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How will Green Logistics Solutions Manifest in Transport Operations in the Future?

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Supply chains have gotten longer while globalization has brought the world and the goods more accessible to consumers. Transport operations have grown in line with economies, resulting increased greenhouse gas emissions and other negative externalities, such as road congestion.

Policies to reduce emissions caused by transportation activities have been made by European Union and its individual member countries, but the ways to decrease the emissions have not yet been implemented in full to transport operations.

The purpose of this study is to understand better the ways to decrease carbon dioxide and other emissions caused by transport activities by transportation mode and to consider the future possibilities of less emitting or even an emission free transport network.

The study has been conducted by using qualitative methods, and a comprehensive literature review was conducted to improve knowledge of various transport modes, current state of the policies imposed for every transport mode, and future possibilities for greener operations.

In the light of this research, it can be said that technological improvements must still be waited for truly green transport operations, but leaps for more sustainable solutions have already been made. Furthermore, to realize truly green transport, governments must commit to more sustainable operations and offer incentives to break the barriers which may otherwise slow down the transition to greener transportation.

Keywords	Transportations, sustainability, green transportation, freight

Contents

1 Introduction

In recent decades globalization has made the world more accessible and the movement of goods easy and time efficient. Freight transportation operations have grown somewhat in scale with the economy, making logistics the backbone of our society, by providing transportation and warehousing services and ensuring people have access to everyday life necessities and more.

In addition, globalization has made supply chains longer and this reflects in transportation distances, which, in turn, affects emissions generated by the supply chains. The logistics field is undergoing great transformation towards more sustainable and energy efficient transportation due to global efforts on governments, policy makers and organizations to reduce greenhouse gas emissions and slow down global warming.

Today green solutions for logistics and transport are still somewhat in progress and the industry is about to face changes in regards introduction of greener logistic solutions in transportation. As logistics operations and freight movement cause a high percentage of greenhouse gas emissions and there is pressure to change those freight movement operations to a more sustainable direction, this study is aimed at gaining more knowledge about the ways of implementing greener transportation solutions and is conducted by using qualitative methods.

This research question is relevant as policies to reduce greenhouse gas emissions have been introduced globally, but they have not yet fully manifested in transport operations. Implementation of greener transportation methods may result in new ways of implementing supply chain solutions and sourcing methods, which in turn may affect the prices or availability of the goods. Furthermore, recent events in Ukraine and sanctions imposed on Russia have made European governments painfully aware of their energy dependence on Russian oil and natural gas, and have further encouraged countries to seek more sustainable options. As greener logistics are not so heavily reliant on natural resources, it enables increased independence of energy and transport services.

2 Supply chain management

Supply chain management activities' purpose is to satisfy the final customer, through integrated and coordinated business processes, and alignment of strategy throughout the supply chain (Green, Zelbst, Meacham, Bhadauria, 2012: 290). The Council of Supply Chain Management Professionals in the United States defines supply chain management as follows:

> … the planning and management of all activities involved in sourcing and procurement, conversion, and all logistic management activities. Importantly, it also includes coordination and collaboration with channel partners, which can be suppliers, intermediaries, third-party service providers, and customers. In essence, supply chain management integrates supply and demand management within and across companies (CSCMP 2016 as quoted in Grant, Trautrims, Wong, 2017: 9)

In supply chain management, both sustainable supply chain management and green supply chain management are terms that are used when talking about supply chains, which consider more than just the economic bottom line. To understand better the variations of the concepts "sustainable" and "green" with respect to supply chains, both are considered in the following sections.

2.1 Sustainable supply chain management

Sustainability has been trending in supply chain management and when discussing sustainability, the commonly used definition is one from the Brundtland Commission:

> Humanity has the ability to make development sustainable to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs. (Brundtland, et. al, 1987).

Sustainable supply chain management incorporates triple bottom line, environmental, social, and economic aspects to the supply chain. Implementing the triple bottom line may include activities such more effective packaging design, which makes it easier to reuse and recycle, shorter lead-times, improved product quality and reduced labour cost due to improved motivation and productivity (Carter and Easton, 2011:49).

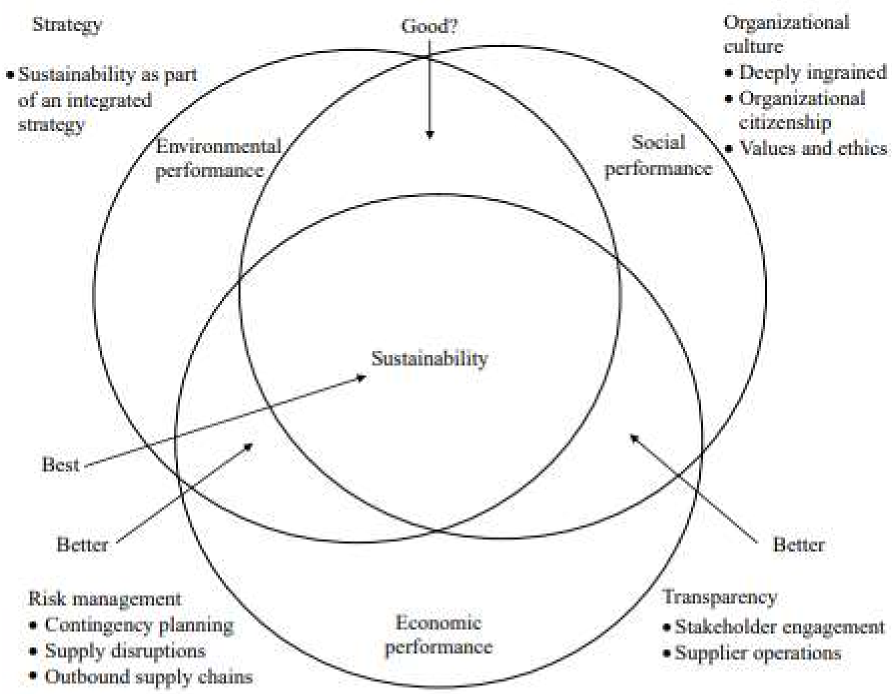

Figure 1. Visual representation of triple bottom line (Carter & Easton 2011: 46)

Creator of the term triple bottom line John Elkington defines the concept as follows:

> the TBL agenda focuses corporations not just on the economic value that they add, but also on the environmental and social value that they add – or destroy (Elkington, 2004: 2).

Seuring and Müller define sustainable supply chains as follows:

> In sustainable supply chains, environmental and social criteria need to be fulfilled by the members to remain within the supply chain, while it is expected that competitiveness would be maintained through meeting customer needs and related economic criteria (Seuring and Müller, 2008: 1700).

When a company is incorporating the triple bottom line in its businesses, it must address issues from all these three sides of its operations, maximize the profitability while minimizing impact to the environment, and maintain or even improve social responsibility (Hassini, et al., 2012: 70). In today's world, where consumers have the access to knowledge everywhere they are, businesses need to address the social and environmental standards to keep their customers committed and ensure their economic performance.

2.2 Green supply chain management

In today's global market, green supply chain management can be considered a managerial tool to increase a company's competitive advantage and strategic implementation to promote firms' environmental and financial performance (Meythi, 2013: 334).

Hockey and Ilsuk define green supply chain management as follows:

> GSCM as an incorporation of environment-friendly initiatives into every aspect of supply chain activities encompassing sourcing, product design and development, manufacturing, transportation, packaging, storage, retrieval, disposal, and post sales services including end-of-product life management (Hockey and Ilsuk, 2012: 40).

Companies should be committed to follow environmental regulations and standards, such as ISO 1400 management standard, design renewable or compostable packages for their products, use supplier certification and selection, reverse logistics, and depending on the commitment level to sustainability, use renewable energy and biofuels (Hockey, Ilsuk, 2012). The main goals of green supply chain management are to eliminate waste throughout the supply chain and for companies to decrease their environmental impact (Meythi, 2013: 334-335). Advantages such as reduction of air emissions, effluent waste, solid waste, and overall improved environmental performance are expected when implementing green supply chain management (Green, et al., 2012: 291).

Even though environmental sustainability is a supply chain level imperative, it needs to be first adopted as a strategic imperative. Top-level management must incorporate environmental sustainability as a key part of its strategy, to communicate throughout all levels of organization the necessity to develop processes and products which are environmentally friendly. Furthermore, as environmental sustainability is a supply chain level imperative, organizations need to develop information systems that are capable of integrating and coordinating sustainability initiatives throughout the supply chain from the company to the suppliers and customers (Green, et al., 2012: 299)

Companies have three different approaches in adopting green supply chain management. When companies commit minimal resources and implement initiatives at the end of the supply chain, such as labelling the products that are recyclable, the company's approach is said to be reactive. In a proactive approach, the company commits modest resources to designing green products and initiate recycling of products to start pre-empting new environmental laws. When a company integrates environmental activities, such as ISO implementation to their business strategies, they are implementing a value-seeking approach (Meythi, 2013: 334). Clients' and competitors' pressures and regulatory pressures are motivations to implement specific strategy of these three approaches (Fasan, et al. 2021:2703).

There is no consensus on effectiveness of green supply chain management, in terms of its ability to yield improved financial performance. Some authors argue that firms may lose competitive advantage due to increased costs which will follow on implementation of environmental sustainability guidelines (Jorgensen and Wilcoxen, 1990 quoted by Fasan, et al., 2021:2074). Conversely other studies find that by being the first to adopt environmental sustainability and implement green supply chain practices, companies gain competitive edge and can generate value in the long run (Sen, 2009, Barratt, Oke, 2007 quoted by Fasan, et al., 2021:2074).

Paul Polman, former CEO of Unilever talks in his interview by GreenBiz 350 podcast, about net positive effect which companies could have towards environmental, social and governance aspects. Courage from the leaderships of organizations is needed to build a business model, which would not only be net zero towards climate change but net positive towards environment and social situation. There is no time to wait for the next generation to take action as these issues need to be addressed now. Companies which have committed to initiatives, which are saving environment or improving social standing of the people are doing better. Customers are awakening to the fact, that endless consumption without addressing environmental issues and global warming is not sustainable in the long run and the companies which react to this change may have the competitive edge in the future markets (Makower, J., 2021).

3 Green logistics

Logistics is part of a supply chain which is involved with transportation and warehousing of the goods. Green logistics is considered as managing the flow of goods with consideration for the environment, without losing the logistical efficiency (Simm, 2021:1). Global resources are strained by the consumption speed of products, as linear economy principal is “make – take – waste”. Green logistics, including circular economy aims to produce products in such a way, that the resources used for the product can be easily recovered and reused thus preventing the value of the resources to deteriorate (van Buren, et al. 2016:2).

Green logistics activities include reducing the energy usage in logistics activities, reducing waste, and measuring the environmental impact of distribution strategies. Whereas traditional supply chains are focused on reducing the costs of production, green logistic is concentrating more on environmental impact of production and may lead to new working methods and models (Sbihi, et al. 2009:159-160).

Product design is also considered in green logistics operations. Three product aspects are relevant in producing more environmentally friendly products. First, the carbon footprint of the product, which refers to production manner of the product, secondly transportation and inventory needs to be taken to account, and thirdly reverse logistics activities, implying the value recovered from the items after their use. This way, environmentally friendlier products can be chosen even at the level of individual customers (Dekker, et al., 2011:673).

Furthermore, packaging of the product causes waste, causing a strain to the environment, because all the packaging needs to be handled and transported by the retailers as well as the waste processors. By using returnable transportation items such as pallets and containers and by optimizing package sizes to reduce waste generated by packaging, the environment can be saved. For example, diapers are packed by sucking air away from them to fit more into the package (Dekker, et al. 2011:674-675).

3.1 Reverse logistics

Reverse logistics is considered as green logistics activity. The European Working Group on Reverse Logistics defines reverse logistics as follows:

> The process of planning, implementing and controlling backward flows of raw materials, in process inventory, packaging and finished goods, from a manufacturing, distribution or use point, to a point of recovery or point of proper disposal. (REVLOG quoted by Dekker, et al, 2004:5)

When products are discarded from use, they still may have some remaining value, which can be recovered. Product recovery made by collecting, inspecting, sorting, cleaning, or dissembling and remanufacturing old discarded goods in a reverse logistics system can save some portion of the value of the product. The action taken to recover the value is dependent on the state of the product and the demand for the result with the cost associated to the process. When reverse logistics is integrated to a supply chain, the term “closed loop supply chain” is used (Dekker, et al. 2011: 676).

3.2 Circular economy

Circular economy creates value to the supply chain by prolonging the use of resources inside the economic circle. By recycling, waste is reduced among with consumption of raw materials as they are recovered from waste flows. Products are designed to be easily taken apart and reused, and lifespan of products is prolonged through maintenance and repair. Circular economy aims to create economic and social value along with value creation in terms of the environment. These are achieved by reusing the raw materials in a supply chain, which adds economic value of the goods and adds resilience of the resources (van Buren, et al., 2016:3).

Building a circular economy will require changes simultaneously in various subsystems such as logistics, and changes in consumer behaviour and governmental policies. Furthermore, to reach the goal of improving the supply chain system, monitoring the efficiency of the system is needed, because inefficient circular system can create more problems than linear system through excess transport usage and unattractive working conditions, such as waste recycling (van Buren, et al. 2016: 2)

3.2.1 Barriers to the transition to circular economy

There are barriers in the logistic industry which may prevent the transition towards circular economy. Institutional barriers comprise legal and financial frameworks and daily practices which are set up to maintain the linear economy. Building the circular economy, cooperation among stakeholders is required; for example, to build functional systems where environmentally friendly transport means are used to create seamless multimodal transport. This might lead to forming longer partnerships in order to share business principles and sharing risks with preferred business partners, which could be considered cartel forming. Furthermore, as waste is not considered as a recourse in legal point of view and cross-border waste transportation is regulated by The European Waste Shipment Regulation which can be considered as a barrier for international trade (van Buren, et al., 2016: 11)

The costs of transitioning to circular economy are perceived as economic barriers. In many cases, costs and profits of circular economy are unevenly distributed across the supply chain requiring the companies interested to start transitioning to circular economy to have investment power to building processes in a different way. Furthermore, vested interests may hinder the search for more sustainable alternatives, as preserving the status quo is considered more important. For instance, transport companies whose profit margin is highly dependent on the amount being transported, may be unwilling to decrease the source of their income, nor share transport capacity. Lack of incentives from the producers using the services of transport company can also be considered as a barrier for the company to transit to circular economy (van Buren, et al., 2016: 12).

Social barriers include consumer behavioural aspects. As materialization and consuming are still the norm of society, incentives for suppliers and distributors may not be sufficient. Companies may be locked in the system, where other stakeholders are not yet aware of the benefits of circular economy. Consumers are interested in low cost and new goods, rather than recycled products and paying more for goods which will last longer or can be repaired and recycled. Change in consumer behaviour can be expected when their peer groups are also changing their behaviour towards circular economy, and sharing the knowledge about better practices and costs of consumerism to the globe (van Buren, et al., 2016:13).

3.3 Facilities in green logistics

Transportation and warehousing are parts of logistic activities and in green logistics the facilities around the supply chain have also their part in greening the operations. Terminals and distribution centres may operate electric equipment, such as electric forklifts to move goods around, which would not generate additional emissions, if the electricity is sourced from renewable resources. But in container terminals where distances are longer and conditions are environmentally more challenging, for example many starts and stops are needed, diesel is still the main power source of the equipment. Steps towards more greener operations have been taken and manufacturers of this operating equipment have been speaking in favour of turning to electrically powered internal transport equipment (Dekker, et al., 2011:674).

Furthermore, energy efficiency of warehouses has been a concern for many companies, also driven by costs, but also environmentally efficiency. Net zero buildings have been built to reduce environmental impact of warehousing. This has been done by using sophisticated lighting and installing solar panels. Even port authorities have added the pressure to reduce emissions by obligating substantial reduction in emissions when building and operating new container terminals (Dekker, et al., 2011: 674).

3.4 Conclusion on green logistics

Green logistics is an investment, which will benefit the companies and societies in the long run. Economic benefits, not to mention environmental benefits from implementing green logistics principles, are considered substantial, but they require cooperation among the stakeholders and strategic input from the government level. Warehouse operations should be implemented more efficiently by reducing the use of diesel powered machinery in internal transport and improving energy efficiency of used facilities.

Circular economy can result in increased independence from raw materials, as value is maintained and created by reusing and recycling the materials used to produce goods, resulting in less waste throughout the supply chain. Change in consumer behaviour, governmental policies and business practices is required to transition towards circular economy (van Buren, et al., 2016: 2,15).

4 Resilience in global supply chains

Resilience in supply chains is a relatively less established concept than sustainable supply chain management, but resilience is imperative for well-functioning supply chain. From an organizational perspective, resilience definitions include to prepare and react to unforeseen disruption and restore regular activities over an acceptable period of time, or the ability to move to a more favourable state. It is systems' ability to survive and meet business objectives irrespective of the significance of the disruption (McClelland, 2009 quoted by Sawyerr and Harrison, 2019: 78, Negri, et al. 2021: 6).

Efficiency and cost minimization have been the priority of companies' logistics planning and thus low-cost sourcing and just-in-time delivery have been widely used strategies for companies to organize their logistical procedures. Most companies consider supply chain risk management as a reactive process, but COVID-19 and volatile demand has forced companies to rethink their approach to supply chain risk (DHL, 2021: 11).

Resilience can be built through stocks and designing of the supply chain so that suppliers and places with less risks are identified, by monitoring resilience and by assessing how much time will it take for the suppliers to recover from disruption (Baldwin and Evenett, 2020: 124). Furthermore, mapping and stress testing the supply chain may lead companies to find risks they were not aware of (Simchi-Levi and Simchi-Levi, 2020).

Literature from supply chain resilience identifies three phases of resilience: pre-disruption, during disruption and post-disruption; and practices to implement resilience are proactive, concurrent, and reactive based on disruption phase. Proactive practices include supply chain risk assessment, increasing capabilities, supply chain design and visibility, increasing collaboration and control and segmenting or regionalizing to avoid too much centralization and these practices refer to a state where disruption is anticipated. Such practices include for instance responsiveness, flexible supply chains, agility, additional inventory, flexible supply basis and flexible transportation. Reactive practices, after the disruption, include ability to recover and learn, building social capital and knowledge management (Negri, et al. 2021: 6).

4.1 Drivers of supply chain resilience

Drivers of supply chain resilience have also been studied and different categories that foster supply chain resilience have been found. Trust, cooperation, and visibility are important drivers, as visibility improves responsiveness and decision-making which enhances supply chain performance. These are part of organizational characteristics, which include risk management culture, orientation to learning and supply chain orientation (Negri, et al. 2021: 6).

The relational categories include drivers such as diversification, better transport planning and safety stock, operational flexibility, switching suppliers, low inventories and using ICT. These categories are not usually industry specific and thus the importance and relationships of the drivers may vary depending on the industrial sector (Negri, et al., 2021: 6).

Proactive and reactive driver categorization includes business certifications to ensure compliance, vertical integration, globalization because it removes trade barriers, training and development, and quality management as proactive enablers. Reactive enablers include responsiveness to customers' needs, multi-sourcing and public and private collaboration, and responsiveness to competitors' strategy (Negri, et al. 2021: 6).

4.2 Lessons learned from COVID-19

The COVID-19 pandemic led many supply chains into crisis as the pandemic exposed vulnerabilities of global supply chains and especially reliance on China for supplies. This situation may force companies to re-think their value chains and diversify their supplier base. Furthermore, some have come to conclusion that self-reliance should be developed, and as automation has already reduced the labour costs, reshoring of operations can also increase resilience (Baldwin and Evenett, 2020: 112, 114).

Even though shorter supply chains and reshoring would be a more sustainable solution in terms of travel miles and emissions finished products cause, it may not be the most resilient solution for supply chains. Empirical evidence shows that supplier diversification would not speed up the recovery of the supply chain from disruptions. On the contrary, it may slow it down as long-term relationships with the supplier may lead to further investment and faster recovery (Baldwin and Evenett, 2020: 124).

Multisourcing critical components from a diverse set of suppliers would give companies more options should problems occur in the future. China will most likely be used for manufacturing goods in the future also, but organizations may adapt their sourcing strategies so that in addition to China, they have suppliers and manufacturing capacity elsewhere to secure flexibility and resilience (DHL, 2021: 11).

5 Road freight transportation

Road freight transportation has increased dramatically in recent decades, especially in developed countries. Freight transportation has grown almost in line with the economy resulting in externalities, such as congestion, noise, and rising emissions (McKinnon, Browne, Piecyk, Whiteing 2015: 9). Freight movement operations are responsible for almost a quarter of greenhouse gas emissions at the European level. Road transport is the biggest emitter within this sector, accounting for more than 70 percent of greenhouse gas emissions in 2014 (EU Commission, n.d.b).

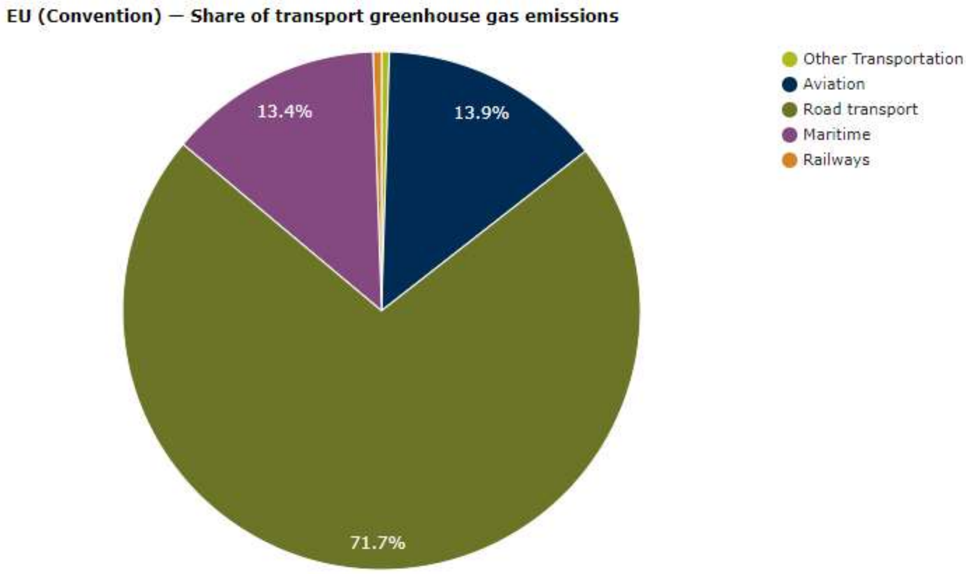

Figure 2. Greenhouse gas emissions from transport by mode in 2016 (European Environment Agency, 2019).

In 2019 road freight was the most dominant mode of transportation, especially in inland freight movement where more than 76 percent of total freight movement was completed by road haulage in 27 EU member states (Statista a., 2021, Eurostat a., 2021) The transportation sector is heavily dependent on fossil fuels and greenhouse gas emissions from transport operations have increased on average 3 percent per year since 2014, air freight being the most increased freight mode compared to 1990 levels (European Environment Agency, 2020)

In 2020 the European Commission presented an ambitious plan to reduce greenhouse gas emissions by at least 55% by the year 2030, compared to levels in 1990 (EU Commission a. 2020). In the transportation sector the European Commission plans to implement this plan by increasing the efficiency of the transport system e.g., encouraging the shift to lower emission transport modes, speeding up the deployment of low-emission alternative energy for transportation and moving towards zero-emission vehicles (EU Commission n.d.b).

Individual countries are also implementing new restrictions in hopes to slow down and stop global warming. In the United Kingdom, the Prime Minister announced in 2020 that selling new petrol and diesel cars in UK will end by the year 2030. To enable this change, huge investments in building the charger points network must be made, and government is providing grants for homeowners and businesses, to install charger points to ease the transition to greener transportation (GOV.UK 2020).

5.1 General ways to reduce emissions in road haulage

In the 1990s studies of road freight pollution were published in several countries, addressing the need for change in transportation methods. From these studies, three approaches to reduce emissions and other externalities caused by trailers were introduced, known as ‘avoid, shift, improve’. By reducing the ratio road tonne-kms to GDP, shifting the freight to alternative and less polluting options when possible, and improving utilization of trailers by reducing the vehicle-kms to tonne-kms could the transport activity be reduced (McKinnon, et al., 2015: 9).

An efficient way to lower emissions and costs of road haulage would be to bundle transports and avoiding empty runs. This could mean for example that express transit should be abandoned or cut to a minimum as they tend to underutilize the trailers. Moreover, aerodynamics of the trailers could be improved by permanent side walls and vehicle wraps, which could reduce fuel consumption up to 7-12 percent. Furthermore, by integrating tractor and the trailer, which would optimise the profiling of the truck and eliminate most of the turbulence created by the gap between the tractor and the trailer, the coefficient of drag could be reduced. Low rolling resistance tyres are considered cost efficient way to lower the friction of the trucks, which could reduce the fuel consumption up to 6 percent and by regularly training drivers to drive smoothly and with foresight could the fuel consumption be reduced by 5-8 percent (Psaraftis, 2016: 210, McKinnon, et al., 2015: 169). Furthermore, co-modality needs to be developed so that each transport mode is used as efficiently and economically as possible. Information and Communication Technology (ICT) enables improvement of co-modality by enhancing the infrastructure, and traffic and fleet management (Blanquart, et al., 2016: 24)

5.2 Electronic vehicles

Electronic vehicles are hoped to be the answer in reducing the greenhouse gas emissions from transport in the future. While electronic cars do not produce emissions while in use, it needs to be considered, how the electricity to power these vehicles is produced. Most of the electricity produced in European Union is from nuclear power, but fossil energy sources are also in high demand. For example, UK is dependent on fossil fuels for roughly three-quarters of its electricity (DECC, 2011 quoted by McKinnon, et al., 2015: 170).

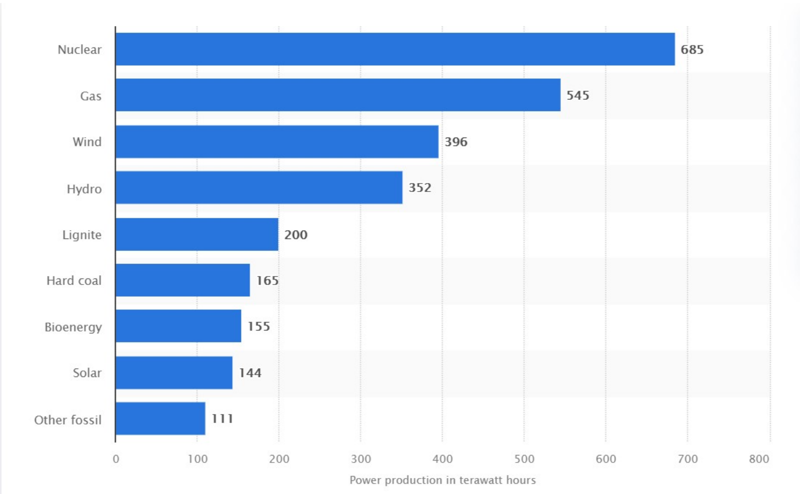

Figure 3. Electricity generation in the EU in 2020, by fuel (Statista b., 2021)

When considering the benefits and sustainability of electricity powered vehicles, their ultimate energy source must be taken into consideration, as the net-carbon benefits from switching to battery-powered freight delivery vehicles are very small if the primary energy source is fossil fuels (McKinnon, et al., 2015: 170).

5.2.1 Batteries for electronic vehicles

Within the next decades electric vehicles will supersede cars with traditional petrol- and diesel-powered motors. The most pressing problem with electronic vehicles is that their batteries need metals, which are limited in production and difficult to recycle. It has been estimated that on average an electric passenger car would need approximately 20 kg of nickel, 20 kg of cobalt and 60kg of lithium compounds (Yoon, 2021).

The battery itself is made of two electrodes, which are called anode and cathode and they are separated by layer called electrolyte. To produce electricity, lithium ions shuttle internally from one anode to cathode.

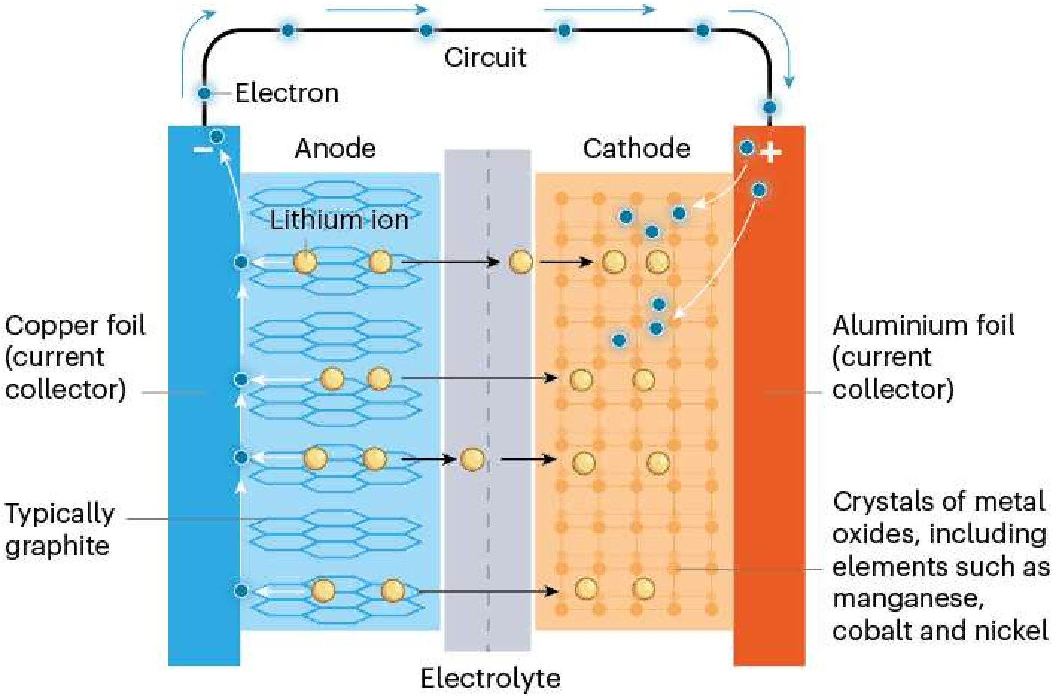

Figure 4. Cell chemistry of lithium-ion battery (Castelvecci 2021: 336-339).

Lithium-ion batteries, which contain hundreds of kilogrammes of metal, such as cobalt and nickel, and power most of today's electronic vehicles, have stayed largely unchanged for decades. Even though the energy density of Lithium-ion batteries has risen around 4 percent a year for decades, improving the performance of these batteries will be challenging, as it would mean much bigger battery sizes with current technology (Yoon, 2021).

5.2.2 Challenges with raw materials

According to the International Energy Agency's Stated Policies Scenario (STEPS), demand for minerals for clean energy technologies will double, and in its Sustainable

Development Scenario (SDS), this demand quadruples by the year 2040. Half of this demand is for battery materials (IEA a., 2021: 50).

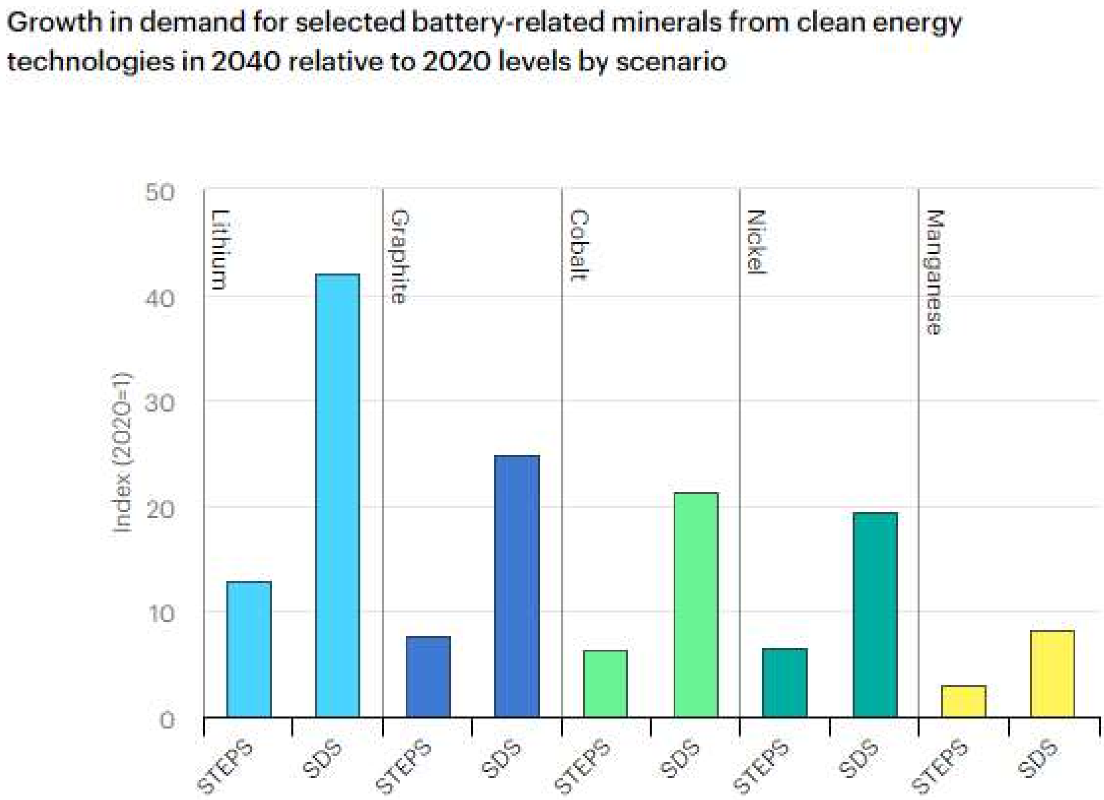

Figure 5. Growth in demand for selected battery-related materials from 2020 to 2040 by scenario (IEA 2021: 47)

Furthermore, as electronic vehicles become more common, copper, aluminium, and other investments are needed to enhance electricity networks (IEA a., 2021: 5). Energy networks account for 70% of today's mineral demand, but their share of demand will considerably fall in the future, whereas for example demand for electronic vehicles will continue to rise (IEA a., 2021: 50). As electronic vehicles become more common, demand for the raw materials required for their batteries will go up, and it may cause temporary shortages in distribution, as current processing capacity may not be sufficient to answer drastically increased demand (Castelvecchi, 2021: 336-339).

In a Dutch study concerning metal demand in renewable electricity in the Netherlands, it is stated as follows:

> Opening a new mine takes about 10 to 20 years. --- Therefore, if demand rapidly increases, supply cannot quickly follow suit (van Exter, et al., 2018).

Even though this study has been made from the Netherlands' perspective, it can be upscaled to global supply chains, when raw materials for electronic vehicles reach their peak in demand.

Scientists have two challenges to work on while anticipating road transportation to transfer to electronic vehicles. One is to how to cut down the metals in batteries because some of them are expensive and scarce and often problematic since mining and refining them causes significant pollution and CO_2 emissions. Furthermore, most of the global supply of cobalt is located in the Democratic Republic of the Congo and human-rights activists have raised concerns over working conditions there, especially regarding workers' health conditions and child labour (Castelvecchi, 2021: 336-339; Yoon, 2021)

The other pressing problem scientists must resolve is how to improve battery recycling, as it is still in most cases more cost efficient to mine the metals than recycle them. Government incentives and expectation of forthcoming regulations has encouraged battery- and car manufacturers to spend billions of dollars on reducing the cost of battery manufacturing and recycling (Castelvecci, 2021: 336-339).

There are two main processes to recycle lithium-ion batteries called pyro-metallurgical or hydrometallurgical, and various ways combining these two processes which are under development. For now, recovery of valuable cobalt and nickel is prioritized in recycling processes, and less valuable metals are not recovered. Lithium and manganese, which are less valuable metals used in electronic vehicle batteries are technically recyclable, but they are hard to separate, but as the demand increases it may become economically desirable to recover also these raw materials (UTS, 2019: 9).

5.3 Multi-modal transportation to help congestion problems

In road haulage, congestion is affecting supply chain efficiency in a costly way, as time spent in traffic is considered as a loss and causes increased operational costs. Furthermore, lower driving speeds cause significant increase in fuel consumption, thus resulting in increased CO_2 emissions. It has been estimated that the cost of congestion to road users in the US from lost productivity, wasted fuel, and reduced mobility in urban road networks would be around $85 billion annually (Taylor, et al., 2013, quoted in McKinnon, et al., 2015: 42).

Shifts to less polluting transportation modes are considered beneficial over longer distances, as rail and water borne solutions are both less polluting and more cost-efficient than road haulage. Furthermore, by transferring some of the transportation to less polluting options, thousands of truck kilometres can be saved and more space is available on the roads for other road users, while congestions may decrease (McKinnon, et al., 2015: 157, Dekker, et al. 2011: 673).

In past years, many different terminologies, such as multi-modal, intermodal, co-modal have been used in literature, but they all have at least one similarity: the use of more than one transport mode. Multi-modal transportation is defined as transportation of goods by at least two different modes of transportation and the transportation unit can be for example a box, a container, or a vessel or vehicle. In intermodal transportation the emphasis is on the transportation unit. The goods are transported inside the same intermodal transportation unit, without handling the goods themselves when changing the transportation mode. Co-modal transportation focuses on efficient use of different modes. It is used by a group of shippers in the chain, and transportation modes are used smarter way to maximise the benefits of different transport modes to enhance sustainability. Even though all these definitions highlight different aspects of the transportation mode, the term multi-modal, does not exclude any of the other definitions. (SteadieSeifi, et al., 2012: 2)

5.4 Information and communication technology (ICT)

Information and communication technology can improve supply chain visibility, responsiveness, and efficiency and thus have a substantial impact on coping with the growing complexity of logistics. Companies can better predict and develop operational strategies for the future through connectivity and information sharing, which enables them to increase options for capitalizing efficiency and sustainability (Blanquart, et al., 2016: 29, 31). Monitoring of current activities with ICT systems offers possibility to identification of deviations from plan or target, which enables proactive intervention and compensatory measures immediately. Availability of ICT systems allows elimination of some components of the transportation process, thus enhancing efficiency (Psaraftis, 2016: 211)

The application of information and communication technology in the transport domain is called Intelligent transport systems (ITS) (Lytrivis & Amditis, 2014). Various forms of ITSs are being used within the present supply chains such as multi-modal transport planning, automated and digitalized solutions for customer clearance, declarations, and in port and terminal operations. Benefits of ITS can be realized both on the level of individual transport mode, and within and across supply chains. (Blanquart, et al., 2016: 30-31). Furthermore, as geofencing, which is a location-based service, where for example GPS, RFID or cellular data triggers a pre-programmed action when the device or RFID tag enters or exits from a virtual boundary set up around geographical location, is slowly becoming more common, operations in terminals, transport hubs and cross-docking facilities can be optimized and handling of goods can be made seamless by reducing waiting times and increasing safety (Blanquart, et al., 2016: 31; White, 2017).

The future of multimodal logistics can be shaped by the ITS systems, as concepts now being developed such as synchro modality, cross-chain control centres, autonomous controlled transport vehicles and other automated transport systems which require advanced information systems, may ultimately lead to self-organizing logistics (Blanquart, et al., 2016: 31).

5.5 Green corridors

As most transport of goods takes place between logistics hubs, the concept of smart corridors connecting these hubs can add value to companies by extended connectivity and information sharing (Blanquart, et al., 2016: 29). The European Commission introduced the Green Corridors concept in 2009, in their efforts to decarbonise transport, which essentially means long-distance freight transport corridors, where environmental impact is reduced by using advanced technology and co-modality (EU Commission, 2009). A few notable characteristics for green corridors have been identified such as reliance on co-modality with adequate transhipment facilities at strategic locations and integrated logistics concepts, reliance of advanced technology, and collaborative business models (Psaraftis, 2016: 87). Green corridors could be seen as corridors that connect industrial and logistic clusters by safe and secure infrastructures, information sharing and real-time connectivity that would provide end customers reliable, fast, sustainable, and low-cost delivery (Blanquart, et al., 2016: 30).

These green corridors are both economically efficient and environmentally sustainable and this is based on consolidation of transportation of large volumes of freight over long distances in between the first and last miles. With this premise, competitiveness of rail and waterborne transport options, which are more environmentally friendly than trucks, would be improved. Increased competitiveness would lead to higher possibilities of involving train and ships in freight transportation. This shift of transportation modes is expected to alleviate congestion problems that European road transportation faces, and thus improve reliability, reducing the transportation time. The realization of these international corridors will require cooperation from multiple different stakeholders such as European Commission member states, local authorities, transportation operators, shippers, financers, and owners of the infrastructure (Psaraftis 2016: 87-88).

5.6 Alternative fuels for transportation vehicles

The depletion of fossil fuels, rising petroleum prices and the fact that road transportation contributes highly to global warming with carbon dioxide emission, have increased the interest in alternative fuels. Renewable biofuels, such as biodiesel, methanol, ethanol, butanol, hydrogen, and synthetic natural gases which could be used to power trucks with combustion engines are hoped to be helpful resources in decreasing CO_2 emissions caused by road transportation. There are various alternative fuels that can be used with combustion engines, with little or no modifications, which makes them desirable options as replacement for fossil fuels. Furthermore, as these alternative fuels are mostly produced in domestic resources and they are more easily available than fossil fuels, energy dependence will be reduced (Salvi, et al., 2013: 405-406, Ramadhas, 2011: 8).

Green transportation could benefit from vegetable oils, as they can be produced from variety of bio-feedstocks and are renewable, carbon neutral and thus environmentally friendly. They can be utilized as motor oils with little to no modifications to engines.

However, vegetable oils have too high viscosity for today's modern diesel engines, which may lead for example incomplete combustion, due to a poor atomization and choking the injectors because of low oxidation. Furthermore, the high flashpoint of vegetable oils may cause cold starting problems. Fortunately, there are several ways to lower the viscosity of vegetable oils such as heating, dilution and blending, micro-emulsion and transesterification to make them compatible with diesel engines. (Salvi, et al., 2013: 407).

Hydrogen powered cars are also believed to contribute to reduction of emissions from road transportation. Hydrogen does not contain carbon compounds and is thus clean and efficient replacement for fossil fuels. On combustion, hydrogen emits water vapor, therefore using it would result in few or no emissions that would affect air quality (Ramadhas, 2011: 14).

Hydrogen is manufactured from water using fossil fuels or clean energy sources. In consideration of emission reduction, fossil fuels should not be used to produce hydrogen, since this would not lead decreased emissions, which is the objective of using alternative power sources for transportation (Ramadhas, 2011: 245). There are still problems in production, storage, and safety of hydrogen, so those must be considered before it can be considered as viable alternative for fossil fuels (Salvi, et al., 2013: 417). As hydrogen is for example lighter than air, has low viscosity and thus leaks easily and is flammable, rules must be made to regulate technical aspects of hydrogen while risk management and choices of responsibility should be made at a political level (Ramadhas, 2011: 260).

There are many sources of alternative fuels which could be produced from various sources. To make these options more viable and cost-effective, capital and operating cost should be reduced. Furthermore, more research should be made to introduce more alternative energy sources and ways to regulate the safety of those sources (Salvi, et al., 2013: 417).

5.7 Conclusion of road freight transportation

There are many things to consider when contemplating the future of road freight transportation. EU and individual nations have thrusted their hopes of greener road transportation on electronic vehicles, but many improvements must be made to the technology of electronic vehicles, and to the infrastructure that empowers them. To increase the distance electronic vehicles can drive without charging, the size of the battery should be increased tremendously. It has been estimated that to provide same energy as a diesel car with 50-litre tank, electric car should have battery which weighs 2500 kilos (EU Commission quoted by Klumpp, 2016: 9).

Furthermore, as the batteries of electronic vehicles are made from metals, which are in some cases scarce, or located in areas where production is unethical and mining and refining them generates CO_2 emissions, recycling of the battery materials needs to be enhanced to ensure sustainable production.

Consideration of the source of energy which powers the electronic vehicles must be made, as the electricity produced from fossil sources would not decrease substantially the emissions caused by road haulage. The European Union strives to be the leader in clean energy production, but at the same time, the second largest source of power is natural gas, and as can be seen in Figure 6, oil and petroleum products have been dominating the energy sector for decades.

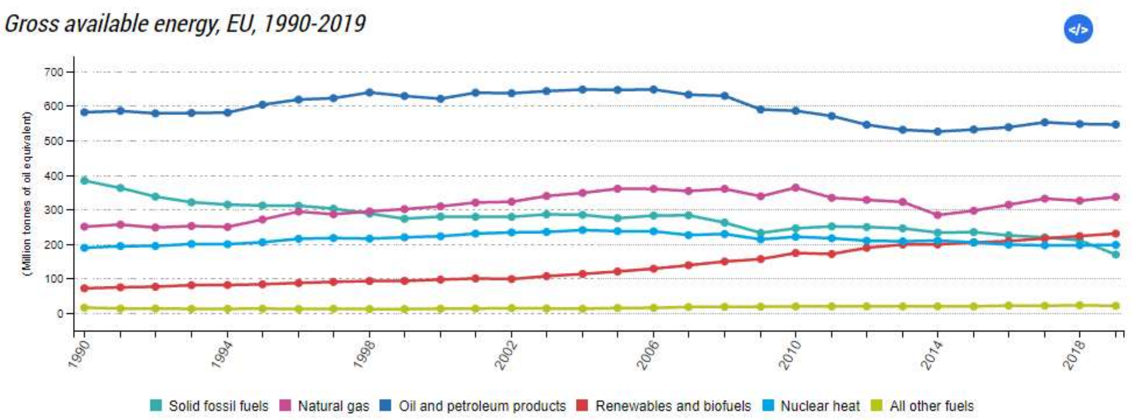

Figure 6. Gross available energy, EU, 1990-2019 (Eurostat b, 2021).

Intelligent communication systems have the potential to enhance logistics services by producing real time data and making logistics procedures a seamless flow. Unfortunately, adoption of ICT systems remains uneven as smaller businesses focus mainly on transportation operations and larger companies focuses more on coordination and service management and are thus more likely to adapt the tools of intelligent freight

(Blanquart, et al., 2016: 24). Furthermore, ITC systems require investments which are not always a possibility for smaller businesses.

Technology will be playing crucial part in transportation greening efforts, it must be noted that even though innovations are made, it will take time for them to be fully realized in the transportation business. The average age and investment cycle for heavy-duty trucks is from five to ten years, and even more in developing countries, which means that while there is theoretical potential to transport freight greener also in road haulage, it will take time to for these innovations to actualize in practice (Klumpp, 2016: 7).

6 Sea freight

Sea freight is known as a cost-effective way to transport bulk goods from one side of the globe to another, but it is also a growing source of greenhouse gas emissions and has been under-regulated compared to other transportation sectors. Sea freight is also expected to increase significantly in the future due to growth in the world economy and consequent transport demand. Maritime transport is responsible for approximately 2,5 percent of global greenhouse gas emissions, which translates to 940 million tonnes of CO_2 annually (EU Commission, n.d.c., EU Commission, 2013: 2-3).

Even though maritime logistics is considered a more environmentally friendly transport mode compared to other transportation modes, ships generate various emissions which are considered negative if not kept under control. Besides the greenhouse gas emissions, the shipping industry emits pollutants such as sulphur oxides, nitrogen oxides and particulate matter, and those emissions are much higher than in any other modes. Ships use bunker fuel as their power source. This is the residual fraction left from distilling cleaner fuels, such as petrol and diesel, and this bunker fuel contains much more sulphur particulates compared to fuels used in road transportation (McKinnon, et al., 2015: 183).

Greenhouse gases generated by international shipping were not regulated before the year 2011, when the Marine Environment Protection Committee (MEPC) adopted the Energy Efficiency Design Index (EEDI), a benchmarking scheme that aims to indicate the ship's CO_2 emissions in relation to its transport work (Psaraftis, 2016: 31, 269).

Furthermore, the International Maritime Organization (IMO) has designated the Baltic Sea, the North Sea and the English Channel as Sulphur Emissions Control Areas, in 2008, with the purpose of limiting sulphur oxide emissions (Psaraftis, 2016: 269). IMO has also adopted globally legally binding energy-efficiency measures across the entire industry. (IMO, n.d.). In 2013 the EU Commission communicated to European Parliament the need to integrate maritime transport in the EU's greenhouse gas reduction plans as it was the only transportation method not included in that commitment (EU Commission, 2013: 2).

Shipping is less polluting transportation option compared to other transport modes, but its dependence on oil, sulphur dioxide and nitrogen oxide emissions added to greenhouse gas emissions and technological advances elsewhere calls for action to reduce the environmental impact of maritime transport (EU Commission, 2013: 3).

6.1 Strategies to reduce the emissions in European area

In 2013 European Commission introduced a strategy to reduce greenhouse gas emissions from maritime transportation.

The strategy consists of 3 consecutive steps:

- Implementing a system for monitoring, reporting and verification (MRV) of emissions
- Definition of reduction targets for the maritime transport sector
- Application of a market-based measure (MBM) (EU Commission 2013: 4).

6.1.1 Monitoring, reporting and verification (MRV)

From 1st January 2018, large ships over 5000 gross tonne of loading or unloading cargo or passengers are expected to monitor and report their CO_2 and other relevant information such as fuel consumption and distance travelled at ports in the European Economic Area. Furthermore, from year 2019 onwards, companies which have had ships performing transportation activities in the European Economic Area in the previous calendar year must submit to the Commission and flag States of these ships satisfactorily verified emissions reports. The flag States of these ships then report the data to the International Maritime Organization, which produces annual summary report to International Maritime Organization Marine Environment Protection Committee (EU Commission n.d.c.).

The implementation of monitoring, reporting and verification could, according to the impact assessment carried out in the context of this strategy, reduce greenhouse gas emissions up to 2% annually and result to € 1.2 billion net savings for the maritime transportation sector, in reduced fuel bills. (EU Commission, 2013: 3, 5).

There are challenges in the MRV system, including the usefulness of the reported data, as basing it on cargo carried or distance carried may be irrelevant to measuring CO_2 emissions or fuel consumption. Monitoring per-voyage basis would not be practical, especially for vessels operating in shorter distance and thus performing multiple voyages in short time, as it would increase administrative burden tremendously. Furthermore, when implementing any energy efficiency measure, consideration need to be made to the fact, that ship operators do not have control over weather conditions, trade imbalances or port congestion (Psaraftis, 2016: 295).

6.1.2 Setting reduction targets

The main objective for MRV would be provide reliable data of the emissions caused by maritime transportation. Thus, a global process of reporting and verification should be established so adequate information would be available throughout the supply chain about the performance of the shipping sector. By establishing this reporting and verification system, the administrative burden of ship-owners, ship-managers and flag states would be limited, and transparency and accuracy of the information would be provided. Furthermore, this process would also provide policy-makers necessary data, to make informed decisions and implement new requirements. At the EU level, consideration of International Maritime Organizations efficiency standards and availability of technologies for reducing emissions needs to be made (EU Commission 2013: 6-7).

When setting these reduction targets, difference in transportation modes needs to be considered. In road transport emission reduction measures are imposed on the manufacturer, whereas in maritime transport the ship operator is responsible and this needs to be on an individual ship level. In some instances, ships may be competing with land-based modes and could lose their competitive advantage because of these reduction measures, which could result in increased overall CO_2 emissions (Psaraftis, 2016: 295).

6.1.3 Market-based measures (MBM)

By implementing the polluter-pays principle, market-based measures can effectively remove the market barriers related to access to finance. This can be cost effective way to achieve emission reductions throughout the economy. Three options in implementing these market-based measures were considered most promising in impact assessment to address greenhouse gas emissions. The first option is ‘A contribution-based compensation fund’, where complementary instrument would already be in place such as speed limits, and voluntary contribution to the fund is foreseen as opt-out option. The second option is ‘A target-based compensation fund’ where all the ships covered by the regulation would be set a target and pay a membership fee for sector-wide entity, which would have responsibility to ensure compliance with the target. This entity would also provide support with efficiency investments and provisions in case target would not be met collectively. The third option is ‘An Emission Trading System (ETS)’ which has been used in Europe for different industries and would mean that every ship would be surrendering allowances at the end of the set period which would correspond with the ships emissions of the set period (EU Commission, 2013: 8).

The polluter pays principle implemented in MBM helps internalize the external cost of emissions, by making the owner of the ship pay for the CO_2 emissions occurred. Furthermore, by using the monies raised by MBM to purchase for example offsets, which could be used to buy for example wind farms, reduction of CO_2 emission could be done outside of maritime sector (Psaraftis, 2016: 270).

The International Maritime Organization has also been considering market-based measures to decrease emissions from maritime sector, but there has not been consensus among the countries which proposed MBM, and some developing countries were strongly against any MBM. Disagreement over how the collected monies would be used to benefit the developing countries also arose while discussing the measures of the MBM. In year 2013 Marine Environment Protection Committee (MEPC) decided to suspend further discussion of MBM for the time being (Psaraftis, 2016: 294).

6.1.4 Initial International Maritime Organization greenhouse gas Strategy

In 2018 the International Maritime Organization approved follow-up program to where member states would submit proposals on how to reduce greenhouse gas emissions to Marine Environment Protection Committee, which is decision-making body and usually establishes a Working Group on Reduction of GHG Emissions from Ships. Building on current mandatory energy efficiency requirements this working group draw a draft on measures to increase carbon efficiency of ships and further reduce greenhouse gas emissions. In November 2020 the Marine Environment Protection Committee approved these amendments. This revised strategy is envisaged to be adopted in year 2023 (IMO, n.d.).

To ensure industry wide emission reduction the International Maritime Organization has established a series of baselines for fuel consumption for each type of ship and cargo capacity. In the future, newly built ships need to beat the set baseline, which will get progressively tougher. From the year 2025 ships built need to be significantly more energy efficient than the baseline set, and by the year 2025 ships will be 30% more energy efficient compared to ships built in 2014 (IMO n.d.).

6.1.5 Technological measures to decrease emissions

Besides the legislation and monitoring the emissions caused by the maritime transport, technological measures to decrease emissions have been introduced. These include more efficient and thus energy-saving engines, more efficient propellers, alternative fuels, redesign of ship hulls, trapping exhaust emissions and various kites. Logistics-based measures include efficient supply chain management, optimized weather routing, speed optimization, fleet management and other logistic operation which may impact the efficiency of used resources. Both logistics-based and technological measures would decrease emissions, but logistic-based reductions are considered short-term solutions and technological measures long-term solutions (Psaraftis, 2016: 269-270)

6.2 Logistic-based measures to decrease emissions

Speed and route optimization can be considered as logistics-based measures to decrease emissions from maritime transportation. As emissions produced by a ship are directly proportional to fuel consumption, slow steaming has been gaining popularity among ship operators. Slow steaming is a concept where the ship sails slower than designed to decrease fuel consumption, which will also decrease emissions. Reconfiguring the engine to achieve lower output has also been an option to attain slower speed. Among the emissions reduction of slow steaming, another perhaps more important benefit for maritime industry today is cost reduction followed by reduced fuel consumption (Psaraftis, 2016: 299-302).

In the future, one way to reduce emissions is to build ships with less horsepower, so they cannot sail as fast as ships today. Maersk is a forerunner in technological based measures, as their new flagship Triple-E fleet which can carry 18,000 TEU containerships have been designed to travel at 17.8 knots as opposed to 20-26 knots, which is the industry norm. Triple-E emits 20% less carbon dioxide per container moved as Maersk’s previous flagship Emma Maersk, which was the world largest container vessel (Psariftis, 2016: 303).

Routing decisions of the vessels can also influence emissions caused by maritime activity. Even though the simplest answer to routing decisions could be to use the route of less sea mileage, exceptions occur from the payload of the ship. In case there are several harbours to deliver the cargo the route with less sea mileage may not be the route with less emissions if the heaviest cargo is unloaded last. Optimizing the route so that the heavier cargo will be unloaded earlier can reduce the overall emissions caused by the transportation, even though the route would be longer (Psaraftis, 2016: 326).

6.3 Controlling sulphur emissions

Maritime transportation produces among greenhouse gas emissions also undesirable sulphur emissions, which can cause acid rains and health defects in both humans and animals. These high sulphur emissions are mainly caused by the fuel used, as in heavy fuel oil, used in deep sea-trades, the percentage of sulphur can be as high as 4,5%. To tackle these undesirable side effects, the Marine Environment Protection Committee and European Commission introduced Sulphur Emission Control Areas (SECAs) in efforts to lower the sulphur and nitrogen emission caused by maritime transportation. The first step towards lower emissions however is to set a cap to total sulphur emissions and from January 2020 International Maritime Organization has set the global sulphur cap to 0,5% instead of the previous 3,5% and down to 0,1% in SECA areas. Exhaust gas cleaning systems and alternative fuels have been suggested as measures to control sulphur emissions (Kontovas, C. 2020: 1; Psaraftis, 2016: 354).

While these efforts to cut down sulphur emissions will be effective and have positive effect on health of both humans and animals, progress on cutting down greenhouse gas emissions has been quite slow. The initial IMO strategy was adopted in 2018 and the goal is to reduce greenhouse gas emissions by at least 50% by 2050 compared to year 2008. The relation of maritime transportation’s contribution to global warming and climate change is quite complex. Trade-offs between the health issues caused by sulphur and nitrogen emissions and global warming caused by the greenhouse gas emissions must be considered, as reducing the sulphur emissions may contribute to global warming if the link between various emissions are not considered. As ships emit greenhouse gas emissions that contribute to global warming, sulphur oxide emissions cause cooling through effects on atmospheric particles and clouds, whereas nitrogen oxide increases the level of ozone, and these effects contribute to both warming and cooling of the atmosphere (Kontovas, C., 2021: 1-2).

While policymakers are focusing on restricting greenhouse gas emissions and other particulates which maritime transportation emits, the consideration has been made independently without considering that these emissions are interdependent and will affect global warming in diverse ways. Sulphur emissions cause cooling in the atmosphere, and strong regulation of these emissions could result to shipping industry further contribute to global warming, especially when it's not likely that carbon dioxide emissions can be cut in the same proportion (Kontovas, 2021: 2, Psaraftis, 2016: 58).

6.4 Hydrogen ships

At the moment hydrogen is seen as viable alternative to fossil fuels to power the ships in the future. Using hydrogen and other alternative fuels to power the ships instead of fuels that ships use now, the shipping industry could cut its carbon dioxide emissions by 95% by the year 2035, but there are still problems with the technology, which need to be worked on before hydrogen can be used in maritime transportation. (Meister, 2021).

Hydrogen is mostly found in chemical compounds and it needs to be separated before it can be used to power the ships. This separation can be done, for example using electricity to draw hydrogen and oxygen separate in water compounds and store the hydrogen to containers. As this process demands lots of electricity, it is important to use renewable energy sources in this process to avoid creating more emissions. (Meister, 2021).

In 2027 one hydrogen ship is set to sail from Copenhagen to Oslo and it is leading the way to bigger hydrogen ships in the industry. To power this ship with hydrogen, it will be equipped with proton-exchange membrane (PEM) fuel cells, which resembles a battery. The problem of these PEM-fuel cells is that they are not very efficient, as around 50 percent of hydrogen's energy will be wasted, for example via heat generation. Currently solid oxide fuel cells are being developed so that at least 60 percent of the power that hydrogen produces can be used to power the engines in ships. Another problem with hydrogen is that it is highly combustible and its volume to mass ratio is large. To make it take less space hydrogen can be liquified by freezing it to -250 degrees Celsius, but it can also be compressed, so that its pressure is higher and thus it fits to smaller space (Meister, 2021).

6.4.1 Safety considerations when using hydrogen as a power source

To convert hydrogen as a power source for the maritime industry is no small feat. Making hydrogen safe to use in smaller spaces where personnel cannot be evacuated as easily as on land, more knowledge of safety aspects is needed. Especially knowledge of how hydrogen behaves on leakage scenarios in enclosed spaces and in typical ship design helps develop mitigating measures when using hydrogen as power source for ships (Frithiof, 2021).

Due to high detonation risk of hydrogen and because it can embrittle materials which would be safe with other natural gases, fuel cells for hydrogen needs to be made from certain types of steels. Therefore, safety measures such as ventilation location and detectors of leakage need to be considered when planning the design of the ships (Frithiof, 2021).

Land based transportation has already used hydrogen as a power source, and even though utilizing it with maritime transportation needs adjustment and rigorous safety measures, knowledge gained from using hydrogen and storing it with cars and trucks will make it easier as there is no need to start from scratch (Frithiof, 2021).

6.5 Impact of COVID-19 to maritime transportation

The COVID-19 pandemic has affected the whole world, as restrictions have been placed on traveling and gatherings, but also some commercial activities were closed in efforts to slow down spreading of the virus. The pandemic has led to disruptions in economics and logistic chains and shipping industry has also been following this negative trend (Millefiori et al., 2021: 1, 5).

Maritime transportation constitutes approximately 80 percent of global goods trade. Restrictions imposed on both traveling and transportation also affected the shipping industry in a way that cargo ships were equipped with crews which were isolated from the mainland to prevent the spreading of the virus. Health screening was required from the crews and harbours had shortage of workers, which affected the cargo transportation and resulted harbours being in state of deadlock. Furthermore, due to the isolation of the shipping crews, the containers could not make new loading to their return voyage to Asia, resulting in an empty container problem. (Yazir, D., et al. 2020: 253-254).

Research of COVID-19's impacts on maritime transportation has been made and according to data collected from Automatic Identification System (AIS) receivers, and according to one research made by Millefiori et al., the decrease was modest in the first half of 2020 when compared to year 2019, but greater decline was noted during April-June in 2020, when restrictions were tighter globally. Noteworthy variation in the main types of ship traffic is that dry bulk ships slightly increased during this period while other types, such as container ships, wet bulk and passenger ships mobility decreased (Millefiori et al., 2021: 5).

In recent years, Asia and especially China has become a centre of global container shipping, as most of worlds container ports are in Asia, such as Shanghai and Singapore. Moreover, the share of goods, which are ideal to ship in containers has risen and because containers have other advantages, such as compatibility for multimodal use and shorter loading and unloading times, popularity of container shipping has increased. This added to the empty container problem, which arose from the COVID-19 isolation of the shipping crews, prices of maritime transportation have risen significantly during year 2021 (Yazir et al. 2020: 260).

During COVID-19 pandemic length of the supply chains caused strain to suppliers, manufactures and retailers. Due to the lockdowns and restrictions imposed to shipping crews access to raw materials and sales products was restricted which can also cause bullwhip effect to through the supply chain. Due to the ongoing empty container problem, suppliers are still stretching their limits to be able to fulfil the need of their customers.

6.6 Supply chain information distortion can cause bullwhip effect

Distortion of information within a supply chain causes a bullwhip effect, where demand order variabilities amplify as they are transmitted up to the supply chain. These information distortions can be seen as costly inventories, as within a supply chain, there can be more than one year's supply. With a typical consumer product, variability in orders can cause amplification even though consumer sales do not have such a variability. This can be caused by a manager's rational decision making combined with four identified causes of bullwhip effect, demand forecast updating, order patching, price fluctuation and rationing and shortage gaming (Lee, et al. 1997: 93-95)

To mitigate the bullwhip effect, companies have started to implement programs to address it. Information sharing in a timely fashion, channel alignment, inventory planning, and pricing coordination are a few of the steps which could help tackle the problem. By understanding its causes companies can counteract the bullwhip effect. (Lee, et al., 1997: 98,101).

6.6.1 Demand forecasting

Demand forecasting, a method such as exponential smoothing, where future demand is updated as new daily demand data becomes available, is used by managers to determine how much to order from the supplier. An order is placed to meet the needs of future demand alongside the safety stock needed when lead times are long. When sites further up the supply chain also use this same method to forecast their future demand, swings are even bigger (Lee, et al. 1997: 95).

The bullwhip effect created by forecasting data can be mitigated by information sharing. By making demand data accessible throughout the supply chain, from downstream site to upstream site, manufactures can better forecast the real need for their products and plan the production accordingly (Lee, et al. 1997: 98-99).

6.6.2 Order batching

Processing orders frequently costs time and money and thus in order patching orders are placed within a certain timeframe, such as weekly or even monthly. Furthermore, costs for transport can be significantly different for smaller batches, compared to full trailer loads, which tend to be more cost efficient, and this may also act as an incentive to work less frequently, and lead to longer order cycles. If a supplier faces an unpredictable stream of orders, where there is a spike in demand once or twice a month, and no demand for the rest of the month, orders from the customers can overlap, causing surges in demand periodically and contributing to bullwhip effect within the supply chain (Lee, et al., 1997: 96).

Using ICT systems and sending orders via EDI could reduce the of paperwork and thus also reduce the costs generated with higher order frequency. Bullwhip effect is also generated by pricing of less than a truck load compared to full truck load, which can cause ordering restrictions even though orders would come via through EDI. Some suppliers have solved the problem by offering their clients more products, so that they can break the full truck load to multiple different products, instead of ordering only one product. This would save the costs for the client and would also reduce the bullwhip effect generated by large irregular ordering batches (Lee, et al. 1997: 100).

6.6.3 Price fluctuation

Forward buy where goods are bought in advance of requirements, due to price offers placed by the manufacturers, is especially used in grocery industry. Manufacturers and distributors can offer periodically price discounts, quantity discounts and other promotions, which result in price fluctuations. Due to the promotions, customer buy goods in quantities, which do not reflect their needs and stock up for the future. This may result to higher inventory costs, but if this cost is lower than the price differential, forward buying is sensible, but results to bullwhip effect (Lee, et al. 1997: 97).

Controlling price fluctuation is the key to reduce the bullwhip effect. Manufacturers create the effect themselves by offering discounts, which could be better controlled with uniform wholesale pricing policy. By pricing their goods with lower price with, for example, a value pricing strategy, fluctuations can be minimized, and customers can still be committed to use the supplier’s services (Lee, et al. 1997: 101).

6.6.4 Rationing and shortage gaming

Manufacturers can ration their products if demand exceeds supply, meaning that customers receive only a portion from their order. If rationing is known by the customers, they can exaggerate their real need to receive more goods. This gives the supplier little information of the real demand for the product and may cost in excess inventory and unnecessary capacity increases. When the original need for goods is filled, customer will cancel their orders, which may result in over capacity for suppliers (Lee, et al., 1997: 98).

Gaming in shortage situations can be eliminated by rationing orders by past sales records instead of orders received. This way customers have no need to exaggerate their need and place multiple orders, which are cancelled when the original need is fulfilled. Furthermore, by sharing capacity and inventory information to their customers, suppliers can help to mitigate their need to engage in gaming (Lee, et al., 1997: 101).

6.7 Conclusion of maritime transportation

Maritime transportation has been thus far the least regulated form of transportation and the International Maritime Organization has only a few years ago started to restrict sulphur emissions in the shipping industry and placed reporting obligations on ships, as it attempts to reduce greenhouse gas emissions from the industry. Market based measures to decrease CO_2 emissions will be drawn based on the reliable data gathered from the monitoring, reporting and verification system on ships which have transportation activities in a calendar year. Together with the effects of COVID-19 maritime transportation is in turmoil which causes the prices to increase, but maritime industry is resilient and even though there have been challenges, it has been able to continue and even increase its operations in specific markets.

As the investment cycle for ships may be up to 50 years, it takes time for all the innovations to realize in maritime transportation, but regulators, shipping lines, port operators and oil companies have now been challenged of the green conception which has delayed the greening process from the start. Possibilities to equip older ships with devices which decrease emissions will be reinforced with the market-based measures considered by the International Maritime Organization and when hydrogen ships will be secured and tested there might be increasing number of greener options for maritime transportation to tackle the emissions caused by its operations (McKinnon, et al., 2015: 187-188).

7 Rail freight

Global transportation needs are growing fast and thus growing greenhouse gas emissions have been under consideration for policy makers both globally and locally. For some reason one transportation mode has been underrepresented in these discussions for a greener future, and that is rail freight transportation. Rail freight is one of the most energy efficient transport modes, as it has the ability to provide mass transport with less energy consumed per unit transported. The possibility to power this freight option with electricity and thus renewable energy makes rail freight important part in the battle against greenhouse gas emissions and global warming (Climate Change Org, 2018: 217; IEA, 2019).

Road freight is the primary transport mode in inland transportation, especially in the EU, and it accounts for more than half of carbon emissions caused by freight transportation. Bottlenecks are formed by the heavy-duty trucks in European roads, compromising the safety of private car drivers and supply chain reliability. By changing inland freight operations from road to rail freight, emissions could be decreased, as even one per cent of road traffic transported by rail translates into approximately million tonnes of reduced CO_2 emissions per year, according to the report commissioned by the German Federal Ministry of Transportation (Möbius B., 2021).

The main hindrance for rail freight to meet its capacity in providing carbon-free transportation option is the scale of investments needed for its infrastructure. Furthermore, as rail freight is reliant on its infrastructure it’s unable to move goods flexibly to end receivers and thus it is dependent on other transportation modes to make the last mile deliveries. Especially in rural areas rail freight cannot be developed due the scale of investments needed for the infrastructure (Climate Change Org, 2018: 217).

7.1 Steps towards emission free rail freight by individual countries

Even though rail freight is one of the lowest-emitting transport modes, 55 percent of its total energy consumption in year 2020 was powered by oil. The main challenge for rail freight is electrification which could lower the emissions by up to 30 percent compared to emissions caused by locomotives powered by diesel. Half of the European rail lines are electrified but for example, in North America the corresponding figure is only 0,5 percent. (Climate Change Org, 2018: 223; IEA b., 2021)

Positive development in greener railway systems has been achieved in past few years by Indian Railways, which has taken significant steps to become a net zero carbon emitter. By the year 2023 Indian Railways have planned to electrify broad gauge routes to eliminate diesel traction and achieve 100% electrification. Furthermore, over 600 stations in India have been certified by ISO:14001 Environment Management System (Pinjarkar, 2021).

Other countries in the world are also committing to development of rail infrastructure. Germany has put into service two hydrogen fuelled trains already in 2018 and more is expected to follow. Germany has also committed to better its rail network as the infrastructure plan for 2030 provides €270 billion investment of which 40 percent will be for rail. With this investment the capacity of German rail network will be increased by 20 percent and 70 percent of its national network will be electrified (Climate Change Org, 2018: 219,224).

Smaller steps to greener rail freight have been taken by Union of Pacific Railroad and Russian Railways, which have been interested in powering their locomotives with natural gas, which would not be a non-carbon-free option but would still reduce carbon dioxide emissions significantly compared to locomotives powered by diesel fuel (Climate Change Org, 2018: 224).

Nevertheless, there are operators that have no intention to move away from carbon emitting rail freight, as Turkish private operator Kofez Ulastirma has ordered five diesel powered locomotives and the Kazakh railway company ordered 300 new high-speed light diesel engines locomotives to their fleet which were to be delivered in 2019 (Climate Change Org, 2018: 224).

7.2 Innovations to help rail freight to meet its decarbonation potential

Intermodal rail freight could be a solution in greener logistics operations especially if diesel powered locomotives would be replaced with locomotives powered either with hydrogen or electricity produced from renewable resources. In rail lines where electrification is not economically viable due to a low throughput hydrogen or battery electric trains with charging points and partial electrification of the track could replace locomotives powered by diesel (IEA b., 2021).

Different information and communication technology solutions should be invested in to create more interoperable and intermodally connected and most of all more flexible inland freight option. By adopting technology solutions and sharing data rail operations could be optimized and integrated more comprehensively with other transport modes, enabling seamless transportation network based on cross-modal systems with road, sea and air transport operators, which in turn could improve efficiency and increase revenues (Möbius B, 2021; IEA b., 2021).

Furthermore, the potential offered by IT can be used also to improve other aspects in rail operations, which would result to reduction in greenhouse gas emissions. By utilizing IT systems, filling rate of the trains can be improved, thus providing savings energy up to 17 percent. Computer assistant driving modes can reduce braking and acceleration, saving traction energy up to 20 percent. This could also improve the punctuality of rail operation (Climate Change Org, 2018: 225).

In addition to optimization of locomotives by powering them with greener more sustainable resource efficiency of trains can also be improved in other ways. Moving a train generates traction which translates to about 85 percent of the total energy consumption of the vehicle. By using new composite materials, the weight of the vehicle can be reduced by 20 to 30 percent which would decrease the traction energy and emissions. Energy recovering systems, such as flywheel and battery, which could also store energy recovered, can eventually lead to reduced energy demand. Train aerodynamics also have potential in reducing traction as for instance in Alstom’s high-speed railcar (AGV) which has a 25 percent improvement in the drag coefficient, when compared to traditional locomotives, resulting in up to 15 percent savings in traction energy. ABB has developed “Resibloc Rail”, which is an oil-free traction transformer and can reduce energy costs by 10 percent compared to traditional transformers which can result up to 38 tonnes reduction in carbon dioxide emissions yearly. Indian Railways have also made experiments with renewable energies, by incorporating solar panels to power lights, fans and mobile charging points in passenger trains (Climate Change Org, 2018: 223, 225).

7.3 COVID-19 impacts on rail operations

COVID-19 pandemic affected mobility in railroad operations more to the passenger transport as railway companies needed to offer services for its clients while still addressing the needs for social distancing. Even though energy consumption and carbon dioxide emissions were reduced during the pandemic as a result of reduced need for the services, the energy intensity of railroad operations rose more than two-thirds. This caused considerable costs for railway companies, and as a result, many countries announced recovery measures to help restore railway activities (IEA b., 2021).

7.4 Conclusion on rail freight

Inland transportation relies heavily on road transportation even though rail freight could offer competitive and emission free option, especially for longer distance haulage. Improvement of rail infrastructure may be expensive but could provide much needed emission reduction and slow down global warming. Information and communication technology solutions could provide data sharing which would enable seamless transportation network with other transportation modes which in turn would improve efficiency and profitability of rail freight (Möbius B, 2021; IEA b., 2021).

To build infrastructure and reduce emissions in rural areas, where power network would be difficult and futile to build due the investments needed, locomotives powered with hydrogen or battery electric trains with charging points could be used to replace the diesel-powered locomotives offering emission free option for road freight (IEA b., 2021).

It seems possible for rail freight to become the back bone of inland freight transportation with an option for mass transportation and thus less energy consumed per unit transported. Even though rail freight is dependent on its infrastructure and cannot provide last mile deliveries, with the help of multimodal freight options and information and communication technology solutions, building a transportation network around it would seem reasonable step on our fight against global warming (Climate Change Org, 2018: 217, IEA, 2019, Möbius B, 2021).

8 Air freight

The aviation industry has developed fast, from learning to fly, to fly faster and further. Globally there are more than 100,000 flights occurring every day, which represents over 400 departures per hour. In 2017 airlines carried 56 million tonnes of freight worldwide. Because its fast-paced development within past century, aviation has been the forefront of innovation and is one of the most reliable modes of transportation in the world today. Sharing and leveraging technology and practices from aviation will help this mode of transportation to become more sustainable and successful (ICAO, n.d.).

Greenhouse gas emissions from transport have been increasing every year since 2014 and the fastest growing emitter is air freight transport. It has been estimated that greenhouse gas emissions were 29 percent above 1990 levels in 2018, and reduction in transport emissions would need to be drastic to achieve the European Commission's Green Deal objective of carbon neutrality by 2050 in all sectors and EU member states. To make this matter even more dramatic, the International Civil Aviation Organization (ICAO) forecasted before COVID-19 pandemic, that emissions from this sector could triple by 2050 compared with 2015 levels (European Environment Agency, 2020, EU Commission, n.d.d.).

The industry has made an effort, making policy actions to improve fuel efficiency and it has reduced the fuel consumption per passenger, but the environmental benefits created have been outpaced by the growth in air traffic, especially passenger transportation. Less than 15 percent of emissions caused by this sector is created from freight transport, but it is still the second biggest source of greenhouse gas emissions after road transport. Air Transport Action Group (ATAG) has set high targets to become more sustainable, such as achieve carbon neutral growth by 2020 and reduce net emissions 50 percent by 2050 according to International Air Traffic Association (IATA). European Commission's Green Deal and set target by the industry increases the pressure for aviation sector to decarbonize (EU Commission, n.d.d. IES, n.d., McKinsey & Company, 2020:15).

8.1 Policies to reduce emissions in aviation

Aviation is responsible for about 2 percent of global carbon dioxide emissions, from which 1,3 percent is from international aviation. Fuel efficiency has increased in recent years, and amount of fuel burned per passenger dropped 24 percent between years 2005 and 2017, but heavy growth in air traffic has outpaced these benefits. Policies and targets have been set by different global organizations, to reduce the emissions caused by aviation and ways to offset the emissions by projects which reduces emissions in other sectors have been thought of (Traficom, 2022, EU Commission, n.d.d.).

8.1.1 European Commission tackling emissions from aviation

In year 2021 the European Commission adopted the European Green Deal, which is series of legislative proposals which aims to achieve climate neutrality by 2050 in the European Union. One of the intermediate targets for these legislations adopted is to reduce greenhouse gas emissions at least 55 percent by year 2030. The European Green Deal package includes several pieces of EU climate legislation, including EU ETS (EU Commission, n.d.d.)

European Commission has set up EU Emissions Trading System (EU ETS) to tackle greenhouse gas emissions produced by its Member States. From 2012 onwards, carbon dioxide emissions from aviation have been under the EU ETS. This market-based measure requires airlines operating in European area to monitor, report and verify their emissions and to surrender tradeable allowances against those emissions. The system has so far reduced emissions caused by aviation by more than 17 million tonnes per year, but despite it, aviation accounted 3,8 percent of total CO_2 emissions in European level (EU Commission, n.d.d., VRR, 2020).

The scope of EU ETS was decided to limit to flights within the European Economic Area (EEA), until year 2016, even though it was designed to apply to emission within, from and to EEA, which includes EU Member States, Iceland, Norway, and Liechtenstein. With this limitation, the EU wanted to support the development of International Civil Aviation Organization’s (ICAO) global measure Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA). From year 2017 onwards, EU decided to maintain the scope of EU ETS limited to flights in European Economic Area, as Resolution by the ICAO Assembly was adopted on global measure in 2016. EU ETS will be reviewed in the light of the international developments in CORSIA and will revert to its original scope in 2024, if new amendments will not be made. (EU Commission, n.d.d.).

8.1.2 Global scheme of emission reduction

International Civil Aviation Organization’s (ICAO) introduced its Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) and was agreed on 2016. As emissions from aviation have been steadily growing every year, CORSIA is designed to keep the carbon dioxide emissions to 2020 levels, by offsetting the growth in emissions after 2020. Participation to CORSIA is voluntary and exemptions have been given to low aviation activity states, but it is expected to offset around 80 percent of emissions above year 2020 during years 2021-2035 (EU Commission n.d.d.).

In total 69 countries, which include all EU countries are joining to CORSIA’s pilot phase from 2021 to 2023 and the rest are expected to join later, during the first and second phases. Initiative covers 191 countries, which are committed to reduce emissions from international flight. The implementation and operationalisation of the scheme is highly dependent on national measures enforced at domestic level. From 2019 onwards, all airlines flying international routes are required to monitor and verify their carbon dioxide emissions, and from 2021 onwards they are required to offset the emission cap. Under CORSIA, options to reduce emissions and meet the CO_2 cap set by the policy are to fly more efficient aircraft, using better technology to cut delays and optimize flight routes, using lower carbon fuels to reduce emissions from transportation activity and invest in carbon offsetting schemes either within or outside of the industry (EU Commission n.d.d., VRR, 2020, IES, n.d.).

8.2 Freight operator’s input to emission reduction

Cargo side of aviation is leading the way to cleaner aviation either through offsetting or sustainable aviation fuel (SAF) and have been driving carbon reduction throughout the supply chain said International Airlines Group’s director Willie Walsh in IATA World

Cargo Symposium in 2021. Best way for the industry to reduce carbon emissions is believed to be sustainable aviation fuel, which can be produced from feedstock, such as agricultural waste and could reduce the life-cycle carbon footprint up to 80 percent and is considered as medium-term option for controlling emissions growth. But for SAF to become powering force of aviation, production would need to be increased significantly, which would require costly investments. Furthermore, competition is faced from other sectors as the supplies are limited (Brett, 2021; Rucinski et. al., 2021).

IATA’s head of cargo, Brendan Sullivan says that shippers have become more environmentally conscious and thus sustainability is air cargo’s license to grow. Thus, in year 2021, airlines are committed to achieve net-zero carbon emissions by 2050. This would be achieved by using SAF to power the airplanes and by leaning to new aircraft technologies, such as electric and hydrogen powered aircrafts. By improving operations and infrastructure, and for example reducing the time aircrafts need to circle near the airport to be allowed to land, by enhancing fuel efficiency systems and air management programmes, sustainability of aviation can be upgraded. As aviation cannot become completely emission free in near future, credible offsetting of the emissions and carbon capture is also used as a tool to achieve net-zero carbon emission (Brett, 2021).

IATA had introduced a strategy in 2009, which addresses climate change, and one base of the strategy was already then, to adopt global carbon offsetting scheme for the whole industry. Offsetting the emissions has been considered somewhat futile way to reduce the emissions, because not all offsets were credible, but in aviation industry offsetting schemes are governed by the Civil Aviation Organization (VRR, 2020; Brett, 2021).

8.3 Hydrogen powered planes cutting industry’s emissions

Though hydrogen powered aircrafts are not likely to become industry norm in near future, hydrogen is gaining traction as a sustainable fuel option for aviation. The planes using hydrogen as power source would only emit water, and would advance the industry’s efforts to cut emissions, but there are still significant challenges to overcame to make this a reality (EU Commission b., 2020)

The most important components in a hydrogen aircraft are tanks for hydrogen, fuel system, fuel cells and hydrogen direct-burning turbines. Hydrogen and fuel cell technology has developed significantly in the last decades. While hydrogen can be stored in pressurized gas form, liquid form is more suitable for aviation as liquid hydrogen storage tanks are lighter and require less space than tanks for gaseous hydrogen, but compared to kerosene, liquid hydrogen tanks are four times bigger. Cryogenic cooling down to 20 degrees Kelvin is required to liquid hydrogen, and these temperatures must be handled by fuel system to distribute, feeding and vaporization to the fuel cells or turbines. In fuel cell powered aircraft, hydrogen converted to electricity drives electric motor, fan or propeller. Adding for example battery as an energy storage to this system, fast loading of the system can be better ensured. In hydrogen combustion airplanes, hydrogen is burned directly in a turbine to create thrust. To increase efficiency compared to conventional engines, cryogenic cooling of the fuel is used (McKinsey & Company, 2020: 25).

To realize hydrogen powered aviation, infrastructure for refuelling and transporting hydrogen must be developed so that planes can be refuelled on runways. Furthermore, storing technologies in planes need to be advanced and redesigning plane interiors is required to integrate necessary systems to be able to power planes with hydrogen. By year 2035 it could be possible to power commercial passenger aircrafts, which could fly up to 3,000 kilometres with hydrogen and by the 2040 onwards range of flight could already be up to 7,000 kilometres, according to the hydrogen-powered aviation report released in 2020 (EU Commission b., 2020).

8.4 COVID-19 effects on air freight

Commercial flights and air passenger traffic was mostly affected by the COVID-19 pandemic spreading through the world. Restrictions imposed on travelling caused commercial flights to reduce drastically, and April 2020 there were up to 75 percent fewer commercial flights globally and 98 percent reduction on international passenger demand compared to April 2019. The impacts on air cargo have been less severe, as demand had fell by 18 percent in June 2020 compared to June 2019. In April 2020 demand had fell up to 28 percent, but due to a vital role in the rapid transport of goods, air freight has not suffered such drastic reduction as commercial flights (IEA, 2020).

As passenger flights were drastically reduced, international cargo had approximately 70 percent less belly capacity in June 2020 compared to previous year. This affected negatively to aviation industry's efficiency because share of cargo in total air traffic increased, but cargo aircrafts are usually older and thus less efficient than passenger planes. Due to reduced belly capacity, surge of cargo-only operations was seen in the spring of 2020, where modified passenger aircraft offered cargo transportation with less space than regular cargo aircrafts, resulting in low fuel efficiency levels (IEA, 2020).

Silver lining for whole aviation industry's energy efficiency has been accelerated retirement of ageing and uneconomical aircrafts due to the lower demand in long-distance travel. More than 550 older, less efficient aircraft have been retired and will probably never fly again (IEA, 2020).

8.5 Conclusion on air freight

European Commissions Green Deal and ICAO's CORSIA has set reduction targets for aviation industry to reduce their emissions globally. By the year 2050 aviation is aimed to be climate neutral. These market-based measures have already decreased emissions significantly, but due to the fast passed growth in the industry, aviation is still huge contributor to carbon dioxide emissions in global scale (EU Commission n.d.d).

Cargo sector in aviation is leading the way to carbon reduction, encouraged by their shipper's which have become more environmentally conscious over the years. Sustainable aviation fuel (SAF) is considered the best medium-term option for reducing the emissions, but for SAF to become the powering force in aviation, production would need to be increased significantly and it would require costly investments and would face competition for raw materials from other sectors (Brett, D., 2021, Rucinski, T., et. al., 2021).

In the future, hydrogen is considered to be feasible option in powering aircrafts, but significant challenges need to be overcome to make hydrogen powered aviation a reality. As liquid hydrogen requires more storage base than kerosine used today and would require cryogenic cooling down to 20 degrees Kelvin. The pipes, valves and compressors in aircrafts would need to be able to handle these temperatures, and leakage of material be avoided (EU Commission b., 2020, McKinsey & Company, 2020:25)

9 Conclusion

The purpose of this research was to gain more knowledge about the ways in which greener transportation is implemented for different transportation modes in the future, and what measures have been already taken to improve energy efficiency in fast paced logistic industry, where increased scale of operations is outpacing the benefits received from technological solutions, which have made transportation more energy efficient.

Though transportation operators across the different industries have realized the benefits of greener logistics operations, reduction in global emissions on logistics activities will require policy makers and governments input and commitment to tackle greenhouse gas emissions. Holistic approach between transport modes could be considered more widely because by improving multimodal transport availability and information sharing and integration, supply chains could be constructed more efficiently and sustainable ways.

The author of this thesis was mainly considering the greener options for different freight modes, road, sea, rail and air freight and did not consider how planning of city logistics could beneficiate the greening efforts of overall transportation industry. Furthermore, current legislation of most countries does not approve drones to be used as last mile deliveries, but in the future, this may also be a possibility to decrease road transport and congestion in cities and reduce greenhouse gas emissions.

To conclude, transportation service operators are facing pressures to transition to ever greener transportation options. Electric vehicles, slow steaming, improved usage of rail freight operations and more energy efficient airplanes are already the new norm of the industry, but to reach the reduction targets set by for example European Commission by 2050, new innovations and technological improvements such as hydrogen powered vehicles in all transportation modes, and ICT-systems must be implemented in wider scale than is possible at this time. Commitment to the reduction targets is needed throughout the industry and with the assistance of governments and policy makers, as greener transport operations cannot be achieved by just the transportation sector alone.

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