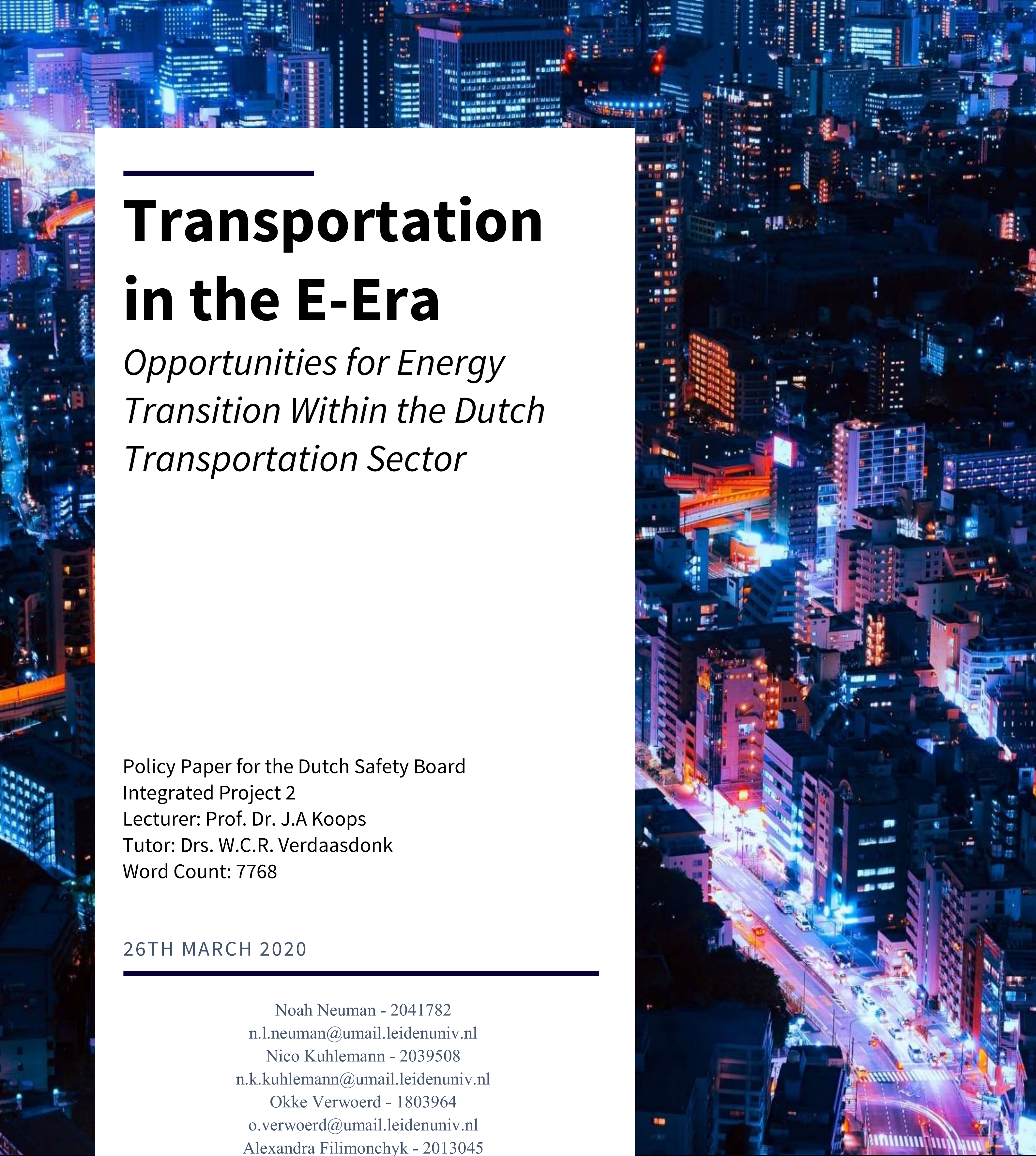

Transportation in the E-Era

Opportunities for Energy Transition Within the Dutch Transportation Sector

Policy Paper for the Dutch Safety Board
Integrated Project 2
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Executive Summary

This paper is written by order of the Dutch Safety Board with the assignment to explore potential safety hazards that are related to the emerging climate change and energy transition. The focus of this policy paper lies on the electrification of transportation vehicles. The purpose of this policy paper is to, first off all, outline the hazards and safety risks that come with the electrification of vehicles and secondly, to provide the Dutch Safety Board with problems that need to be investigated in order to maximize possible safety gains in the transition to electric vehicles.

The electrification of vehicles has potential risks. First off, electric vehicles use lithium batteries as their source of power and these come with their own threats and dangers. The main problem with the lithium batteries is that they are combustible. Also when a fire ignites in an electric vehicle it is hard to extinguish because of the enclosement of the battery pack and the high amount of water that is needed.

Besides the risk of the batteries in electric vehicles causing fires, there are other potential dangers as well. First of all, the heavier weight of E-bikes leads to higher chances of incidents occurring. Secondly, the higher speeds that can be achieved by E-bikes can result in more serious injuries in case of a crash. Also other road users may not be prepared for the higher speeds of E-bikes, resulting in higher risks at intersections. Lastly, because electric cars are powered by electric batteries they hardly make any sound compared to other cars. Because of this reduced amount of sound other road users may not always notice these electric cars, therefore, resulting in higher risks on the road .

Lastly, the increasing demand of electric vehicles will have an effect on the power grid. The higher amount of electricity that will be needed to charge all these electric vehicles could result in voltage imbalances, power losses or cascading failure.

To mitigate these problems multiple policy options will be explored in two main fields of interest. The first one being personal safety hazards connected to the electrification of the transport sector in the Netherlands. This is further broken down into different forms of transportation (electric cars, electric bikes, public transport and aviation). The second field of

interest is the impact of electrical vehicles on the electrical grid. Based on the criteria of the Dutch Safety Board we recommend research into the causes of battery fires in electric vehicles this should be followed by a research into the effective education and awareness of fire fighters in order to effectively respond to electric vehicle fires. Furthermore, we recommend the research into the perception of these new electric vehicles in traffic with a special focus on the speed at road crossings for electric bicycles and a special focus on the lower noise levels for electric cars as these issues are specific to these types of transport. This research would serve as a basis for further policy that optimizes safety in traffic. For public transport there are no specific different focuses as the risks are similar to those of regular cars. In the future there might be an increase of electric planes but for now we recommend not to investigate the safety of electric planes as this falls outside of the 5 year scope of the Dutch Safety Board. Considering the safety of the electrical grid in the Netherlands we recommend research into the probability of an overload of the power grid caused by the simultaneous charging of electric vehicles. Based on this research the risk of blackouts happening can be mapped and limiting policy restrictions can be put in place to minimize the risk of a blackout.

Introduction

The earth is heating up; there is no way around it anymore as the Netherlands have been reaching new heat records every year (Nu.nl, 29 December 2019). Extreme weather events, heat waves, glacier retreat and the rising sea levels are just some examples of global warming effects that are currently affecting societies all over the world (Misra, Shukla & Verma, 2017). According to scientists, the primary cause of global warming could be attributed to extensive Carbon Dioxide (CO_2) emissions that derive from burning fossil fuels. People have been changing the composition of gases in the atmosphere greatly since the beginning of the Industrial Revolution. CO_2, a usually very important component of our atmosphere, has increased enormously over the past few decades (Yakir, 2011). This results in global warming as CO_2 and other pollutants collect in the atmosphere and absorb the heat of the sun that bounces off the earth. The heat and radiation of the sun would usually escape back into space, but CO_2 and other polluting gases have been blocking the heat from escaping earth, resulting in a greenhouse effect (Thacker & Sinatra, 2019).

Current debate on global warming has focussed attention on reducing the emission of greenhouse gases into the atmosphere. Governments across the globe are actively trying to implement policies that reduce CO2 emissions to combat climate change. Likewise, the Dutch government has laid down a climate policy that has the goal of reducing CO2 emissions by 49% by 2030 and 95% by 2050 (Government of the Netherlands, n.d.). Moreover, a trend of reducing your Carbon footprint is set in motion amongst the Dutch population. One of the most noticeable trends in reducing CO2 emission efforts is the rise in electric cars amongst consumers; the Tesla Model S has been the best-selling car in the Netherlands for the past two years, according to Statistics Netherlands (2019). Furthermore, Statistics Netherlands reports that the number of electric cars has been on the rise for years and that the amount of fully electric vehicles (FEVs) has doubled by January 2019. 45 thousand FEVs have been recorded on the road on 1 January 2019, twice the number recorded one year previously (2019). There is no doubt that this increase is linked to awareness and fear about climate change amongst the population, as electric vehicles (EVs) are seen as a potential green replacement for the conventional combustion engine cars, due to their low Carbon emissions (Bak-Jensen & Pillai, 2010; Erdemir & Holmberg, 2019). As a matter of fact, the technology to electrify 72.3% of the transport sector within the EU exists today (Dominković et al., 2018).

However, certain risks need to be taken into consideration that will tag along with such turbulent developments in energy transition. The Dutch energy sector is facing a big shift towards a greener and sustainable future, but the simultaneous rise of EVs is raising concerns about what implications this will have for the Dutch power grids. This concern is due to the fact that the electricity consumption of an FEV per day is comparable to that of a single household of four (Dharmakeerthi, Nadarajah & Saha, 2011). The drastic increase in electricity demand in a short amount of time will have a huge impact on the power grids, as they are not built to compete with the pace of our current energy consumption (Darabi & Ferdowsi, 2011). Moreover, this is an issue that is occuring in the Netherlands already; multiple Dutch newspapers have been reporting that Amsterdam has to reduce the power over electric charging stations between 6PM and 9PM to prevent a blackout in the city (Veldhuizen, 6 March, 2020; Voermans, 2020).

In light of current climate change developments and policies, the Dutch Safety Board (DSB) has given us the assignment of exploring potential safety hazards that tag along with emerging climate change- and energy transition issues. Therefore, this paper seeks to clearly outline the hazards and safety risks that surround the electrification of transportation vehicles.

In addition, this paper hopes to provide the DSB with interesting issues to investigate in order to explore potential safety gains in the transitioning to electric vehicles. The focus of this paper will be on electrified transportation vehicles from a consumer point of view. This direction was chosen, because we believe that the population of the Netherlands will be impacted the most by the eventual safety risks that tag along with the transition to electric transportation. We have made use of newspaper-, academic journal- and think tank articles in order to investigate potential risks in the electrification of the transport sector.

In the following paragraphs a problem analysis will be given. This section will focus on the subtopics of lithium batteries, e-bikes, electric cars and power grid overload. Furthermore, this paper will provide an additional problem analysis that expands on future safety hazards. This additional analysis includes the subtopics of public transport and aviation. Next, this paper will dive into the criteria on which the policy recommendations of this paper are based. Lastly, this paper will present the policy options and summarize our findings in the conclusion.

Problem Analysis

The following analysis shall examine the potential risks of emerging low-emission technologies. The analysis shall include an examination of lithium-ion batteries which are found within electrical vehicles. The electrification of vehicles such as e-bikes and electric cars produce their own safety challenges which will be prevalent in the future, as we see an increase in energy demand and electrical vehicle usage. This paper shall examine how these safety challenges may impact individual safety. The analysis shall conclude with an investigation on how the electrification of the transport sector will impact the power grid.

Problem Analysis: Individual Safety Hazards

Lithium Batteries

As was mentioned in the introduction, people in the Netherlands are switching to electric vehicles in order to save the environment because of their low carbon emissions (Bak-Jensen & Pillai, 2010; Erdemir & Holmberg, 2019). Electric vehicles have a low carbon emission because they do not require a combustion engine for power, instead they use electric batteries as their source of power (Union of Concerned Scientists, 2018). However, these electric batteries have their own threats and dangers (Lazarenko et al., 2018).

The main flaw the lithium battery, the type of battery that is used in electric vehicles, has is that it is combustible. Tests by Lazarenko et al. showed that the batteries can cause an irreversible thermal reaction, resulting in the release of flammable and toxic gases and in some cases even an explosion (2018). This irreversible thermal reaction can be caused by a disturbance to the battery's stable mode of work (Lazarenko et al., 2018). Other causes of self-ignition include short-circuits, errors in the powertrain design: for example the use of a wrong type of cable, natural disasters: floods can cause short-circuits that may lead to ignition, or road accidents: accidents can physically damage the cells within the battery pack, resulting in a short-circuit (Lebowski, 2017).

When a lithium battery in an electric vehicle ignites a fire, it differs from a normal fire in a few ways. Firstly, the spreading fire cannot be controlled by normal carryable extinguishers. Secondly, the way in which electric vehicles are designed enclose the main components, including the battery pack, within the body of the vehicle. When a fire occurs it is, first of all, hard to reach and secondly only noticed at a very developed stage due to the enclosement (Lebowski, 2017). Another problem with fires in electric vehicles is that the fire department and rescue workers do not always have the right equipment or training to respond correctly to these types of fires. Results of tests by Lazarenko et al. (2018) show that the amount of water needed to extinguish a fire in an electric vehicle can get up to 6000 litres. Some fire trucks do not even have the capacity to hold this amount of water, therefore, making it difficult for the fire department to extinguish such a fire. Electric vehicles also have different types of batteries and different types of designs. This is also an issue for the fire department and rescue workers, because different types of batteries require different types of extinguishers and different types of designs require different types of approaches for rescue workers (Lazarenko et al., 2018).

In short, lithium batteries show their own dangers and challenges. Not only could the user of the car be impacted by dangers, such as self-ignition and a thermal reaction, but also first respondents and rescue workers are impacted by the unique approaches that have to be taken into account when trying to extinguish a battery fire. The next paragraph will dive further into the potential individual safety hazards that EVs can pose on the population of the Netherlands.

E-Bikes

For the past 20 years there has been a constant rise in E-bike sales. Especially in the Netherlands there has been a high demand for e-bikes and currently it is one of the largest E-bike markets in the world (Fishman & Cherry, 2016). When looking at the safety of E-bikes there are two main points that should be focused on. The first is the technical issues that arise from the e-bikes design. E-bikes are between 10 and 15 kilograms heavier than regular bikes, due to added motor and battery pack (Van Boggelen et al., 2013). This added weight leads to higher chances of falling or other types of accidents when mounting, dismounting or manoeuvring at low speeds (Kooijman et al., 2011). In addition, as mentioned previously, the lithium batteries of the e-bike can cause a fire hazard when improperly used (Hung & Lin, 2020). Both of these hazards are inherently linked to the design and technical characteristics of the e-bikes. Considering the development of technology, these problems will most likely get smaller over time as newer bikes tend to be lighter and have safer batteries.

The second safety hazard is linked to usage of the e-bike in traffic. Mainly the characteristics of the e-bike users, but also the perception of e-bikers by other traffic users, can lead to dangerous situations and possible accidents (Evan, 2004). When looking at the demographics of the e-bike users, there is an overrepresentation of the elderly. The elderly are more likely to sustain more serious injuries from accidents compared to younger people (Li et al, 2003). The weaker physical state of the elderly, combined with the heavier bikes, leads to dangerous situations at lower speeds. Especially in areas densely populated by the elderly, there is a higher risk of one sided accidents with a higher impact due to the higher likelihood of serious injury.
Other road users are not prepared for the higher speeds of e-bikes creating more risks at intersections where the different kinds of traffic meet. Inexperience of the rider leads to risk taking behaviour. Guo et al. (2014) showed that there are differences in risk taking behaviour when comparing e-bikers to regular cyclists. These new behaviours coupled with the relatively new introduction of e-bikes in traffic makes it hard for current drivers to assess the driving behaviours of e-bikers at road crossings (Petzoldt et al., 2017). At road crossings e-bikes and other motorized traffic meet. The risk taking behaviour of the e-bikers coupled with the inexperience of other road users with the speed of e-bikes leads to an increased risk of accidents.

Put differently, e-bike hazards can be linked to design characteristics and behaviour of e-bike users in traffic. The weight of the bikes often leads to all sorts of accidents during dismounting or manoeuvring at low speeds. Furthermore, e-bike users tend to take higher risks in traffic, which could lead to an increase in traffic accidents. Not only electric bikes can pose a danger to traffic participants. The following paragraph will dive into specific traffic situations to discuss how electric cars pose a hazard on traffic participants as well.

Electric Cars

E-Bikes are not the only new EVs that can have an impact on driving behaviours and traffic, since the electric cars also come with some caveats. Due to the cars being powered by electric motors, rather than combustion engines, they produce almost no sound compared to their counterparts. The reduction of car noise emissions could be seen as positive, however it also creates a potential safety hazard. Due to the quietness of these electric cars, mainly when driving at lower speeds, pedestrians and other traffic participants have struggles with hearing the incoming electric cars (Agterberg et al., 2016). Traffic participants such as cyclists and pedestrians, sometimes rely on these traffic-related sounds made by conventional cars, in order to become aware of an approaching car (Stelling-Kończak, Hagenzieker, & Wee, 2015). Therefore, the “silent killers” as the electric cars are called (Wright, 2019), can have a significant impact on road users that rely on auditory information as one of the methods of noticing oncoming vehicles. This impact on traffic awareness can lead to an increase of road accidents. Particularly when vision is partially obscured, cyclists and pedestrians heavily rely on auditory information of incoming cars (Agtererg et al., 2016). Therefore, the safety hazards of quiet FEVs need to be taken into consideration before this technology is implemented on a larger scale.

Having explored the individual safety issues that EVs present, this paper will dive into a bigger and more overarching EV issue. The next few paragraphs below will discuss how the electrification of the transport sector could seriously impact the Dutch population as a whole.

Problem Analysis: Overloaded Power Grid

Electric vehicles are more in demand than ever; the Tesla Model S has been the best-selling car in the Netherlands in 2018 and 2019 (Statistics Netherlands, 2019). According to Statistics Netherlands, the amount of FEVs has been on the rise for years in the Netherlands and is expected to grow only further. Moreover, the number of FEVs on the road has doubled since 2019; approximately 45 thousand FEVs could be registered on 1 January 2019. This is twice the number that has been recorded on 1 January 2018 (Statistics Netherlands, 2019). The rapid growth of this striking trend is undoubtedly linked to the low Carbon emissions of FEVs. People have gained worldwide interest in electric cars as they are seen as a potential solution to the reduction of CO2 emissions in the transport sector (Bak-Jensen & Pillai, 2010; Erdemir & Holmberg, 2019).

However, certain risks tag along with the turbulent transition from conventional combustion engine cars to fully electric vehicles. The Dutch energy sector is facing potentially big implications due to the continuous rise of FEVs. The rapid growth of electric vehicles is currently raising concerns about what implications this will have on the Dutch power grids. The reason for that is, in order to drive your electric car, it needs to be charged as well. Switching to electric vehicles will pose a huge pressure on the electric power grids in the Netherlands as the current power grids are not built to keep up with maximum synchronized electricity consumption, such as collectively charging an electric car after work (Bayram, 2017).

The current increase in electricity demand, with the rising popularity of FEVs, is often just approximately a few percent. It does not sound like much, but it does make a huge difference in new power generation capacity for electrical power grids. Usually, an electricity demand increase of a few percent would not become an issue for a power grid, if spread out over an entire day (Darabi & Ferdowsi, 2011; Dharmakeerthi, Nadarajah & Saha, 2011). The increase of electricity demand, due to FEVs entering the system, is particularly challenging because power grid capacity is built around demand diversity, rather than being able to carry synchronized maximum demands (Darabi & Ferdowsi, 2011). To visualise this, imagine if everyone on your street decided to switch on their washing machine at the same time. This would cause the local power substation to overload and go dark in an instant, as it cannot handle synchronized maximum electricity demand. However everyone turning on their washing machine at the same time is a very unlikely scenario. Power grids are built around demand diversity, rather than synchronized maximum demand, as it saves infrastructure costs; everyone turning on their washing machine at the same time is a very unlikely scenario and building a power grid around such scenarios would not be efficient (Bayram, 2017). However, everyone charging their electric vehicles is not an unlikely scenario within ten years, or even now.

Moreover, this is a scenario that is currently happening in Dutch cities already; Dutch newspapers have been reporting that Amsterdam has to reduce the power of electric charging stations between 6PM and 9PM to prevent a blackout. According to Algemeen Dagblad (AD), electricity demands generally rise around 6PM, as everyone comes home from work. This is also the time at which FEV owners charge their cars, creating an unintentional drop in voltage and an overloaded power grid (Alkemade, Eising & Onna, 2014; Voermans, 2020). Power grids are overloading, because the electricity consumption of a charging FEV per day is comparable that of a single household of four (Dharmakeerthi, Nadarajah & Saha, 2011). Put differently, the rise in electricity demand is a current issue that is relevant for large cities, like Amsterdam. Combined with the ambitious Dutch climate change policy change by 2030, this will sculpt enormous implications for energy supply in the Netherlands.

Furthermore, a UK analysis of 2017 substantiates the risks that FEVs will pose on the electricity power grids all over the world. Green Alliance (2017) has researched how consumer choices, like purchasing FEVs, would impact the UK energy system. The research concluded that 900 FEVs entering the energy system of a town with a population of 6,800 could lead to an overloaded power grid and brownouts throughout the town (Green Alliance, 2017). A brownout, a partial blackout in a city, is typically caused by a drop in voltage supply by, for instance, everyone turning on their washing machine at the same time.

Besides the growing number of FEV's, current trends show a steady increase in e-bike sales and usage which leads to a higher energy demand (Fishman and Cherry, 2016). Although electric bicycles have a relatively small battery pack that can be charged from a regular wall socket, they do add to the strain on the electric grid. However, the net impact of e-bike use is bound to the previous form of transportation that is substituted. When switching from non-electric modes of transport to electric modes, the impact of the rising number of e-bikes has a net positive impact on the already limited power grid. This is due to the fact that the previous form of transportation had no demand for electric energy. When changing from other forms of electric transport (e-cars, trams and trains) the net impact on the power grid is significantly lower as the efficiency of electric bikes is very high (Mutze and Tan, 2005). Meaning that e-bikes are both a problem and solution to an overloaded power grid depending on their usage. Considering the current division of electric modes of transportation and combustion engine transportation there is a higher likelihood of the first scenario happening where electric bikes replace modes of transportation that are powered by fossil fuels. Therefore, the growing number of electric bikes would create a larger energy demand and thus more strain on the electrical grid.

Furthermore, higher electricity consumption has a wide variety of impacts on the power grid; voltage imbalances, power losses and overall instability could result in a cascading failure. Power outages throughout a whole city could occur and it goes without saying that this would be disastrous to large cities. Blackouts would lead to indirect casualties amongst the population of the Netherlands, thus making the issue of an overloaded power grid due to FEVs a lot more vital to investigate (Dharmakeerthi, Nadarajah & Saha, 2011).

In short, the electrification of transportation methods will pose a huge impact on the Dutch power grids. The reason for this lies in the infrastructure of current power grids; they are not built to keep up with higher electricity demands and maximum synchronized electricity consumption. The overloading of a power grid could have a blackout as consequence, which is without doubt disastrous to large cities in the Netherlands. The next section of this paper will provide an additional problem analysis that will dive deeper into the safety hazards previously discussed. In addition, this section of the paper will present the safety hazards of an aviation technology that is not utilized yet, but will be in the future.

Problem Analysis: Additional Safety Hazards

Public Transportation

As stated, climate change and its impact has resulted in the emergence of new security challenges. The state of the climate crisis expresses the drastic need for carbon emission reduction strategies. The emergence of low-emission technologies such as electric cars, e-bikes and their lithium batteries, have been techniques to help combat climate change through energy transition (Clairand et al, 2019). The success of these technologies has caused them to be adopted within the public transportation sector. This may be seen in the form of electric trains, hybrid buses, and more environmentally friendly taxi services (Clairand et al, 2019). However, these low-emission changes within transportation have had their own safety implications, and with the adoption of such technologies in the public transportation sector, their safety implications may be transferred as well.

As mentioned above, lithium batteries have their own safety implications. Rechargeable lithium-ion batteries are the focus, as these are found within electric vehicles (Department of Safety, 2020). The dangers of these batteries are that they contain extremely flammable electrolytes (Department of Safety, 2020). This is problematic as there have been many cases of lithium battery fires. Notably, in 2013 a number of Tesla Model S electric cars caught fire after sustaining damage (Kong et al, 2018). The adoption of lithium-ion batteries within the public transportation sector could have severe implications such as fires, explosions and other forms of hazards may threaten individual safety on a large scale. Due to the existing hazards with lithium-ion batteries, an investigation into potential safety gains within this technology may be of interest to the Dutch Safety Board. An investigation or research into the flammability of this technology may help increase the safety of such technologies, through the adoption of flame-retardant materials around the batteries.

Extinguishing electrical vehicles that have lithium-ion batteries has further safety concerns which should be closely investigated before the transition from carbon to electric within the public transportation sector. In order to successfully extinguish such fires, the fire needs to be extinguished and the temperature of the lithium-ion battery needs to be reduced (Kong et al, 2018). The batteries need to be cooled, if not there is a chance the battery might reignite, leading to another fire (Kong et al, 2018). In addition, there is an electrical hazard when extinguishing electrical vehicles and their batteries which may affect the individual safety of people and fire fighters (Kong et al, 2018). With all of these implications, it may be valuable for the Dutch Safety Board to investigate the inadequate knowledge on the lithium-ion battery flammability and examine more effective measures for extinguishing electrical vehicles fire before the gradual electrification of the public transportation sector.

The electrification of the transportation sector and the public transport sector may produce environmentally beneficial changes. However, it is important to note that introducing a large number of electrical vehicles could raise implications in regards to the power grid of any city or state (Clairand et al, 2019). The safety concern is, with the flooding of electrical vehicles within the vehicle market and transport sector, will the current electrical infrastructure or power grids be able to facilitate the increased demand for energy. Especially, with an increased demand coming from the public transportation sector. According to some studies, there could be many safety implications towards the power grid. These safety concerns come in the form of voltage imbalances, increased frequency of blackouts and brownouts, and equipment overloads (Dharmakeerthi et al, 2011). In addition, another study showed that the recharging of electrical vehicles puts pressure on the distribution systems of power grids. With an integration of thirty percent of charging electric vehicles to the power grid, there is roughly ten percent voltage deviation (Clairand et al, 2019). Due to power grids being critical infrastructures for societies, ensuring the prolonged safety of such systems is a valuable opportunity for research by the Dutch Safety Board.

Aviation

In 2019, the aviation sector was responsible for 12% of CO2 emissions within the entire transport sector (ATAG, 2020a). Carbon emissions produced by the aviation industry is, however, expected to increase between 300 and 700% by 2050 (European Commission, 2019), mainly due to the accumulating rise of air travel passengers every year (ICAO, 2019a). The aviation industry, and the companies operating within it, generally have been known to be committed to climate action, with the long term goal in mind of reducing its carbon footprint (ATAG, 2019). Because the aviation industry has limited options in reducing its CO2 emissions (Chiaramonti, 2018), their primary task is to transition towards more sustainable and cleaner forms of energy which can replace standard fossil fuel.

One of these new forms of energy that can power a plane, is electricity, which would naturally remove the carbon emitted from propulsion of airplanes, entirely (Han, Yu, & Kim, 2019). Multiple electric planes are already in operation (Dowling, 2018), and a large amount of aviation projects are in progress in the case of fully electric powered airplanes, or hybrid planes (Airbus, 2019) These electrical aviation projects however, are highly unlikely to completely replace the common jet fuel planes within the near future (Walker, 2019). The batteries that are used to power the electric planes have a relatively low-energy density when compared to using fossil fuel as a power source. This means that these batteries are insufficient in powering large aircrafts, used for medium-to-long-haul flights, and could therefore only be employed for short-haul flights. Moreover, these batteries can form a significant weight issue in relation to these larger aircrafts, and in order to make them safe and operational, major investments would need to be made in designing new planes, and changing the infrastructure of the airports (Kivits, Charles, & Ryan, 2010). Economic life cycles of aircraft models run for a long time, and in addition to the high research & development costs within the sector (Kim, Lee, & Ahn, 2019), aircraft manufacturers are highly unlikely to drastically replace all aircraft models in the next couple of years. Additionally, these aircraft manufacturers are more focused on improving their current designs and systems, because in regards to traveling by air, there is not a better alternative form of travel that comes close to the affordability and quickness of air travel (Walker, 2019).

Because of all these difficulties regarding electric planes, there is a superior short-term solution within the aviation sector, Sustainable Aviation Fuels (SAFs). SAFs refer to all the sustainable fuels that are an alternative to the conventional fossil fuels, which can either be sustainable biofuels or sustainable non-biological fuels (ATAG, 2017). In order to help the aviation industry with their goal of achieving their climate targets, SAFs have the ability to reduce the CO2 emissions up to 80% of the current aircraft models (ATAG, 2020a), since the SAFs can be used as ‘drop in’ fuel alternative to the kerosene-jet fuel aircraft models (Energy Transitions Commission, 2018).

Concerning the safety hazards of electric planes, the batteries used to power an electric plane are mainly lithium-based batteries and therefore would pose the same safety threats as the lithium-based batteries used cars and e-bikes, such as the threat of explosion and catching fire (Han, Yu, & Kim, 2019), as well as the potential threat to health and environment, due to the toxic and corrosive materials (ICAO, 2019b).

Furthermore, in regards to other safety hazards of electric planes, there is not a lot of data available concerning accidents and incidents that have taken place with electric planes. As of now there has only been one electrical plane that has crashed, and this accident is still under investigation (DSB, 2018). Due to this lack of data, it cannot be concluded that electric planes have more additional safety hazards than regular jet fuel planes, on top of the safety threats of the batteries.

Criteria

Now that the problem has been analysed, the criteria on which the policy options are based need to be discussed. The policy options this paper recommends are based on the official research protocol of the Dutch Safety Board, as can be found on their website.

The Dutch Safety Board conducts investigations into subjects because of one or more concrete incidents, with the goal of finding out the underlying causes of the incident. Therefore, the conducted research exceeds in value, because it no longer focuses on a single case (Onderzoeks-protocol, 2020, p.6). If there are other institutions or companies that can research a specific incident, the Dutch Safety Board does not conduct the research in order to maximize everyone's capabilities (Onderzoeks-protocol, 2020, p.6). There are a few types of incidents the Dutch Safety Board is obliged to conduct research into. These mandatory investigations are laid down in law and originate from international treaties . The types of incidents that are mandatory to investigate consist of: aviation incidents, shipping incidents, railway incidents and industrial incidents (Onderzoeks-protocol, 2020, p.11). Another aspect the Dutch Safety Board has to take into account while selecting incidents to investigate is that it has a limited capacity of only 70 people working there in total. Therefore, not all incidents can be investigated and choices need to be made (Onderzoeks-protocol, 2020, p.6).

These choices are made based on a series of questions. The investigation is only conducted if the answer to at least one of the questions is positive. The questions are as follows. Is there a large societal commotion? Are civilians exposed to risks caused by others? Can the Board bring an end to the complicated problem? Is the DSB the right institution to investigate the incident? Is the knowledge that is needed to conduct the investigation available? (Onderzoeks-protocol, 2020, p.6-7) These are the questions that form the basis of the policy options that follow next.

Keeping the criteria of the DSB in mind, the policy paper itself is bound to a set of specific criteria to come to a concrete policy recommendation. The first one being the realm of transportation this paper is limited foremost to problems related to transportation of people in the Netherlands. This criteria is further specified as the paper examines consumer focused (bottom up) energy transitions in the transport sector. The second criteria is related to the feasibility of the policy option. Policy options should be low cost high impact for maximum safety gains. Lastly, the research and policy options should have a direct (short term) effect on the safety of the Dutch transportation system.

Policy Recommendations

Lithium Batteries

The use of lithium batteries in electric vehicles comes with threats and dangers (Lazarenko et al., 2018). The main problem with the lithium batteries consists of two aspects. Firstly, the battery packs in these electric vehicles can self-ignite due to multiple causes. Secondly, once a fire in an electric vehicle occurs it is both very difficult and dangerous to extinguish it.

When looking back at the criteria from the Dutch Safety Board that decide whether an investigation will be conducted, this problem needs to be investigated. The reason for this is that the problem has a positive answer to at least one of three criteria questions. Namely, “Are civilians exposed to the risk caused by others?” and “Is there a large societal commotion?” (Onderzoeks-protocol, 2020, p.6-7). Since more people are using electric vehicles the risk of a fire occurring in someone’s electric vehicle has the possibility of harming other citizens. Also, because more people are using these electric vehicles, the dangers that come with this use have an impact on society. The other specific criteria for the policy how to options in this paper are discussed after the policy recommendation for this problem.

The policy recommendation this paper offers in order to combat this problem is to do research into how to effectively educate and train fire fighters and other rescue workers in order for them to effectively respond to fires in electric vehicles in a safe manner. This research and the training programs should consist of the multiple aspects to the problem. First of all, research into how to extinguish fires in electric vehicles. Secondly, research in the different types of electric vehicles and their different kinds of batteries. Thirdly, training on how to use different types of equipment needed to extinguish the fires. Lastly, research into the risk of electric shock and poisonous gases that occurs while extinguishing fires in electric vehicles.
Returning to the specific criteria for the policy options in this paper, this policy option is viable. First off, it is within the realm of transportation. Secondly, the research should result in

maximum safety gains, because both the knowledge of extinguishing fires in electric vehicles and the equipment needed to extinguish the fires will be available. Also because of this, the policy option has a short term effect on the safety of the Dutch transportation system.

E-Bikes

The constant increase of electric bicycles in traffic brings about multiple problems. The first one being the risk of falling or causing a traffic accident when mounting, dismounting or manoeuvring at low speeds. To mitigate this problem we believe research into the infrastructure of areas densely populated by e-bike owners is beneficial and would give insights into the causes of e-bike crashes. The second problem of e-bikes is the perception of these new and faster modes of transportation. The introduction of e-bikes on the road has led to drivers having trouble assessing the speed at which e-bikes go at crossings leading to dangerous situations. We propose research into the perception of speed of e-bikes by other road users to minimize dangerous situations and accidents happening at road crossings.

Electric Cars

Because of the recent developments concerning the increase of electric cars within the Netherlands, their quiet characteristic poses safety risks for road users that sometimes have to rely on auditory information when they need to localise oncoming traffic. Therefore we recommend doing research into the traffic awareness of road users in regards to electric cars, and look into the implications this awareness has on the overall Dutch traffic system. Through this research, we could have a better understanding of the perception and awareness of electric cars within the Dutch traffic system, and in doing so, find new ways to promote this awareness in order to reduce traffic accidents relating to this new technology.

Power Grid Hazards

This paper has explored what impacts the rise of electrical cars in the Netherlands will pose on the electric power grids. The problem analysis concluded that the rising electricity demand could damage the power grids, with blackouts as a consequence. The Netherlands are currently struggling with the increased electricity demand, due to FEVs, and this problem will rise only further. An overloaded power grid could become a potential safety hazard to the population, as blackouts will lead to casualties. Therefore, based on the analysis previously given, we feel that there is a need to investigate the impact that electric cars will have on the Dutch electricity grids.

Public Transportation

As mentioned, the benefits of the electrification of the public transportation systems would help reduce emissions and help tackle the climate crisis. However, before technologies such as electrical taxis and electrical/hybrid buses, which include lithium-ion batteries, are heavily introduced into the public transport sector, the safety challenges they produce should be addressed. Therefore, the following recommendations will focus on identifying safety gains within electrical vehicles, the lithium-ion batteries that power them, and the impact the increased energy demand on the power grid from electrical vehicles.

Due to the flammability of the lithium batteries found within electrical vehicles, and the many cases of fires and explosions due to the batteries, there are many potential safety gains which the Dutch Safety Board could investigate. We recommend research into increasing the safety of lithium batteries. This can be done by adding flame retardants to the electrolytes found within the lithium batteries (Kong et al, p.4, 2018). Research into effective flame retardants that maintain the conductivity of the electrolytes would increase the safety of the lithium batteries, and would be a good point of interest for the Dutch Safety Board.

In response to the hazards caused by the batteries such as vehicle fires and explosions, reducing the safety of public transportation, research into effectively extinguishing fires would be beneficial for the Dutch Safety Board. This would be vital if electrical and low-emission technologies equipped with the hazardous lithium batteries, will be adopted within the public transportation sector. Especially due to the fact that hazards within public transport have the potential to produce more harm to a greater number of people. Additionally, due to the potential electrical hazard of extinguishing electrical vehicle fires, fire fighters need to adopt new extinguishing methods such as carbon dioxide (Kong et al, p. 8, 2018). This would be valuable for the Dutch Safety Board if the public transport sector would be electrified, because there are currently no specific measures to effectively extinguishing vehicle fires. In fact, the National

Fire Protection Association held an investigation and concluded that there is a lack of knowledge of the flammability of the lithium batteries and unclear measures to help suppress and extinguish electrical vehicle fires (Kong et al, p. 8, 2018).

Finally, if the efficiency and safety of lithium batteries and electrical cars are increased, the popularity of electrical vehicles would lead to more electrical vehicles within the transport and public transport sector. The power grids within many cities will not be able to facilitate the heightened demand for energy, created by the charging of electric vehicles. The adoption of electrical vehicles within the public transport sector would increase the pressure on the power grid. In order to avoid voltage deviations, voltage imbalances and blackouts, the Dutch Safety Board should research into preserving the stability of the power grid in response to the electrification of the public transportation sector.

Aviation

The implementation of electric planes faces several major difficulties, such as the insufficiency of supplying enough energy for medium-to-long-haul flights, as well as the significant design and infrastructural changes that would need to be made in order to implement these new aircraft models. Because of these obstacles, the electrification of the aviation sector is unlikely to rapidly take place within the near future, in regards to commercial flights, and relates more to long term solutions of reducing CO_2 emissions. It is more likely that the aviation's energy transition will shift more towards Sustainable Aviation Fuel in the coming years, since this renewable source of energy can be used with existing aircraft models.

When taking our criteria in mind, by looking at short term policy options for the Dutch Transportation System, we feel that electrification within the aviation sector, is not recommended as a point of research in regards to short term solutions of energy transition.
Moreover, further developments within the area of safety threats of electric planes, will already be monitored by the DSB, since they are obligated to investigate aviation incidents, which would include electrical plane incidents (Onderzoeks-protocol, 2020, p.11).

Conclusion

The Main Findings

The ever-growing climate crisis has pushed for effective carbon emission reduction strategies. Climate change mitigation efforts such as the electrification of the transport sector help reduce carbon emissions and pollution levels. The adoption of electrical vehicles and their lithium batteries produce new safety challenges. These can be separated between the dangers they pose to 1. Individual safety and 2. The Power grid.

Individual safety can be affected by the emergence of these new low-emission technologies. Lithium batteries, due to their flammability, have the potential to catch on fire and explode, threatening the individual safety of electrical vehicle users. E-bikes also create new security challenges due to their weight and velocity. This is especially true for the elderly as they are more susceptible to serious damage, making them a risk group. E-bikes aren't the only electrical vehicles which produce safety challenges on the individual level. Electrical cars have reduced levels of noise pollution, this creates dangerous situations for pedestrians and cyclists who rely on sounds for awareness. Electrical cars and their lithium batteries have additional safety challenges. Electrical vehicle fires due to the flammability of the lithium batteries pose fire and electrical hazards. Extinguishing EV fires is complex as they cannot be extinguished using water, and must be extinguished using other methods, and the temperature of the batteries needs to be reduced to prevent re-ignition. All these security challenges would pose greater threats to individual safety if these technologies would be adopted into the public transportation sector as well as the aviation industry, which is also looking for more sustainable forms of energy.

With an increasing presence of electrical vehicles within the transport sector, due to their low-emissions, safety implications are raised in regards to the stability of the power grid. Due to the rechargeable lithium batteries, electrical vehicles can be plugged in and charged. However, current power grids will not be able to facilitate this growth of energy demand, such as collective recharging of electrical vehicles. This is especially true due to the fact that power grid capacity is built around demand diversity. The rise of electrical vehicles threatens the stability of power grids due to the high levels of synchronized electricity demand from charging electrical cars and e-bikes. This increase in demand has significant safety implications as it may cause an increase of voltage imbalances, blackouts, power losses and increased instability of the power grid. The popularity of electrical vehicles means they might be adopted on a greater scale within the public transportation sector. This would be problematic, as the energy demand would increase even more, putting more pressure on the stability of the power grid. There is a visible trend of the electrification of transport as a whole, not only public, so recommendations into preserving the stability of the power grid are vital.

Final Recommendations

After analysing the possible risks of the current energy transition within the transport sector in the Netherlands, the next recommendations can be made to ensure or improve a safe energy transition. The main high impact issue that was found is the rising demand of electric energy due to electrification of the transport sector. This causes an overload of the existing energy grid. We recommend the DSB to investigate the likelihood of blackouts/ brownouts happening when energy demands peak due to the simultaneous charging of electric vehicles in urban areas. These main recommendations can be split into multiple sub-parts.

- What is the max capacity of the electricity grid in urban areas?
- How many electric vehicles are used in the city/ city district?
- Is there an expected increase of electric vehicles in the city/ city district?
- Are there blackouts/ brownouts happening in areas with relatively high amounts of electric vehicles?
- What are the consequences of a blackout/brownout happening in an urban area?

If these questions get answered, areas at risk of a blackout or brownout can be identified. Creating a map of these at risk areas will add to the awareness so local governments can act to increase the peak limit of the power grid or limit the users of the grid to minimize the risk of a blackout/brownout happening.

The second main issues directly related to the electrification of the transport sector in the Netherlands are the new safety hazards electric vehicles have compared to the existing gasoline powered vehicles. The first one being the danger of battery fires in electric vehicles. Battery fires differ from normal fires as they have to be extinguished using different methods. Our recommendation to the DSB is to research the awareness of fire fighters across the country considering the different methods needed for extinguishing electrical vehicle fires. This research would give an overview of the possible at risk areas of battery fire response.

Lastly, electric vehicles have different characteristics compared to non-electric vehicles. The differences include: lower noise levels, higher speeds and faster acceleration. It takes time for the population to adjust to these new characteristics, we recommend research into the perception of electric vehicles. Considering the large scope of this recommendation it can be split into multiple categories: electric cars, electric bicycles and future changes.

Electric cars are significantly more quiet than other gasoline powered vehicles. Research has shown other traffic users do rely on auditory senses when participating in traffic. Our recommendation is to research the detectability of electric cars by other road users. Findings from this research could give useful insights whether new policy measures have to be taken to enhance awareness among road users.

Electric bicycles are faster than regular bicycles especially inexperienced riders or physically less able riders (elderly, handicapped etc.) are at a higher risk of causing accidents. Combined with the higher speed at which they go, the introduction of electric bikes on the road leads to new safety hazards. We recommend the DSB to research the speed perception of electric bikes at road crossings. Research into this topic could be used as a measurement that serves as a basis for new policy surrounding the electric bicycles in traffic.

Besides the current electrification of the transportation sector it is highly likely that other forms of transportation will be electrified in the future. The sectors of aviation and public transport have been examined and although there are steps taken in the electrification of these forms of transport we recommend to not do research into their possible safety hazards as the development of electric plains will still take time and the problems the public transport sector faces are similar to the problems electric cars have but on a smaller scale.

The climate crisis has put pressure on countries all over the world and has emphasized the need for carbon emissions reduction. The Dutch government is pushing for carbon footprint reduction strategies. One of these strategies has been the emergence of low-emission technologies through the electrification of the transportation sector. However, these technologies have their own safety implications and these should be addressed and improved upon before the complete adoption of electrified modes of transport. We recommended that the Dutch Safety Board investigates the safety challenges electrified modes of transport bring to ensure a safe and sustainable energy transition in the transportation sector.

Bibliography:

Agterberg, M., Commandeur, J., Hagenzieker, M., Stelling-Konczak, A., & Van Wee, B. (2016). Auditory localisation of conventional and electric cars: Laboratory results and implications for cycling safety. *Transportation Research Part F. Traffic Psychology and Behaviour, 41*, 227-242. Retrieved from https://www.sciencedirect.com/science/article/abs/pii/S1369847815001503

Air Transport Action Group (ATAG). (2017). *Beginner's Guide to Sustainable Aviation Fuel.* Retrieved from https://aviationbenefits.org/downloads/beginners-guide-to-sustainable-aviation-fuel/

Air Transport Action Group (ATAG). (2019). *Over 200,000 commercial flights using low-carbon fuel show an energy transition is possible.* Retrieved from https://www.atag.org/component/news/?view=pressrelease&id=117

Air Transport Action Group (ATAG). (2020a). *Facts & Figures.* Retrieved from https://www.atag.org/facts-figures.html

Airbus. (2019). *E-Fan X: A giant leap towards zero-emission flight.* Retrieved from https://www.airbus.com/innovation/future-technology/electric-flight/e-fan-x.html#objective

Alkemade, F., Eising, J., & Van Onna, T. (2014). Towards smart grids: Identifying the risks that arise from the integration of energy and transport supply chains. *Applied Energy*, *123*, 448-455. Retrieved from https://www.sciencedirect.com/science/article/pii/S0306261913010167

Bak-Jensen, B., & Pillai, J.R. (2010). Impacts of electric vehicle loads on power distribution systems. *Vehicle Power and Propulsion Conference*. 1-6. Retrieved from https://www.researchgate.net/publication/224224203_Impacts_of_electric_vehicle_loads_on_power_distribution_systems

Bayram, I.S. (2017). *Plug-in Electric Vehicle Grid Integration.* Artech House power engineering series. Retrieved from http://web.a.ebscohost.com.ezproxy.leidenuniv.nl:2048/ehost/detail/detail?vid=0&si

d=bed69ebc-d18f-494a-8ad6-31d9ef77d4ce%40sessionmgr4006&bdata=JnNpdGU9ZWhvc3QtbGl2ZQ%3d%3d#AN=1825908&db=e000xww

Casey, C., Grant P.E. (2010). Fire Fighter Safety and Emergency Response for Electric Drive and Hybrid Electric Vehicles. *The Fire Protection Research Foundation,* 1-129.

Chiaramonti, D. (2019). Sustainable Aviation Fuels: The challenge of decarbonization. *Energy Procedia, 158*, 1202-1207.

Darabi, Z., & Ferdowsi, M. (2011). Aggregated Impact of Plug-in Hybrid Electric Vehicles on Electricity Demand Profile. *Transactions on Sustainable Energy, 2*(4), 501-508.

Department of Safety. (2020). The Hazards of Lithium Batteries. *Tufts University*. Retrieved from https://viceprovost.tufts.edu//ehs/files/The-Hazards-of-LithiumBatteries.pdfhttps://viceprovost.tufts.edu//ehs/files/The-Hazards-of-Lithium-Batteries.pdf

Dharmakeerthi, C.H., Mithulananthan, N., & Saha, T.K. (2011). Overview of the impacts of plug-in electric vehicles on the power grid. *2011 IEEE PES Innovative Smart Grid Technologies*, Perth, WA, 2011, pp. 1-8. DOI: 10.1109/ISGT-Asia.2011.6167115

Dominković, D., Bačeković, I., Pedersen, A., & Krajačić, G. (2018). The future of transportation in sustainable energy systems: Opportunities and barriers in a clean energy transition. *Renewable and Sustainable Energy Reviews, 82*(P2), 1823-1838.

Dowling, S. (2018). Norway's plan for a fleet of electric planes. *BBC Future.* Retrieved from https://www.bbc.com/future/article/20180814-norways-plan-for-a-fleet-of-electric-planes

Dutch Safety Board (DSB). (2018). Crash, Pipistrel Alpha Electro, close to Onstwedde, 13 October 2018. Retrieved from https://www.onderzoeksraad.nl/en/page/12366/neergestort-elektrisch-vliegtuig-13-oktober-2018-groningen

Energy Transitions Commission. (2018). ETC Sectoral Focus – Aviation. *Reaching Net-Zero Carbon Emission: Mission Possible.* Retrieved from http://www.energy-transitions.org/mission-possible

Erdemir, A., & Holmberg, K. (2019). The impact of tribology on energy use and CO2 emission globally and in combustion engine and electric cars. *Tribology International*, *135*, 389-396.

European Commission. (2019). *Reducing emissions from aviation.* Retrieved from https://ec.europa.eu/clima/policies/transport/aviation_en

Eurostat. (2019). Climate Change – Driving Forces. *Statistics Explained*. Retrieved from https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Climate_change_-_driving_forces

Evans, L., 2004. Traffic Safety. *Science Serving Society*. Bloomfield Hills, MI.

Fishman, E., & Cherry, C. (2016). E-bikes in the mainstream: reviewing a decade of research. *Transport Reviews: Cycling As Transport*, *36*(1), 72-91.

Government of the Netherlands. (n.d.). *Climate Policy.* Retrieved on 27 February 2020 from https://www.government.nl/topics/climate-change/climate-policy

Green Alliance (2017). *People power. How consumer choice is changing the UK energy system.* Retrieved on 1 March 2020 from https://www.green-alliance.org.uk/resources/People_power_how_consumer_choice_is_changing_UK_energy_system.pdf

Clairand, J.M., Guerra-Terán, P., Serrano-Guerrero, X., González-Rodríguez, M., & Escrivá-Escrivá, G. (2019). Electric Vehicles for Public Transportation in Power Systems: A Review of Methodologies. *Energies, 12*(16), 3114.

Guo, Y., Liu, P., Bai, L., Xu, C., & Chen, J. (2014). Red light running behavior of electric bicycles at signalized intersections in China. *Transportation Research Record*, *2468*(1), 28-37.

Hagenzieker, M., Stelling-Kończak, A., & Van Wee, B. (2015) Traffic Sounds and Cycling Safety: The Use of Electronic Devices by Cyclists and the Quietness of Hybrid and Electric Cars. *Transport Reviews, 35*(4), 422-444, DOI:10.1080/01441647.2015.1017750

Han, H., Yu, J., & Kim, W. (2019). An electric airplane: Assessing the effect of travelers' perceived risk, attitude, and new product knowledge. *Journal of Air Transport Management, 78*, 33-42.

Hung, N., & Lim, O. (2020). A review of history, development, design and research of electric bicycles. *Applied Energy, 260*, Applied Energy, 15 February 2020, Vol.260.

International Civil Aviation Organization (ICAO). (2019a). The World of Air Transport in 2018. *ICAO Annual Report 2018.* Retrieved from https://www.icao.int/annual-report-2018/Pages/the-world-of-air-transport-in-2018.aspx

International Civil Aviation Organization (ICAO). (2019b). Chapter 4: Electric, Hybrid, and Hydrogen Aircraft – State of Play. *Destination Green, The Next Chapter. 2019*

Environmental Report. Retrieved from https://www.icao.int/environmental-protection/Pages/innovative-fuels.aspx

Kim, Y., Lee, J., & Ahn, J. (2019). Innovation towards sustainable technologies: A socio-technical perspective on accelerating transition to aviation biofuel. *Technological Forecasting & Social Change, 145*, 317-329.

Kivits, R., Charles, M., & Ryan, N. (2010). A post-carbon aviation future: Airports and the transition to a cleaner aviation sector. *Futures, 42*(3), 199-211.

Kong, L., Li, C., Jiang, J., & Pecht, M. (2018). Li-Ion Battery Fire Hazards and Safety Strategies. *Energies, 11*(9), 2191.

Kooijman, J.D.G., Meijaard, J.P., Papadopoulos, J.M., Ruina, A., & Schwab, A.L. (2011). A bicycle can be self-stable without gyroscopic or caster effects, *Science, 332,* 339-342.

Kovácsová, N., De Winter, J., Schwab, A., Christoph, M., Twisk, D., & Hagenzieker, M. (2016). Riding performance on a conventional bicycle and a pedelec in low speed exercises: objective and subjective evaluation of middle-aged and older persons. *Transportation Research. Part F, Traffic Psychology and Behaviour, 42f*, 28.

Kroesen, M. (2017). To what extent do e-bikes substitute travel by other modes? Evidence from the Netherlands. *Transportation Research Part D: Transport and Environment, 53,* 377-387.

Lazarenko, o., Loik, V., Shtain, B., Riegert, D. (2018). Research on the Fire Hazards of Cells in Electric Car Batteries. *Safety & Fire Technology,* 108-117.

Lebkowski, A. (2017). Electric Vehicle Fire Extringuishing System. *Przeglad Elektrotechniczny, 93*, 329-332. DOI:10.15199/48.2017.01.77.

Li, G., Braver, E. R., & Chen, L. H. (2003). Fragility versus excessive crash involvement as determinants of high death rates per vehicle-mile of travel among older drivers. *Accident Analysis & Prevention*, *35*(2), 227-235.

Ma, C., Yang, D., Zhou, J., Feng, Z., & Yuan, Q. (2019). Risk riding behaviors of urban e- bikes: a literature review. *International journal of environmental research and public health*, *16*(13), 230

Misra, A., Shukla, J., & Verma, M. (2017). Effect of global warming on sea level rise: A modeling study. *Ecological Complexity*, *32*, 99-110. Retrieved from https://www.sciencedirect.com/science/article/abs/pii/S1476945X17300910

Nu.nl. (2019, 29 December). *Minitornado's en hitterecords: het Nederlandse weer in 2019.* Retrieved on 25 March 2020 from https://www.nu.nl/binnenland/6020023/minitornados-en-hitterecords-het-nederlandse-weer-in-2019.html

Onderzoeksraad Voor Veiligheid (2020). *Onderzoeks-protocol*. Retrieved on 28 of February 2020 from https://www.onderzoeksraad.nl/nl/page/12058/werkwijze-onderzoeksraad

Polakowski, K. (2018). Dangers to which electric vehicle users may be exposed and ways to prevent them. *Przegląd Elektrotechniczny*, *94*(11), 146–148. DOI:10.15199/48.2018.11.3

Quintiere, J.G., Crowley, S., Walters, R.N., Lyon, R.E., Blake, D. (2016). Fire Hazards of Lithium Batteries. *U.S. Department of Transportation Federal Aviation Administration,* 1-24.

Randall, T. (2016). Here's How Electric Cars Will Cause the Next Oil Crisis. *Bloomberg.* Retrieved on 26 of February 2020 from https://www.bloomberg.com/features/2016-ev-oil-crisis/

Statistics Netherlands. (2019, 10 May). *Aantal volledig elektrische auto's verdubbeld.* Retrieved on 25 March 2020 from https://www.cbs.nl/nl-nl/nieuws/2019/19/aantal-volledig-elektrische-auto-s-verdubbeld

Sun, P., Bisschop, R., Niu, H., & Huang, X. (2020). A review of Battery Fires in Electric Vehicles. *Fire Technology,* 1-36.

Thacker, I., & Sinatra, G.M. (2019). Visualizing the Greenhouse Effect: Restructuring Mental Models of Climate Change Through a Guided Online Simulation. *Education Sciences, 9*(1), 14. Retrieved from https://www.mdpi.com/2227-7102/9/1/14

Union of Concerned Scientists (2018, 25 Februrary). *How do Battery Electric Cars Work?.* Retrieved on 27 February 2020 from https://www.ucsusa.org/resources/how-do-battery-electric-cars-work

Veldhuizen, R. (2020, 6 March). Tesla-auto slurpt evenveel elektriciteit als tien huishoudens – Klopt dit wel? *De Volkskrant*. Retrieved on 25 March 2020 from https://www.volkskrant.nl/wetenschap/tesla-auto-slurpt-evenveel-elektriciteit-als-tien-huishoudens-klopt-dit-wel~b1a5b5f6/?referer=https%3A%2F%2Fwww.google.com%2F

Voermans, T. (2020, 13 February). Vermogen elektrische laadpalen omlaag, anders stad 'op zwart'. *Algemeen Dagblad.* Retrieved on 13 February 2020 from https://www.ad.nl/auto/vermogen-elektrische-laadpalen-omlaag-anders-stad-op-zwart~a1878199/?referrer=https://www.nieuwskoerier.nl/news/611226-laadpaal-op-halve-kracht-anders-gaat-het-licht-uit

Walker, D. (2019). Electric planes are here – but they won't solve flying's CO_2 problem. *The Conversation.* Retrieved from http://theconversation.com/electric-planes-are-here-but-they-wont-solve-flyings-co-problem-125900.

Wright, M. (2019, 20 November). Electric cars are 'silent killers' visually-impaired woman warns after near miss. *The Telegraph*. Retrieved on 28 February 2020 from https://www.telegraph.co.uk/news/2019/11/20/electric-cars-silent-killers-visually-impaired-woman-warns-near/

Yakir, D. (2011). The paper trail of the 13 C of atmospheric CO 2 since the industrial revolution period. *Environmental Research Letters, 6*(3), 4.