pathways the participants found interesting and relevant and the second was on the specific barriers, criteria and indicators and the initiatives and instruments that can promote the pathway.

The table discussions unfolded well but did also stray aside from the assigned topics. This meant that it was not only the decarbonisation measure category assigned to each table that was discussed but also measures, which was meant for discussion in the other groups. Further, the actors had a lot of knowledge and perceptions in advance, which meant that the discussions sometimes became relatively general. Some of the future objects were not addressed, and others received a lot of attention. The latter counts for the shift to new types of fuels and new regulations and taxation measures, which was discussed by most of the groups. In one way, this was ok because it enabled the actors to debate the future objects and mobilise the discussion towards the future object that interested them the most. But on the other side, some of the conclusions from the groups became somewhat identical, which was not aligned with the objective and desired outcome of the workshop. This might indicate that the future objects were not visible enough in the groups as they had only been demonstrated through the powerpoint slides in the presentations.

It is hard to asses whether the grouping based on epistemic communities worked, as it is not known how the debates have been if the participants were grouped at random.

Each group was to refer back in plenum with the three most relevant pathways, criteria and initiatives. The conclusions on the relevant pathways were not as sharply formulated as intended. Few of the future objects presented that was new to the participants was articulated in conclusions from the discussions. The initiatives and actions the groups concluded on, was not either always in line with the relevant pathways they have chosen as it was hard for the participants to point towards specific actions today. Instead, some of the initiatives identified by the groups might promote other pathways than the ones the group had mentioned. In this way, the groups were formed less around the future objects they were presented to and more about the decarbonisation measures they knew of before the design intervention.

One of the pathways that were common between the groups was to set up a transport research centre in Denmark. This might have been directly influenced by Inge Vierth's presentation of the transport institute triple-F in Sweden. Many groups found that technology testing and research was key to the promotion of any transport innovation. Fuel-mixing was also a pointed to and linked to the future use of electrofuels. Tax levels and road pricing was also highlighted, but it was indicated that the regulation had balance market opportunities by raising tax on the polluting elements.

Finally, several groups expressed a wish for a national strategy on transport with a long term focus and a technology-neutral outlook. This could be backed up by specific target on for the transport area.

Summing up the outcome of the discussions

The groups summed up their table discussion in plenum. The groups had been asked to identify sets of three solution paths, initiative, criteria and barriers they found interesting, but the conclusions did not follow this format for most of the groups. The table below shows the findings from each of the six table discussions. As the feedback did not precisely fit the intended format, the items on the lists have been retrofitted to the appropriate column as best as possible.

Table topic	**Relevant pathways**	**Initiatives and actions**	**Criteria and indicators**	**Barriers**
Demand and logistics	Electrification is the way ahead, but many other initiatives also need to be taken	-	-	Low hanging fruits are not enough to meet the goal
Increase asset utilisation	Timing for planning Flexibility in delivery Capacity increase Co-working	Digitalisation Transport consortium	Distribution times	Low public demand No customer demand for green transport Demand for quick delivery Little knowledge sharing
Energy efficiency	National tax scheme and road pricing Intelligent Transport Systems Relaxation of delivery time and hours	Long-term road map Targets for transport (inspired by SE2030): Fossil energy from HDV pr. inhabitant	Criteria have to be measurable and cannot be distortive Continuous control International connected solutions	Balance between tax schemes and market opportunities Unintended tax consequences of green solutions increasing in cost
Electrification	Technologies have to be tested Raise taxes on diesel to let market decide Fuel Mixing	OPP projects (e.g. betwen Sund & Bælt and eHighways) Raise diesel tax Declaration of CO2 on goods	Fuel mixing demand (with electrofuels)	Low political focus on freight
Liquid fuels	Fuel mixing: 100% non-fossil 2050 More research in techs Dialog on instruments	Municipalities precedents through procurement National partnerships and project support Danish strategy for EU	Technology-neutrality Green demand is expected to increase	From bio to VE fuel mixing Unbalance taxations: should be on CO2 over energy Biogas is supported by agriculture Biogas: certification or physical
Gaseous fuels	Biogas is for heavy trucks (+40t) Electric are economical for lighter trucks (<3-5t) Better regulation of fuels (e.g. as NO)	Certification of biogas in the full chain Optimisation of energy storage Liquify fuels over incineration Travel team from Energistyrelsen European research centre for transport (In Køge) Transport strategy (technology neutral) Tech neutral tax structure	Rising levels of taxation as indicators Criteria to ensure biogas Fuel prices changes behaviour. German demand support the trend	Tax structure: de-alignment Workforce: cheap east European Low knowledge level for large scale actors The willingness is there but break-even is needed Diesel is retained by duties

TABLE 5: SUMMERY OF CONCLUSIONS FROM TABLE DISCUSSIONS

DISCUSSION

By presenting potential low carbon futures, we hoped to form actor constellations around future pathways and gain knowledge on which practices can be done today to promote decarbonisation of freight. Mainly we hoped to create engagement and ownership of the potential routes from the participants in the design intervention. This was partly successful as we got actors engaged around different future objects, but we did not manage to get the desired outcome of the discussions as many of the conclusions was based on external factors. I will discuss this more in depth in the following.

Practical implications for the design intervention

We took a partially agnostic approach to facilitate the discussions around the future objects, which meant that we invited the participants into a frame where they could discuss and form consensus around the future pathways they found interesting. At the same time, we provided a framework to base their debates around. We designed the intervention this way as we are in the space of considerable uncertainty about what desired future pathways look like. In other words, the solution space is so large that we needed a scope to create fruitful discussions.

We found the outcome of the workshop to be mixed. We got actors to form around and discuss future objects, but many of the conclusions from the discussions were not related to the future objects themselves. Instead, many groups commented on externalised pathways that were beyond any of participants ability to act on in practice; many of the suggested solutions would have to be carried out by other actors. Examples of this were the frequent suggestion of regulations of the industry through taxation, which is a valid and likely solution, but probably not enough to support the national ambition of a low carbon society alone. One could also imagine that this would be a quite long route if decarbonisation should only be driven by external regulation, and this challenge keeping the carbon budget.

Seen retrospectively, it was clear that despite good intentions, the lock-in of the industry was also visible and at stake in the workshop setting. While many good ideas were suggested, participants were still thinking in path-dependent measures, as their current space for manoeuvring is restricted by the regime, and therefore was many of the more radical solutions not picked up on. We could have steered the debates and insisted on the groups focusing on just the three distinct pathways they found relevant, but we chose to let the participants form the discussions themselves. One learning outcome is that there is a delicate balance between being agnostic or normative in the facilitation. Using future objects the way we did to open up a discussion works well, but they did not manage to make carbon futures more actionable during the workshop setting.

The need for a common goal

Reflecting on literature, we know that socio-technical systems can freeze in a path-dependency that is hard to escape. This has been studied before with the multi-level perspective (Geels, 2018), that shows certain landscape developments and niche innovations can work to destabilise the system. The landscape pressure of climate change was the reason for the workshop, and the engagement from the many industry actors show how the regime now is trying to adapt. But at the same time, the path-dependency of the system was apparent from the discussion at the workshop as the groups often identified path-dependent measures (like tax regulation), and less attention was given to the radical solutions. This is what Geels (2005) calls the 'dynamically stable' system; but these dynamics are not enough to adjust the system to climate change.

The usual approach to toppling an incumbent regime in the multi-level perspective is to promote niche innovations in protective spaces where the niches can develop outside of the selection environment of the regime (Smith and Raven, 2012). This approach was also seen at the workshop as participants saw the need for testing technology and support the development through research centre and in shared projects. This indicates that the technologies should mature outside of the regime, and only be introduced at the regime level when they are ready for the market.

The transition management theory suggests collective visions can form transition pathways as an approach to escape path-dependency in societal systems (Loorbach, 2010). There is currently no collective visions for freight transport, but the awareness of climate change has introduced an overarching common goal of transitioning to a low carbon society in 2050. This might lead to thinking only in long term strategies and not in how the actors can contribute in the shorter term, which was reflected in the discussions at the workshop as many of the conclusions had a focus on measures that work over an extended time.

Articulations of common goals for freight transport is central to the development of pathways that can be acted upon today. It was not the goal of the workshop to create these visions, as the design intervention focused on bringing the actors together around different future objects, but the workshop might have benefitted from collective visions. This was also expressed in the conclusions from the table discussions as some groups addressed the need for a national strategy and "targets" for freight transport. Loorbach (2010) suggest a small group of 10-15 frontrunners to set the visions, but this might be hard to realise in the context of the freight transport system and the transition management theory is also often used in a more geographical limited context (for example in city-planning). In freight transport, this limited geographical context does not apply, and broad political support is needed to create a common goal and industry-wide targets for CO2 reductions.

McKinnon argued at the workshop for the importance of the speed of decarbonisation if we are to keep the carbon budget proposed by IPCC. The political focus on getting to a low carbon society centres the awareness towards the measures that can lead to full decarbonisation (which is often debated as shifting the energy-mix away from diesel). This lead industry actors to underestimate the potential of management measures for carbon abatement, which was apparent at the workshop as this type of measurement received little attention.

Limitations

My role as a designer was to help to facilitate a design intervention to unfreeze a path-dependent system. As the system analysis pointed towards already at the beginning of this project, the system was frozen and difficult to move to a low carbon society. The system is vast and complex, which makes the use of multiple future objects seem somewhat unmanageable. The notion of future objects hints at the importance of materiality in future practices, but the way the objects were presented at the workshop, through presentations and powerpoint slides, took a lot of the materiality out of the objects. We strived to be agnostic in the facilitation, but it would properly have been easier to get the actors to collaborate around future objects if we had made them more accessible. This would be a fine balance at the workshop between elaborating on the future of the objects without being too normative and still have time for presentation and discussion during the timespan of the workshop.

Having this starting point makes a truly effective design intervention difficult, but also a great challenge for a student like me. Further, while I was able to bring ideas to the table in the workshop design, I did not have the decision-power to decide precisely how the day would be carried out as well as which future objects would be presented to the participants. These things need to be aligned with the ambitions of CONCITO and their experts who also have vast knowledge about the area.

I found McKinnon’s five categories of decarbonisation measures to be an excellent framework to work with decarbonisation measures because it gave an intuitive approach to compare and contrast the many solutions. But I am also aware that having this as a framework has scoped the discussion to target different solutions paths rather than others. In other words, the definition of the solution space is also highly political. Contrarily, many of the conclusions from the discussion were rather general and were overlapping between the groups. This might indicate that there was a need for more steering, not less.

CONCLUSION

In this thesis, I have tried to make low carbon futures more actionable for key stakeholders by using future objects to create infrastructure for change in a design intervention. I learned multiple valuable things by working with my case study. First of all, the transport system for freight in Denmark is indeed a frozen system rooted in a carbon economy with frozen in a future pathway dependent on fossil fuels. This confirms the existing theory of socio-technical systems, which I used to understand some of the dynamics in play. Second of all, while the design intervention was considered successful by engaging stakeholders in making the future, it did not succeed in making a decarbonised future more actionable. Instead, the dynamics of the system came to play in the arena we had created for discussion of future pathways. The structures we had created for collaboration around the future objects mostly let to suggestions of path dependant decarbonisation measures, which proves the complexity of the matter: it is indeed a wicked problem. While it was not surprising that we did not solve this complex challenge in one workshop, we had still hoped for better collective articulations of future pathways from the discussions and more commitment from the regime actors to collaborate around unsettled future objects. Essentially, we did not get the indications to the questions of which pathways were most interesting for regime actors, and how to take the first step towards these desired futures, which we had hoped for. What I got, however, was a better understanding of the system, with which I can create the basis for new interventions and future objects that might be more effectual. Significant transitions like this won't happen overnight!

I still believe that low carbon futures can be made more actionable for regime actors using future objects. Based on my research, I would like to highlight three key findings, which I think is central knowledge for succeeding with this:

Be aware of actors room to manoeuvre – work the system

The complexity of the problem of decarbonisation of freight transport makes it impossible for actors to create radical changes towards sustainability alone. The regime actors are locked-in by old ways, which limits the manoeuvring capacity for actors. Thus, working the system will require new smart ways of creating alliances among actors and enable them to experiment with future pathways and collectively decide what the desired futures are.

The shared vision for transition of freight transport is weak and needs stronger articulation

Even though there are long-term national objectives for reducing carbon emissions, the vision for decarbonisation of freight is not yet established. There is no description of what good looks like, and no concrete targets for the development, which makes action difficult when the actor landscape is so fragmented. The design intervention was focused on solutions without having the vision in place. Perhaps it was the wrong way to start. It is, however, not clear who should be responsible for creating these visions. The workshop participants call for more political involvement, which I think is important in the process of setting the scene for new future pathways.

More clarity for future objects of low carbon futures are necessary to make actors work together in a coordinated way

The future objects used when making the future needs to be more apparent than the ones we used at the workshop, to enable a diverse set of actors to imagine how such a future would look like. It was too difficult for the actors to open potential futures based on the pathways we presented to them, and they chose the easy way out: to talk about things they knew in advance. To avert this, a lot of thought needs to go into the actual representation of potential fruitful future objects before facilitating the process of making the future ‘come to live’. This might require a more normative approach than we took.

Based on my research I suggest that more work needs to go into this topic and focus on how, and by who, a shared vision for decarbonisation of freight can be created to set the scene for future pathways. Based on the research, it might be beneficial to include policymakers in this process to a further extent than what we did in the design intervention. Furthermore, new future objects need to be tested in practical contexts to create engagement and commitment from industry actors around future pathways for decarbonisation of freight. I suggest that better results might come with better articulations of the various future objects as this might spur a stronger collective understanding among actors.

INDEX OF FIGURES, GRAPHS AND TABLES

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APPENDIX

APPENDIX

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APPENDIX 1

CONCITO ‘Decarbonisation of freight transport’ (English translation)

Translation from CONCITO [online] Available at: https://concito.dk/projekter/dekarbonisering-godstransporten [Accessed 21 May 2019]

“The purpose of the project is to elucidate and assess key trends and solution perspectives in relation to a goal of decarbonising the road freight transport sector towards 2030 and 2050.

The focus is on motor and vehicle technologies, fuels and alternative propellants as well as green organisation of urban logistics. The project collects and discusses the latest international knowledge on the solution options with key actors in road freight transport in order to identify the advantages and disadvantages of different decarbonisation routes, and develop actor-driven inputs to what Denmark must do to promote decarbonisation.

In particular, the solution perspectives is viewed in light of how they can be included in the design of the future freight distribution and logistics in Danish urban areas. Therefore, the project will work with public and private actors in relation to goods transportation in the Copenhagen area and other cities in the Nordic region and internationally.”

APPENDIX 2

Decarbonisation measures

Decarbonisation measure category	Intervention	Measure	Ease	Poten-tial
1 Transport Intensity	-	**-**		
1. Transport Intensity	Circular and sharing economy	**Circular and sharing economy**		
1. Transport Intensity	Deceleration	**Deceleration**		
1. Transport Intensity	Dematerializing	**Waste minimization**		
1. Transport Intensity	Dematerializing	**Recycling**		
1. Transport Intensity	Dematerializing	**Digitization**		
1. Transport Intensity	Dematerializing	**Miniaturization**		
1. Transport Intensity	Dematerializing	**Material substitute**		
1. Transport Intensity	Dematerializing	**Additive manufacturing**		
1. Transport Intensity	Dematerializing	**Postponement (wait for de-mand)**		
1. Transport Intensity	Home Delivery of Groceries	**Home Delivery of Groceries**	5	3
1. Transport Intensity	Relocalize / decentralize	**Relocalize / decentralize**		
2 Modal Shift	-	**-**		
2. Modal Shift	Infrastructure Enhancement	**Infrastructure Enhancement**		
2. Modal Shift	Last mile solutions	**Last mile solutions**	1	3
2. Modal Shift	Last mile solutions	**Last mile solutions in general**	7	2
2. Modal Shift	Modal Shift	**Modal Shift**	4	7
2. Modal Shift	Modal Shift	**Synchromodality**	4	5
2. Modal Shift	Modal Shift	**Co-modality**	3	2
2. Modal Shift	Physical Internet (PI)	**Physical Internet (PI)**	2	7
2. Modal Shift	Shift to	**Rail**		
2. Modal Shift	Shift to	**Waterways**		
2. Modal Shift	Shift to	**Bikes**		
2. Modal Shift	Shift to	**Vans**		
2. Modal Shift	Shift to	**2 and 3 wheelers**		
3 Asset Utilization	-	**-**		
3. Asset Utilization	Collaboration	**Supply chain collaboration**	6	6
3. Asset Utilization	Collaboration	**Online load matching**	7	5
3. Asset Utilization	Collaboration	**Co-Loading**	4	4
3. Asset Utilization	Collaboration	**Back Hauling**	5	2,4
3. Asset Utilization	Collaboration	**Crowd-shipping**	3	1
3. Asset Utilization	Logistics	**Digitalisation**		
3. Asset Utilization	Logistics	**Predictive analytics**	7	4
3. Asset Utilization	Logistics	**Re-timing**	6,8	4,2
3. Asset Utilization	Logistics	**Pollution-routing**	5	3
3. Asset Utilization	Logistics	**Vehicle routing**	9	2
3. Asset Utilization	Logistics	**Nominated day delivery**	5	2
3. Asset Utilization	Logistics	**Dis-intermediation (bypassing agencies in supply chain)**		
3. Asset Utilization	Logistics	**Order lead time**		
3. Asset Utilization	Vehicle Loading	**Vehicle Loading**		
3. Asset Utilization	Vehicle Loading	**Standardizing loads**		
3. Asset Utilization	Vehicle Loading	**Consolidations of goods**		
3. Asset Utilization	Vehicle Loading	**Adjust truck size to load**		
3. Asset Utilization	Vehicle Loading	**Mixed load weight/volume**		
3. Asset Utilization	Vehicle Loading	**Pallet stacking**		
3. Asset Utilization	Vehicle Loading	**Load Optimization**	6	5,2
3. Asset Utilization	Transport System	**Restructure supply chains**	3	7
3. Asset Utilization	Transport System	**Telematics**	8	4,2

3. Asset Utilization	Transport System	**Port-Centric Logistics**	7	3,8
3. Asset Utilization	Transport System	**Urban Consolidation Centers**	4	3
3. Asset Utilization	Transport System	**Application of green freight programmes**		
3. Asset Utilization	Transport System	**Logistics centers and ware-house management**		
4 Energy Efficiency	-	-		
4. Energy Efficiency	Driving Efficiency	**Eco-driving and training**	9	4
4. Energy Efficiency	Driving Efficiency	**Platooning**	3	4
4. Energy Efficiency	Driving Efficiency	**Driving Efficiency**		
4. Energy Efficiency	Fuel Efficiency	**Lightweighting of empty vehi-cle**	9	3
4. Energy Efficiency	Fuel Efficiency	**Downspeeding**	8	3
4. Energy Efficiency	Fuel Efficiency	**Aluminium wheels**	7	3
4. Energy Efficiency	Fuel Efficiency	**Low viscosity lubricants**	7	2,6
4. Energy Efficiency	Fuel Efficiency	**Aerodynamic improvements**	7	3,4
4. Energy Efficiency	Fuel Efficiency	**Smart cruise control**	7	3
4. Energy Efficiency	Fuel Efficiency	**Fuel Management**	6	3
4. Energy Efficiency	Fuel Efficiency	**Driver feedback**	5	3
4. Energy Efficiency	Fuel Efficiency	**Tire pressure**	8	1,8
4. Energy Efficiency	Fuel Efficiency	**Idling reduction technologies**	7	2,2
4. Energy Efficiency	Fuel Efficiency	**Low-rolling resistance tires**	7	2
4. Energy Efficiency	Fuel Efficiency	**Exhaust heat recevory**	3	2
4. Energy Efficiency	Fuel Efficiency	**Fuel Efficiency**		
4. Energy Efficiency	Fuel Efficiency	**Fuel efficiency standards (on diesel)**		
4. Energy Efficiency	Fuel Efficiency	**Driveline optimization**		
4. Energy Efficiency	Fuel Efficiency	**Combustion optimization**		
4. Energy Efficiency	Fuel Efficiency	**Engine friction reduction**		
4. Energy Efficiency	Fuel Efficiency	**Turbocompounding**		
4. Energy Efficiency	Fuel Efficiency	**Waste heat recovery 5%**		
4. Energy Efficiency	Fuel Efficiency	**Higher combustion efficiency (2-3%)**		
4. Energy Efficiency	Fuel Efficiency	**Ancillary equipment (a few %)**		
4. Energy Efficiency	Fuel Efficiency	**Automated manual transmis-sion (1-8%)**		
4. Energy Efficiency	Fuel Efficiency	**Powertrain efficiency (incl. engine)**		
4. Energy Efficiency	Fuel Efficiency	**Control systems**		
4. Energy Efficiency	Fuel Efficiency	**Automation**		
4. Energy Efficiency	Fuel Efficiency	**Trailer side skirts**		
4. Energy Efficiency	Fuel Efficiency	**Trailer boat tails**		
4. Energy Efficiency	Fuel Efficiency	**Cab aerodynamics**		
4. Energy Efficiency	Road Conditions	**Smoother roads**	3	1
4. Energy Efficiency	Vehicle Efficiency	**High Capacity Vehicles**	5	6
4. Energy Efficiency	Vehicle Efficiency	**Fleet renewal**	5	5
4. Energy Efficiency	Vehicle Efficiency	**Vehicle Maintenance**	9	3,2
4. Energy Efficiency	Vehicle Efficiency	**Light Weighting**	6	3
4. Energy Efficiency	Vehicle Efficiency	**Preventive Maintenance**	9	2,4
4. Energy Efficiency	Vehicle Efficiency	**Autonomous Trucks**	2	2,2
4. Energy Efficiency	Vehicle Efficiency	**CO2 Vehicle Standard**		
5 Energy Mix	-	-		
5. Energy Mix	Biofuel	**Biogas**	1	8
5. Energy Mix	Biofuel	**Advanced biofuels**	2	6
5. Energy Mix	Biofuel	**Dedicated CNG with Biogas**	4	3,8
5. Energy Mix	Biofuel	**Biofuel**		
5. Energy Mix	Biofuel	**First Generation (Food Crops)**		
5. Energy Mix	Biofuel	**Biodiesel**		

5. Energy Mix	Biofuel	**Biomethane** **Synthetic Natural Gas (SNG)**		
5. Energy Mix	Electrification	**Battery-electric vehicle (BEV)**	6	7,8
5. Energy Mix	Electrification	**eHighways** **Electric road systems (ETS)**	5	8,2
5. Energy Mix	Electrification	**Electrification**	2	7
5. Energy Mix	Electrification	**Hydrogen fuel cell (Electrolyses)**	2	2
5. Energy Mix	Electrification	**Electrofuels** **Synthetic Fuels**		
5. Energy Mix	Electrification	**Power-to-Liquid (PtL)**		
5. Energy Mix	Electrification	**Power-to-Gas (PtG)**		
5. Energy Mix	Electrification	**Battery**		
5. Energy Mix	Electrification	**Plug-in hybrid (PHEV)**		
5. Energy Mix	Electrification	**Hybrid: combination with ICE**		
5. Energy Mix	Electrification	**Vehicle-to-Grid (V2G)**		
5. Energy Mix	Electrification	**Overhead catenary system** **(Køreledning og strømaftager)**		
5. Energy Mix	Electrification	**Road-based conductive system** **(partitioned system and only live at section of vehicle)**		
5. Energy Mix	Electrification	**Road based inductive system** **Dynamic Wireless Power Transfer (DWPT)**		
5. Energy Mix	Fossil fuels	**Cleaner diesel**	8	2
5. Energy Mix	Fossil fuels	**Dual fuel**	3	5
5. Energy Mix	Hybridization	**Hydraulic hybrids**	5	5
5. Energy Mix	Hybridization	**Hybridization**	5	4
5. Energy Mix	Hybridization	**Electric hybrids**	4	4,2
5. Energy Mix	Fossil fuels	**Natural gas**	3	2
5. Energy Mix	Fossil fuels	**Compressed (CNG)**		
5. Energy Mix	Fossil fuels	**Liquid (LNG)**		
5. Energy Mix	Electrification	**Ammonia**		
5. Energy Mix	Fossil fuels	**VE mixing**		

APPENDIX 3

Chart of decarbonisation measures levels

Pathway to Zero		
2. Modal Shift	**Modal Shift**	Modal Shift
2. Modal Shift	**Physical Internet (PI)**	Physical Internet (PI)
3. Asset Utilization	**Transport System**	Restructure supply chains
5. Energy Mix	**Biofuel**	Biogas
5. Energy Mix	**Electrification**	Battery-electric vehicle (BEV)
5. Energy Mix	**Electrification**	eHighways Electric road systems (ETS)
5. Energy Mix	**Electrification**	Electrification

Low Effort / Low Effect		
3. Asset Utilization	**Logistics**	Vehicle routing
4. Energy Efficiency	**Fuel Efficiency**	Tire pressure
4. Energy Efficiency	**Fuel Efficiency**	Cleaner diesel

Possible Opportunity		
2. Modal Shift	**Modal Shift**	Synchromodality
3. Asset Utilization	**Collaboration**	Supply chain collaboration
3. Asset Utilization	**Collaboration**	Co-Loading
3. Asset Utilization	**Vehicle Loading**	Load Optimization
4. Energy Efficiency	**Vehicle Efficiency**	High Capacity Vehicles
4. Energy Efficiency	**Vehicle Efficiency**	Fleet renewal
5. Energy Mix	**Biofuel**	Dedicated CNG with Bio Gas
5. Energy Mix	**Fossil fuels**	Hydraulic hybrids
5. Energy Mix	**Fossil fuels**	Hybridization
5. Energy Mix	**Fossil fuels**	Electric hybrids

Low Hanging Fruits		
3. Asset Utilization	**Collaboration**	Online load matching
3. Asset Utilization	**Logistics**	Predictive analytics
3. Asset Utilization	**Logistics**	Re-timing
3. Asset Utilization	**Transport System**	Telematics
3. Asset Utilization	**Transport System**	Port-Centric Logistics
4. Energy Efficiency	**Driving Efficiency**	Eco-driving and training
4. Energy Efficiency	**Fuel Efficiency**	Lightweighting of empty vehicle
4. Energy Efficiency	**Fuel Efficiency**	Downspeeding
4. Energy Efficiency	**Fuel Efficiency**	Aluminium wheels
4. Energy Efficiency	**Fuel Efficiency**	Low viscosity lubricants
4. Energy Efficiency	**Fuel Efficiency**	Aerodynamic improvements
4. Energy Efficiency	**Fuel Efficiency**	Smart cruise control
4. Energy Efficiency	**Fuel Efficiency**	Idling reduction technologies
4. Energy Efficiency	**Vehicle Efficiency**	Vehicle Maintenance
4. Energy Efficiency	**Vehicle Efficiency**	Preventive Maintenance

APPENDIX 4

Method for ranking decarbonisation measures

The five solutions areas were divided into the intervention categories below, and each solution was ranked 1-9 on a scale of ease of implementation and potential for carbon abatement and given a spread factor of 1-5 indicating the level of agreement between the existing rankings.

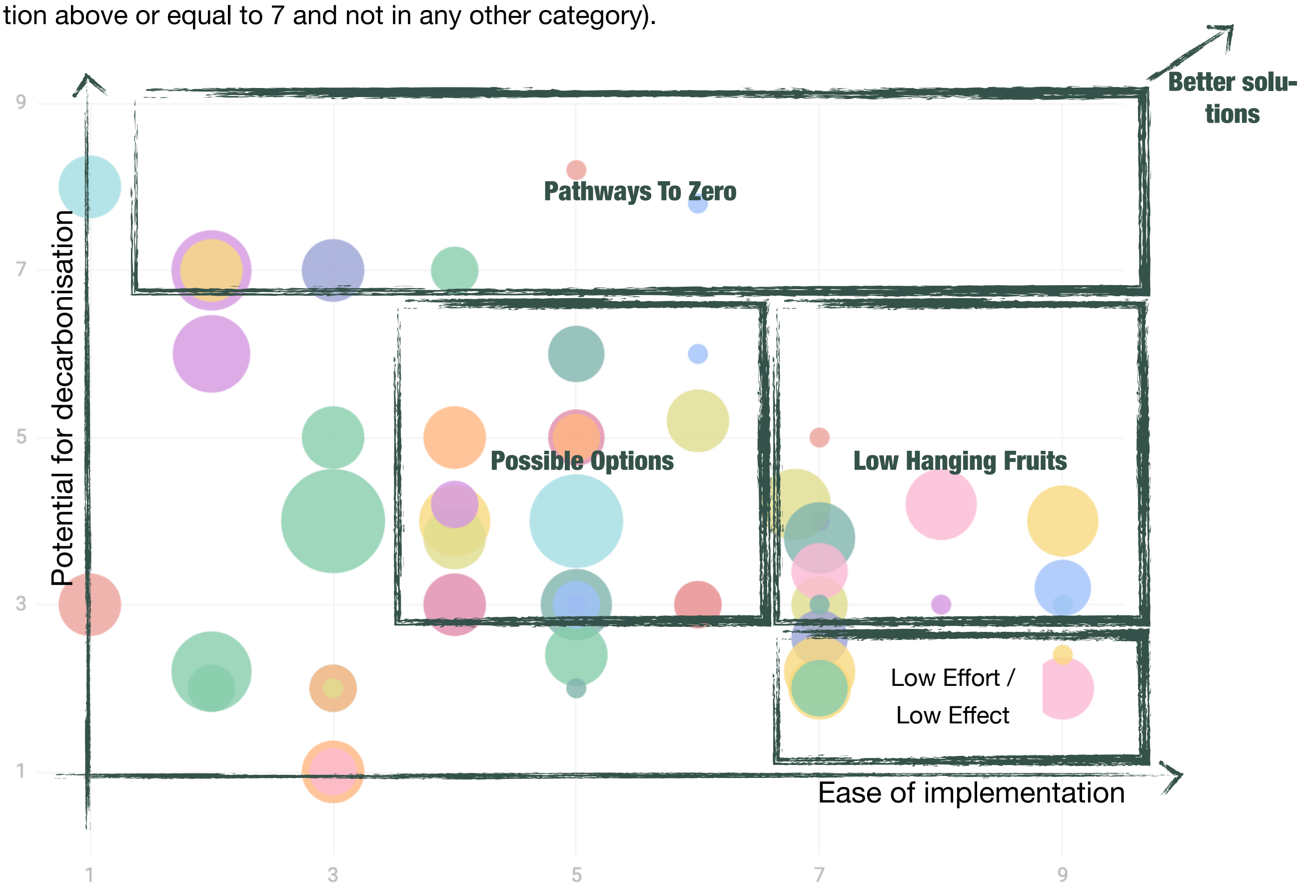
Pathway categories	Ease of implementa-tion	Potential impact
Pathway to Zero	-	High (7-9)
Low Hanging Fruits	High (7-9)	Medium (3-6)
Possible Opportunity	Medium (3-6)	Medium (3-6)
Low Effort / Low Effect	High (7-9)	-

Table of ranking values for decarbonisation measures

Then, solutions for further investigation were aggregated into four pathway categories as follows; all solutions given a score of 7 or more was deemed to be Pathways To Zero (solutions that might lead to net zero greenhouse gas emission in the transport sector), irrespective of the ease of implementation.

The Low Hanging Fruits was considered for solution ranked as a seven or more on the ease of implementation, but also having an impact-score of more than two. The Low Hanging Fruits are the solutions that should currently be considered to reach the carbon budget, but they will not in them self lead to a carbon-free freight system.

The last two categories are ‘Possible Opportunities‘ for categories that might be of interest, but is ranked too low for the two categories already mentioned (with a score of above 3 in both ease of implementation and impact potential) and ‘Low Effect / Low effort’ which is ranked easy to implement (ease of implementation above or equal to 7 and not in any other category).



Graphical illustration of the rankings (own illustration)