POTENTIAL OF BATTERY ELECTRIC TRUCKS ON LOGISTICS AND MANUFACTURING SIDE IN TURKEY

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ABSTRACT

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Master's Program in Sustainable Energy

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Road transportation has 22% of the CO2 emission and 20% of total fuel consumption worldwide. Heavy and medium duty trucks have a small share on the vehicle population, yet they have the biggest share on energy consumption and air pollution per vehicle. The popularity of electric trucks had increased because of the latest environmental issues and fuel dependency on external sources. Countries like Canada, Switzerland, China introduced incentives for the electric truck developments. The production of electric trucks also increased with the environmental concerns. Companies like Tesla, Volvo, Renault Trucks introduced their electric trucks to the market and already signed a deal with companies like Pepsi CO., UPS, etc. However, there are still barriers for electric truck development. The main barrier is the infrastructure of the countries, mainly on charging technologies. Despite having a great potential in terms of fuel consumption and GHG savings, electric trucks are not efficient for all the sectors for their small distance range and because of the current battery technologies. Turkey has a great potential on adopting electric trucks because

of the countries dependence on mining and construction industries. Therefore, medium and heavy-duty trucks have great demand. In addition, Turkey's 41,3% of export is to Europe where environmental issues as emissions are being taking seriously. However, Turkey is at the very early stage on electric mobility infrastructure. The aim of this paper is to analyse the potential of Turkey in terms of electric trucks and charging infrastructure on logistics companies and truck manufacturers' perspective.

Keywords: electric trucks, charging infrastructure, e-mobility, green transportation, battery electric vehicles

ÖZET

ELEKTRİKLİ ARAÇLARIN TÜRKİYE'DEKİ LOJİSTİK VE ÜRETİCİ FİRMALAR TARAFINDAN POTANSİYELİ

Dinçer, Ege Ali

Sürdürülebilir Enerji Yüksek Lisans Programı

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Karayolu taşımacılığı, dünya çapında CO2 emisyonunun %22'sine ve toplam yakıt tüketiminin %20'sine sahiptir. Ağır ve orta vasıta taşıtlar, toplam araç popülasyonunda küçük bir paya sahipken, araç başına enerji tüketimi ve hava kirliliğinde en büyük paya sahiptir. Elektrikli kamyonların popülaritesi, güncel çevre sorunları ve enerji güvenliği nedeniyle artmıştı. Kanada, İsviçre, Çin gibi ülkeler elektrikli kamyon geliştirmeleri için teşvikler getirdi. Çevresel kaygılarla birlikte elektrikli kamyon üretimi de arttı. Tesla, Volvo, Renault Trucks gibi şirketler elektrikli kamyonlarını piyasaya sundular ve şimdiden Pepsi CO., UPS vb. şirketlerle bir anlaşma imzaladılar. Ancak, elektrikli kamyon geliştirmenin önünde hala engeller var. Başlıca engel, ülkelerin ağırlıklı olarak şarj teknolojileri konusundaki altyapısıdır. Elektrikli kamyonlar, yakıt tüketimi ve sera gazı tasarrufu açısından büyük bir potansiyele sahip olmasına rağmen, mevcut akü teknolojileri nedeniyle kısa mesafeli menzilleri nedeniyle tüm sektörler için verimli olamamaktadır. Ülkelerin madencilik, inşaat sektörlerine bağımlılığı nedeniyle Türkiye elektrikli kamyonları benimseme konusunda büyük bir potansiyele sahip.

Ayrıca, Türkiye'nin %41,3'lük ihracatı, emisyonlar gibi çevre sorunlarının ciddiye alındığı Avrupa'yadır. Bu nedenle ağır hizmet kamyonları büyük talep görmektedir. Ancak Türkiye, elektrikli mobilite altyapısı konusunda çok erken aşamadadır. Bu çalışmanın amacı, lojistik firmaları ve kamyon üreticilerinin bakış açısıyla elektrikli kamyon ve şarj altyapısı açısından Türkiye'nin potansiyelini analiz etmektir.

Anahtar kelimeler: elektrikli kamyonlar, şarj altyapısı, e-mobilite, yeşil ulaşım, akülü elektrikli araçlar

Dedicated to my father, Ercan Dinçer

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1: INTRODUCTION

E-mobility is the electrification of the vehicles, either it is commercial or personal vehicle. Increasing greenhouse gas (GHG) emissions and the need to find alternatives for conventional fuel resources had led to an increase on the demand for electric vehicle sector (e-mobility). E-mobility is seen as a great opportunity to decrease GHG emissions. In Europe, passenger cars are accounting for 60.7% of total CO2 emission from road transport (which generates 72% of total CO2 emission among all transportation modes). E-mobility is also a great way to decrease dependency on fossil fuels. It is crucial for fuel importing countries like Turkey. However, due to more complex technology requirements and need for new infrastructure, Turkey is at the very beginning stage on accepting e-mobility. Capital costs, maintenance cost and public acceptance are still at the lower stages. Yet, it can be developed by logistics and car freight companies, rather than individuals because of the economies of scale. Corporal investments are more viable than public investments due to higher capital. Therefore, it would be logical to increase the investments on commercial side. Therefore, e-mobility on heavy and medium duty trucks should be investigated in order to determine the manufacturers and business to business (B2B) customers' motivation. However, there are also other factors that effects suppliers and customers in addition to capital and maintenance costs. Technology anxiety, driving range, lack of charging stations and battery life are few examples of negative motivations. An investment for e-mobility is directly related with the infrastructure of the related city, region, or country. Local grid is directly affected with the electrification of the cars, trucks, or other vehicles. The reason for that is that the local grid capacity should be sufficient for the charging operations. The best optimal charging time listed as night-time while the vehicles are not idle. Therefore, especially for the passenger cars, the demand for the electricity would be at peak at night-time. There are high number of articles and research on e-mobility in literature. They clearly describe the technologies, motivations, barriers, and road maps. However, many of them are involving only personal vehicles rather than B2B developments. Sources for commercial trucks, medium duty, or heavy duty, are very limited. However, since Turkey is at the very beginning stage on converting to e-mobility technology, it has same distance to both personal and commercial vehicles.

Since one of the main barriers is the high costs, electrification of commercial vehicles maybe a better starting point. Logistics companies and commercial vehicle manufacturing companies can benefit from economies of scale while converting to e-mobility. So, making research on heavy and medium duty electric trucks and supplier and B2B demand side could be promising with motivations below.

• E-mobility is popular in literature. However, articles on electrification of heavy and medium duty trucks are limited. Yet, there are plenty of resources that can be used to write an article about it.

• Logistics companies in Turkey are fully devoted to export operations. EU is the main destination to Turkish export. Therefore, EU has more motivation on e-mobility and the income of export fleets are in foreign currencies. Therefore, Turkish currency fluctuations are not affecting the purchase behaviours of logistics companies as much as other sectors.

• Purchase costs are main barrier, especially in Turkey. Therefore, companywide purchases are more viable than individual purchases due to economies of scale.

• Biggest sector in Turkey is construction. So, since they are mainly dependent on trucks, the potential is high.

The local electricity generation is also important for e-mobility. The reason is the need for e-mobility have been occurred because of energy dependency and GHG emission. Therefore, the electricity generation mix is crucial for adopting electric trucks. If the local electricity generation mix highly depends on fossil fuels or coal, even if the vehicles themselves doesn't emit pipe gas, because of the electricity they are using, their GHG emission life cycles would be higher. Also, if the local grid is dependent on imported energy sources, electric vehicles will also increase the dependency.

Considering all the situations related with electricity generation mix, renewable energy investments would also be necessary for countries like Turkey because of their energy profile.

This paper investigates the e-mobility on both supplier side (manufacturers) and B2B demand side in Turkey. First, pros and cons will be examined. After that, current global

and local developments would be listed. Turkey's current e-mobility development and potential will be listed. With all that information, manufacturers' and B2B customers' (logistics companies) motivation on shifting to e-mobility will be determined with survey.

CHAPTER 2: LITERATURE REVIEW

Academic research on electric mobility has increased over several years (Tanco et al.,2019). More than 200 papers were found by using key words such as “electric trucks”, “e-mobility”, “battery electric trucks (BETs)”, “charging infrastructure”, “green transportation”, “electric heavy-duty trucks” and “electric commercial vehicles”. More than a half of those papers were only including electric passenger cars and/or engineering based technical papers which does not related with this paper’s subject. Total of 40 papers among those 200 were directly or indirectly related with this paper.

In addition to the articles, governmental reports, both domestic and international, institutional research and private company reports were taken into consideration. Most of those papers were focused on total cost of ownership, life cycle emission, charging infrastructure and battery technologies. According to Feng & Figliozzi, the electric trucks are economically competitive in higher usage. The importance on climate change and air pollution have been increase and considered as the most important environmental problem (Gholami et al., 2014). Several research projects were conducted, and effects of emission were identified (Kargari et al.,2008; Zhang et al., 2013; Vasudevan et al., 2016; Panwar et al., 2011). Degirmenci, 2017 and Egbue, 2012 mentioned about sustainability, environmental performance, and range confidence. These studies show that, to reduce the GHG emission, generating the electric via renewable sources, mainly solar and wind energy, are very crucial (McKinnon, 2019). The generating mix of Ontario (according to IESO, 2014), consist of nuclear (61%), hydro (24%), natural gas (10%), wind (4%), and biomass (1%). According to Zhou et al., 2017, with this generation mix, Ontario offers lesser GHG emission for the battery electric vehicles. The other studies on TCO concludes that if the total millage of the electric trucks is higher than the diesel trucks, and the lifetime will be at least the same with the truck itself, they can be cost beneficial even if their purchase prices are higher than the diesel trucks. Mulholland, 2018, assumes that battery electric medium and heavy-duty trucks will decrease the road freight emissions from 2035 onwards and will be responsible for approximately 33% of the emission reductions in 2050. According to Taliban et al., the role of the electric trucks is crucial for GHG emission reduction plans in British Columbia, Canada, and concludes that more than 60% of trucks need

to be electrified by 2040. Those studies also conclude that the GHG emission and fuel consumption of trucks are directly affected by the drive cycle (Zhou et al., 2017). Zhou et al., 2017, argues that the studies fail to capture the interactions of drive cycle, payload and temperature on fuel consumption and life cycle GHG emissions. Several examples in the literature have focused on vehicle hybridization to achieve this goal (Kast et al., 2017).

2.1 Characteristics and Potential of Battery Electric Heavy and Medium Duty Truck

Medium and heavy truck manufacturing and road transportation fleet companies are looking for an alternative the conventional truck for the environmental concerns (Björklund, 2011). The importance of the development of battery electric trucks are different in every country and every manufacturer. The main reason for the development in countries and regions are fuel dependency and GHG emission. Countries and regions with GHG emission reduction legislations tend to be more interested with battery electric truck development.

Electric trucks offer significant improvements in terms of GHG emission and fuel consumption reduction. However, these factors rely on current infrastructures and the acceptance of potential users/manufacturers.

2.1.1 GHG Emission

GHG emissions strongly affects the human health and the quality of life (DG Environment, 2018). Road transportation is the most energy- intensive transportation mode and relies mostly to fossil fuels (Çabukoglu et al., 2018). Zhao et al., 2012, mentioned that the combustion vehicles are one of the main contributors to energy crisis' and GHG emissions worldwide. The demand for road transportation is projected to increase 33% (tkm) by 2040. Further expectations by International Transport Forum projected that it would increase 160% by 2050 (ITF, 2017).

Road transportation sector is responsible of 24% of total GHG emissions, which is the second most emitting sector after the power generation industry which is producing 40% of total global GHG emission (Saber and Venagamoorthy, 2011)

The total CO2 emission of transportation sector is estimated as 7.3 billion metric tons, globally. It is the 18% of total CO2 emission that is produced by humankind. It is also

expected to increase 60% by the year 2050.

Freight transportation, where the medium and heavy-duty trucks mainly used, accounts for almost half (45%) of the CO2 emission of transportation. Only medium duty and heavy-duty trucks have emitted approximately 1.8 billion metric tons of CO2 worldwide (Statistica, 2021). The emission from road freight transport is also expected to increase by approx. 70%.

Even if the improvements on energy efficiency, the emissions are expected to grow because of the increasing number of vehicles and increasing demand on transportation (Liimatainena et al., 2019). Therefore, the importance of creating alternatives, such as electrification of vehicles, are strongly needed.

The passenger vehicles and commercial trucks with the battery electric powertrain technology have a great potential to reduce lifecycle GHG emission and energy consumption (National Research Council, 2010).

Trucks are responsible for the CO2 emission in highways, and urban areas respectively 45% and 27% (Safari and Dinçer, 2018).

Even if the heavy-duty vehicles have small portion on total vehicle population, they have been identified as one of the highest contributors of GHG emission (Grigorato et al., 2019). Road transportation produces 20% of the total global CO2 emission and even though the heavy-duty trucks have very small portion on the road transportation, they have a major impact on the total CO2 emission from the transport sector. Therefore, electric trucks have an important potential to mitigate the total GHG emission of road transportation (Plötza et al., 2019).

The management of the medium and heavy-duty trucks' emission has a key role on the emission reduction of road transport emission (Song et al., 2018).

The International Energy Agency already called for rapid electrification of road freight (Teter, 2016).

According to Mulholland, 2018, medium and heavy-duty electric trucks will be highly responsible for the road fright GHG emissions, and they will be responsible for the one third of the emission reductions in 2050.

Increasing the energy efficiency will also be crucial to meet the carbon dioxide emission targets and to meet the zero-emission vehicle's goal, the transitioning must be successful by the end of the century (Kast et al., 2017).

Sen et. al. suggested that even though the electric trucks have higher costs and emissions related to electricity generation, they perform better then alternative fuels in terms of GHG emissions and costs. Figure 1 shows the main factors effecting GHG emissions.

2.1.2 Fuel Consumption

Battery electric cars and hybrid electric technologies are considered as the most feasible solution to reducing the energy consumption and GHG emission of heavy-duty vehicles and have a potential to improve energy security (Zou et al., 2004). Therefore, the size and impact of the medium and heavy-duty sector creates the desire for improved fuel economy and reduced emissions. The greatest fuel consumption difference occurs on stopping for battery electric trucks, unlike conventional trucks (frequent stops increase the fuel consumption of conventional trucks) (Zhou et al., 2017).

Another critical factor that affecting the energy consumption of battery electric and conventional trucks is the operating temperature. The temperatures affect both energy consumption by changing the efficiency of the powertrain and the energy consumption of the air conditioner. The fuel consumption for conventional trucks lower at 20 C. However electric trucks consume more energy at the same heat because the batteries deplete when generating cabin heat. Both conventional and battery electric trucks consume more energy when operating at 7C (or below), and 35C (and above) (Lohse-Busch et al., 2013).

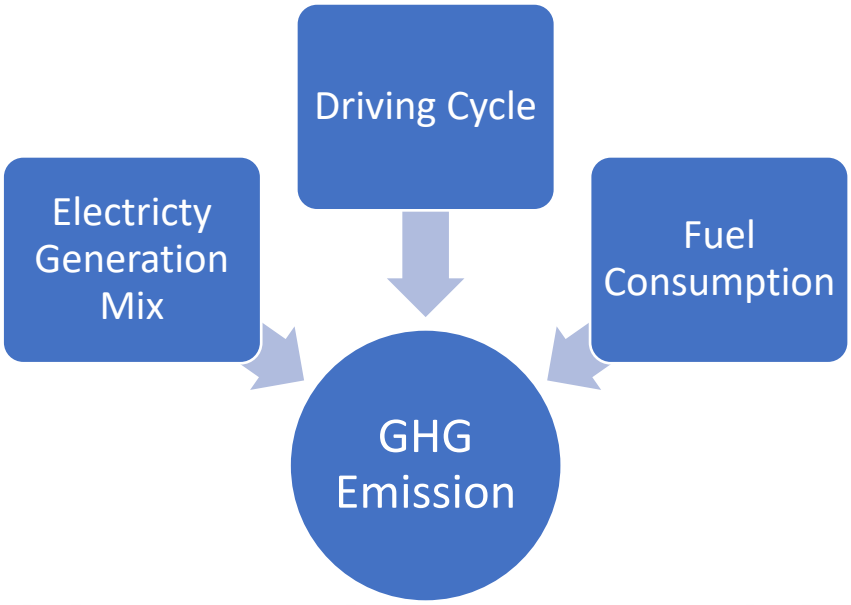


Figure 1. Main factors affecting GHG emission

2.2 Potentials of Electric Trucks

Articles are divided in to 2 main potentials. One is the potential according to purchase behaviour and the other is technical suitability. According to Zhou et al., 2019, electric trucks provide better efficiencies, lesser cost and higher customer satisfaction

2.2.1 Purchase Behaviour

Cost reductions and risk mitigations are considered as significant factors affecting the decision of service providers in positive way (Mohamed et al., 2018). Several articles conclude the effects on the purchase behaviour in different aspects; technology anxiety and battery prices, driver experience (Schmalfuß et al., 2017; Vassileva et al., 2017), and buyer's intention, (Egbue et al., 2017), safety anxiety (Li et al., 2017). These factors have different importance on different countries (and cities). In Norway, for example, having exclusive road rights mainly affects the purchase behaviour of companies. The performance of electric trucks is in better condition on urban deliveries Governments and electric truck producers need to focus on consumer's intention and acceptance of the electric trucks instead of focusing only on the technology (Zhou et al., 2019).

2.2.2 Technology Anxiety

Technology anxiety for battery electric trucks mainly occurs because of the lack of knowledge and trust to technology (Andwari et al., 2017). Technology innovation will solve the technical problems of electric trucks, including increasing mileage, improving safety, improving the convenience of charging, and reducing the price of battery replacement (Zhou et al., 2019). Drivers' anxiety also sets a barrier on adopting the battery electric trucks. There are several factors for the drivers' anxiety. One of the main reasons of the drivers' anxiety is the limited charging stations and the high battery costs (Zhou et al., 2019).

2.3 Designing the Electric Trucks

Designing the truck is a challenge for electric vehicle producers since the batteries have high loads and huge dimensions. There is enough space between the frame rails and in the frontal area to house the engine, fuel cell stack, high voltage battery, and major balance of plant components (Kast et al., 2017).

Replacing the fuel tanks with the batteries will increase the total weight of the truck where the batteries will account for 5% of total gross weight of the vehicle. Medium duty trucks have gross weight between 6000kg and 12,000 kg (Freightliner, 2016), while the heavy-duty trucks are greater than 12 tons MPW (Çabukoglu et al., 2018).

Payload is another factor that is affecting the energy consumption where the energy consumption of battery electric trucks is higher than diesel trucks on 100% payload (Sharer et al., 2007). Gross weight of the truck is important for fuel consumption because even without any additional payload, the fuel is consumed to transport the truck itself (Zhou et al., 2017).

The heavy vehicles are higher potential for electrification than smaller trucks (especially trucks between 12 ton and 18 tons) due to their high weight and large fuel tanks (which can be replaced by batteries) (Çabukoglu et al., 2018). Feasible CO2 avoidance do not validate the effort if the electric trucks have to operate with the same legal bounds with the conventional trucks. So extra weight capacity can be determined for BET's (Çabukoglu et al., 2018). However, it must be considered that the maximum weight still needs to have limitations to avoid the damage on the road surfaces (Poulikakos et al., 2013).

The total annual working days of the trucks are considered as 250 days. The distance travelled, on the other hand, has considered different on urban, regional, and long haul, respectively, 100,200 and 600 km (Mckinsey, 2017).

2.3.1 Drive Cycle

The lifecycle GHG emission and energy consumption of the battery electric trucks are highly dependent on the drive cycle, temperature, and payload (Lohse-Busch et al., 2013; Taptich and Horvath, 2014; U.S. National Research Council (NRC), 2014; Yuksel and Michalek, 2015; Zhao et al., 2016b). Fuel consumption and GHG emission of hybrid trucks are highly dependent on the drive cycle selection (Zou et al., 2017). Zhou et al.,2017 compared BETs with Diesel trucks in terms of their sensitivity to weather conditions. The diesel trucks also tend to be more sensitive to driving cycle than the battery electric trucks. Their consumption is higher than the electric trucks in cities and urban areas because of the unstable driving conditions. Therefore, electric trucks promise higher potential for reducing the fuel consumption and GHG emissions in urban areas (Liu et al., 2018). Electric trucks are also more resilient to unstable driving conditions because of their regenerative braking capabilities

2.3.2 Driving Range

Driving range is one of the most common barriers to heavy duty electric trucks (Franke et al., 2012). Since the average distance that electric trucks can travel is approximately 200kms, (Tanco et al., 2019) it might be insufficient for most of the fields. However, the new technologies are emerging so the total mileage of a truck without charging is increasing. The concerns on driving range are not only related to battery life. There are limited numbers of charging stations, especially in rural areas. Therefore, driving range is being seen as an obstacle for continuous operations. It can either be bypassed by increasing battery life, decreasing battery weight, or increasing the total number of charging stations and charging alternatives.

2.3.3 Total Cost of Ownership (TCO)

TCO also contains of battery cost, battery replacement cost, charging and infrastructure. BET's have higher total cost of ownership (which includes purchase price, vehicle kilometres travelled, fuel price and consumption, maintenance cost,

salvage value and discount rate), then diesel trucks (Liimatainena et al., 2019). The main reason for that is their current technology. However, TCO of battery electric trucks tends to decrease with new technological developments. Yet, BETs don't have higher TCO in every condition. According to Lee et al., 2013, total cost of ownership of Diesel trucks are 22% higher than the e-trucks in New York City. Zhou et al., 2017, mentions that the battery electric trucks consume less energy on 100% payload and drive cycles with infrequent stops. However, GHG emissions for the BET are more than 15% the diesel trucks at 100% payload.

The purchase costs are considered as one of the main barriers on purchase behaviours since it creates the biggest difference on TCO between conventional and battery electric vehicles (Tanco et al., 2019). Base prices for electric trucks are between US$150,000 and US$200,000, where the average price of a typical diesel truck is to US$120,000. However, technological improvements and competition are seen as a promising factor on the cost reduction (BNEF, 2017).

2.4 Battery and Charging

BETs are relying on electricity instead of fuel. Battery is the main component of the electric trucks and has the biggest impact on the purchase price and TCO. Inefficient battery capacity and the battery charging are the main barriers to electrification of the trucks. In order to make a conclusion on battery electric trucks, the optimal density of batteries, charging infrastructure and current actions taken in order to eliminate the barriers need to be studied.

2.4.1 Battery Technology

Recent battery technology developments are promising technically viable battery electric heavy-duty trucks. Further developments also expected to decrease the TCO of heavy-duty trucks (even lower than the diesel heavy duty trucks) because of the decreasing cost of batteries (Liimatainena et al., 2019).

The potential for electrification of trucks will be higher if the battery capacity and charging infrastructure, as well as alternative charging tools, are improved (Liimatainena et al., 2019).

New developments on battery technologies are making battery electric trucks more

attractive as technically and commercially (Liimatainena et al., 2019).

2.4.2 Optimal Capacity of Batteries

The density of battery energy has rapidly improved recent years and it is expected to grow more (Noorden et al., 2014). The optimal battery capacity of medium duty, heavy duty and semitrailers are 150-350 kWh, 400-800 kWh and 600-800 kWh, relatively (Liimatainen et al., 2019). The electric trucks require high-capacity grid, approximately 50kW per single vehicle. Harnung et al., 2013, assumed that 70% of vehicles can be electrified with better density of future batteries with 2000 W h/k. He adds that with the current density of the batteries, even 100 kW will be insufficient to charge largest batteries in time.

2.4.3 Charging and Maintenance

The other critical issue is the infostructure of charging stations (Peterson and Michalek, 2013). Therefore, more developed charging operations (Liu and Song, 2018), and the life cycles of batteries (Peterson and Michalek, 2013; Smith et al., 2012) are making battery electric trucks more viable. Battery replacement and recharging is necessary for the battery electric trucks to operate so the infrastructure of charging facilities are key factors affecting people's opinion on using electric vehicles (Li et al., 2017). Charging stations should be constructed with the consideration of the number of trucks, location and local grid details (Rocky Mountain Institute).

Companies and governments need to cooperate to construct infrastructure for battery electric trucks in terms of charging and battery replacement stations (Zhou et al., 2019). Planning the optimal charging infrastructure can be time efficient for the electric truck owners (NACFE, 2018).

Operation costs contains of fuel, maintenance and component replacement costs (Zhou et al., 2017). Average maintenance cost of the diesel trucks is $0.17/km (Barnitt, 2011), while the maintenance cost for battery electric trucks are 30-50% of the diesels (Lee et al., 2013).

According to Bloomberg NEF, the share of batteries will be 18% of the truck costs in 2018, while they are 48% in 2016 (Tanco et al., 2019). The energy prices for battery electric trucks tend to decrease with the new battery technologies (Tanco et al., 2019). Battery electric trucks can also generate electricity with regenerative breaking.

However, it doesn't provide promising energy for operating the vehicles.

The optimal time for the battery charging is the night-time. Charging for 12 hours with 50 kW is optimal for fast charging stations (Falvo et al., 2014). Day-time charging is also an option for electric trucks; however, it means that the truck is being charged on his "working hours" which can be unacceptable by fleet owner. For that reason, battery swapping is a promising alternative for daytime charging. To create a potential for BET's electric motor control system (Lieven et al., 2011; Steinhilber et al., 2013), battery charging facility (Andwari et al., 2017) and battery replacement technology (Kamga and Yazici, 2014; She et al., 2017) must be developed by governments and companies. Charging stations need supporting infrastructure for the intraday operations like battery swapping (Çabukoglu et al., 2018). An efficient charging station must charge more than one hundred batteries and swap even heaviest batteries in less than a minute during peak hours. Increased number of charging the battery electric trucks doesn't have a critical effect on the grids nationally, however they might be problems on local scale, even if charging operations held overnight (Liimatainena et al., 2019).

2.4.4 Electricity Generation Mix

The electricity generation mix has a major effect on life cycle GHG emissions of battery-electric vehicles. The battery electric vehicles' emissions are highly affected by the electric generation mix. According to various studies, the average GHG emission of battery electric vehicles are lesser than the average of standard LPG vehicles considering the U.S electric generation mix. However, this assumption on lower emission is depending on the location of the charging facilities. On some conditions, if the electricity generation is highly dependent on fossil fuels, the emission of the electric trucks may be even higher than the diesel trucks.

Battery electric trucks offer significant improvements on the paper. However, there are plenty of external factors which makes battery electric trucks to perform under their capacity. Driving range, purchase cost, accident risk, charging problem, battery replacement cost (Andwari et al., 2017; Steinhilber et al., 2013) and technology anxiety (Zhou et al., 2019) are the main barriers on BET's. Figure 2 shows the main barriers of BETs.

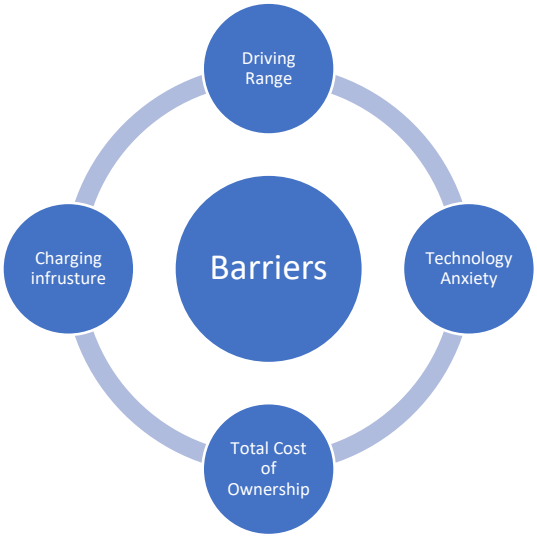


Figure 2. Main barriers of BETs

Many indicators have been gathered as a result of the literature review. 8 of them were directly related with the subject and aim of this article. The indicators which were obtained from literature are 1. demographic variables, 2. approach to bets, 3. economies of scale, 4. emission reduction, 5. fuel consumption, 6. public acceptance,7. battery and infrastructure and 8. truck design.

The indicators have been gathered under 3 main groups. 1.technical, 2. economical and 3. consumer characteristics. Technical indicators are emission reduction, battery and infrastructure and truck design. Economic indicators are economies of scale and fuel consumption. Consumer characteristics are demographic variables, approach to BET's and public acceptance.

58 articles were directly related to those 8 parameters. Each article and the subject they are related to have shown on Table 1

Table 1: Article-Parameter matching

Article	Approach to BET's	Battery and infrastructure	Cost	Emission Reduction	Fuel consumption	Public acceptance	Truck design
Andwari et al., 2017						X	
Barnitt, 2011			X				
Çabukoglu et al., 2018		X		X			X
Degirmenci and Breitner, 2017	X			X			
Egbue and Long, 2012	X			X			
Egbue et al., 2017						X	
Falvo et al., 2014		X					
Fleetcarma, 2013	X						
Franke et al., 2012	X						
Freightliner, 2016							X
Gholami et al. 2014	X			X			
Grigorato et al., 2019				X			
Ji and Sun, 2017						X	
Johnson and Joshi, 2017				X			
Kahn Ribeiro et al., 2007				X			
Kamga and Yazici, 2014		X					
Kargari and Mosturi 2008	X			X			
Kast et al., 2017				X			X
Lee et al., 2013			X				
Li et al., 2017		X				X	
Lieven et al., 2011		X					X
Liimatainen et al., 2019		X					X
Liimatainena et al., 2019		X			X		X
Liu and Song, 2018		X			X		
Lohse-Busch et al., 2013		X			X		
Magsamen-Conrad et al., 2015						X	X
Mahmoudzadeh Andwari et al., 2017	X	X					
Mckinsey 2017							X
Mohamed, Ferguson, et al., 2018			X				
Noorden et al., 2014		X					X
Panwar et al. 2011	X			X			
Peterson and Michalek, 2013		X					
Plötza et al., 2019				X			
Poulikakos et al., 2013							X
Saber and Venagamoorthy 2011a, b.				X			
Schmalfuß et al., 2017						X	
Sharer et al., 2007							X
She et al., 2017		X					
Smith et al., 2012		X					
Song et al., 2018				X			
Steinhilber et al., 2013	X	X				X	X
Tanco et al., 2019	X		X				
Taptich and Horvath, 2014	X						
Teter, 2016				X			
Vassileva and Campillo, 2017						X	
Vasudevan et al. 2016	X			X			
Yang et al., 2018					X		
Yuksel and Michalek, 2015	X						
Zhang and Guo 2013	X			X			
Zhao et al., 2016				X			
Zhao et al., 2016b	X						
Zhao et al., 2017				X	X		X
Zhou et al., 2010						X	X
Zhou et al., 2017			X		X		X
Zhou et al., 2019		X				X	X
Zou et al., 2004					X		
Zou et al., 2012				X			
Zou et al., 2017					X		

CHAPTER 3: METHODOLOGY

A survey is a systematic process for gathering information from (a sample of) people in order to describe the characteristics of the wider population to which they belong. In a survey, data is acquired by asking questions. The questioning tactics used in surveys set them apart. The first method is to ask people pre-made questions. Asking interview questions and documenting the replies is the second sort of survey. The survey approach is frequently used in papers that are concerned with the behaviours and motivations of a large group of people. Since this article is directly related with motivations of the manufacturer and fleet owner companies, the survey methodology would serve the aim perfectly. Representatives from logistics businesses and truck manufacturers make up the common group, which serves as the sample population for this paper.

The main idea of this study is to describe the motivation and willingness of truck manufacturers and logistics fleet owners' on shifting to battery electric vehicles. There were limited number of articles on literature and almost all of the articles were quantitative which were aimed to find "total GHG emission reduction", "total fuel consumption reduction", "best route for electric trucks to operate in better condition" and it goes on. Since this papers aim is to determine the "motivation" of the suppliers and corporal customers' a more qualitative approach is taken. The results, on the other hand, were reflected as quantitative data.

Interviewing with the company representatives appears to be the best solution to determine their motivation. Before preparing any questions for the interview, the pros, and cons of developing battery electric truck technology is determined.

There were 8 variables gathered through literature review which are demographic variables, approach to BET's, TCO, emission reduction, fuel consumption, public acceptance, battery and infrastructure and truck design. More than 15 articles were directly related with the factors affecting the purchase behaviour of customers. In terms of the advantages of battery electric truck technology, GHG emission reduction, fuel consumption reduction and public acceptance were the major factors repeated in many of the articles. The disadvantages, on the other hand were mainly total cost of ownership (TCO) which includes maintenance cost and purchase price, driving range

and technology anxiety.

3.1 Designing Questions

In order to determine the questions to be asked to company representatives, 8 main factors obtained through literature.

1. Demographic
2. Approach to BETs
3. Economies of scale
4. Emission reduction
5. Fuel consumption
6. Public acceptance
7. Battery and Infrastructure
8. Truck design

Total of 30 questions designed in order to collect information about manufacturers' and logistics companies' approach on those 8 parameters. 6 of them are open questions, 2 of them are Likert scale questions which are asked to determine the interest rating of the participants, 9 of them are "yes/no" questions. 3 of them are related with yes/no questions which have been asked to learn the reasons of the answer. 10 of the questions are multiple choice questions.

The distribution of questions is as follow; first 6 questions are demographic questions which related with the information of participants and their companies. Q7 is related with companies' importance on 8 indicators. Questions between Q8 and Q13 are related with the Approach on BET's. Q14-Q17 are about driving range and charging. Q18-24 are related with GHG emissions where Q25 and Q26 are related with fuel consumption. Last 4 questions are determined to gather information about truck designs. Q27 and Q28 are demographic questions. However, the intention of those questions is to determine what type of designs they need for their operations.

The details of designing the survey questions are as follows.

3.1.1 Demographic

One common set of questions are prepared for both logistics and manufacturer companies. Even if the people who attended survey had different demographic background, they haven't been included on questions because the questions are related with companies rather than individuals. Only below 5 questions asked in order to classify the attendants and their companies.

- Which sector are you working for?
- What is your title in the company?
- How long have you been working on this sector?
- How long have your company been operating?
- What is the size of your company?

3.1.2 Economies of scale

Since the major factor of selecting manufacturers and fleet owners were economies of scale, the total number of trucks in logistics fleet should be determined, as well as the year-to-date production of manufacturers. The main idea is to determine the annual need for electric trucks. Therefore, below questions have been gathered in order to obtain related information.

- How many trucks do you produce, or do you purchase/rent to meet your annual operation targets?

3.1.3 Approach to BETs

Approach on BET's cover the supplier side. In order to determine the approach of companies on e-mobility, 5 questions have been asked.

- Which factors are more important for you company?
    - Low fuel consumption
    - Low capital cost
    - High payload capacity
    - Long driving range
    - Low GHG emission

- How is you opinion on e-mobility?
    - Highly negative
    - Negative
    - I don’t have any opinion
    - Positive
    - Highly Positive
- Do you prefer choosing electric trucks for your operations?
- What is your reason?
- Would increasing the incentives on e-mobility effect your decision on purchasing electric trucks?
- Do you purchase or produce electric trucks?
- If your answer is “yes”, how many trucks did you purchase/produce in 2021?

3.1.4 Emission reduction

GHG emission is not a major concern in Turkey. However even if there are no boundaries emission reduction, some companies may still be sensitive about it. Also on the export side, any exports or transportation services to EU can enforce the logistics companies and truck manufacturers to take emission reduction into consideration. Therefore, company opinion on GHG emission reduction, share of export and the share of export to environmentally concerned countries and regions should be identified.

- Do you have any emission reduction targets in your company?
- Do you receive any demands for low emission trucks by your customers?
- Do you calculate your GHG emission?
- If your answer is “yes”, can you share your results for 2021?
- Would you consider taking any steps that will reduce your GHG emissions with increasing some portion of your costs?
- Does the electricity mix in you region effect your decisions on accepting electric trucks?

3.1.5 Fuel consumption

Turkey is highly dependent on fossil fuels. The main fuel consumption comes from transportation sector (TUIK, 2020). In addition to the dependency, Turkey's fuel price fluctuations are highly effective on each individual and companies' budgets. Fuel prices between 2010-2020 are listed in table x.

When the price fluctuations and fuel dependency on foreign countries are crucial, the total fuel consumptions and the willingness to reducing fuel consumption should be determined.

- What is your average fuel consumption per 100km per each truck you bought/hired/produced?
- Do you look for alternatives for fossil fuels?

3.1.6 Public/Customer acceptance

Companies can be either willing to adopt electric truck technologies or not. However, the customers or even the drivers can think the opposite. So, the demand for electric trucks from current or potential customers can be determinant factor. In literature the public acceptance is affected positively by "economic concerns", "state of the art technologies", "lower GHG emissions", and "fuel consumption reduction". The negative side, on the other hand, comes from "technology anxiety", "driving range", "lack of infrastructure" and "high capital and maintenance costs". Questions have been designed to include all of the upsides and downsides of the battery electric trucks.

- Do you receive any demands on electric trucks?
- What is the most important factor that your customers are asking for? Please rank from 1 to 5 (1 is the most important, where the 5 is the least important factor).
    - Lower purchase price
    - Lower fuel costs
    - Lower GHG emissions
    - Long driving cycles
    - Higher payload capacity

3.1.7 Battery and Infrastructure

Battery and infrastructure were threats to e-mobility. High costs of batteries, drive cycle and lack of charging stations and alternatives were main barriers on developing electric truck technologies. However, with the improvement on technologies and investments, those barriers decreased dramatically. Yet, the potential buyers may be unaware of the current developments. Therefore, the company's knowledge on current developments should be determined. In addition to that, their demands on drive cycle, infrastructure and charging times should be identified to see if the current developments would meet their demands or not.

- Do you think there are enough charging stations for electric trucks? If your answer is "no", what is the optimal average distance between charging stations?
- How many KM should a truck travel with a single charge?
- What is the optimal charging time of an empty battery?

3.1.8 Truck Designs

Heavy and medium trucks are commercial vehicles. Therefore, the more they carry, the more profit will the owners get. The battery weight is a big concern for fleet owners because the more the battery weights, the lesser loads the truck carries. Decreasing battery weights and introducing new legislations for electric trucks to be able to carry more load would eliminate these concerns. In order to determine how important is the total payload for manufacturers and logistics companies, the sector of their customers, and the total share of full truck load (FTL) should be determined.

- Which sectors you are working with?
- Where is your main destination on international shipments?
- Do you design the trucks, or do you prefer any designs?
- What is the most important think on choosing trucks to purchase/produce?
    - Low truck weight
    - Bigger fuel tank
    - Low fuel consumption
    - Easy to drive

- Number of maintenance services
- Low maintenance cost
- Low GHG emission
- Other

3.2 Sampling Methodology

The sample population have been chosen in two categories; logistics companies and truck manufacturers. Since the beginning of this article, it is supported that corporal investments would be better for electric car investments because of the economies of scale. The corporal side is divided in two categories as one represents demand side (logistics companies) and the other represents supply side (manufacturers).

Representatives of the companies have been chosen in order to gather the related information. The participants should be at least "specialists" of the related sectors.

The participants have been gathered by using personal contacts and by using platforms like LinkedIn. The leading companies of both sectors have been searched from LinkedIn. The survey link has been sent by direct message to the leading companies' representatives and operation leaders.

At the last stage, the final version of survey has been shared by participants on Microsoft forms. The average survey time have been calculated as 8 minutes and the information have been shared by all participants. The results were listed anonymously.

CHAPTER 4: STATUS OF BATTERY ELECTRIC TRUCKS

Continues use of combustion vehicles has cause energy crisis and GHG emission problems around the world (Zhao et al., 2012). Several countries and manufacturers are studied to maintain wider range of knowledge.

4.1 Electric Truck Developments of Countries and Regions

Several countries and regions have different approach on the electric truck development. The main difference within countries is occurring because of the different goals and different needs. Some of the pioneering countries on battery electric trucks are China, Germany, Switzerland, United States and Canada. In order to obtain a road map for Turkey, the development on these countries need to be studied.

4.1.1 United States

In US, medium duty and heavy-duty trucks are responsible for 28% of the petroleum consumption and almost 26% of the CO2 emission of transportation sector. In addition to that, heavy duty trucks are also responsible for 36% of the NO2 emissions (Kast et al., 2017). U.S. Energy Information Administration projects an 80% increase in truck miles between 2010 and 2050 which means that without an alternative for conventional trucks, the ratios will be higher in the future (Kast et al., 2017). Regulation for low NOx for heavy duty trucks in California is advancing with a feasible adjustment of proposal for implementation before 2023. CO2 emission reduction in the US require 5% reduction for 2021-2027. (Johnson and Joshi, 2017).

4.1.2 Switzerland

Trucks contributes 11% of the transportation CO2 emissions of Switzerland, more than 16% worldwide (Ribeiro et al., 2007). Full electrification of road transport in Switzerland had increased the total electricity demand by 3 TW h per year and it reduces the total CO2 for 1 megaton per year. It is the 5% of total electricity consumption of Switzerland (BFE, 2016).

4.1.3 Latin America

Transportation sector is one the biggest contributor of Latin-American economy. It is responsible for 19% of total CO2 emission. Therefore, battery electric trucks have a high importance for decreasing the total CO2 of Latin America. (United Nations Environment Programme, 2016). Therefore, electrification of road transport has a potential for reducing the CO2 emission by 75% by 2030 (International Council on Clean Transportation, 2017). The potential of electric trucks in Latin America is also promising because of the electric generation via renewable sources in the continent. (United Nations Environment Programme, 2016). According to United Nations Environment Program, 2016 Latin America has one the best positions for battery electric vehicles because of the high renewable electric generation potential.

Brazil and Colombia have VAT exemptions for battery electric trucks (Marchan and Viscidi ,2015). Uruguay, on the other hand, has a high potential of GHG emission reduction due to its renewable energy source, which is more than 90% of total generation.

4.1.4 China

The purchase decision of Chinese companies can be positively affected by the logistics companies, drivers, and operators (Ji and Sun, 2017). 218 million vehicles consumed more than 300 million tons of fuel (gasoline and diesel) in China, 2016. Chinese government set a goal to increase the sales of electric vehicles by 20% by 2025 because of the high fuel consumption and GHG emission (Yang et al., 2018). Electric trucks with a load of 1–3 tons, an electric motor of 35–60 kW, and a cruising range of 200–350 km is being used in urban areas in China. The Chinese government has set a goal of using 500,000 electric vehicles by 2025. In Changsha, 2,000 electric trucks have been used for deliveries in urban areas by 2017 and it is reported that there are 5,000 drivers with the electric truck experience (Zhou et al., 2019).

4.1.5 Canada

Even though the average diesel fuel consumption has decreased by 17%, the total energy used by medium duty trucks in Canada has increased by 19% from 1990 to 2011 (Zhou et al., 2017).

4.1.6 United Kingdom

United Kingdom increasing its share of electric vehicles. The total registered electric and hybrid cars in UK is 100,000 with reaching 13.8% of market share (Office of National Statistics, 2020). Shares of each fuel type is listed on Table 1 Also, in UK, the average mileage between charging station is 6 kilometres (British Broadcasting Corporation). It is also mentioned in BBC that in some regions, the average distance can be increase to 97km, such as in Southwark, London.

Even if the motivation to use BETs are high in UK, the number of electric trucks in all fuel type is lower than 0,01% (ACEA, 2020).

Table 2. Share of Fuel Types in UK (2020)

Fuel Type	**Percentage**
Petrol	0,60%
Diesel	99,30%
Hybrid electric	0,00%
Electric (battery electric + plug-in hybrid)	0,00%
LPG + Natural gas	0,10%
Other + Unknown	0,00%

4.1.7 European Union

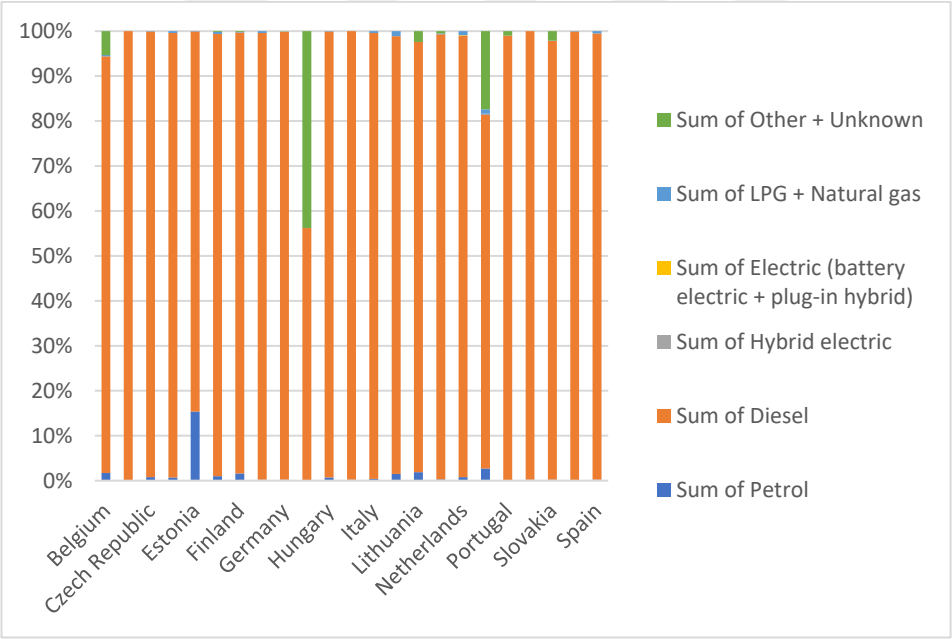
Concerns on GHG emissions and fuel consumptions had been increased also in EU which had let to proposal of HDV's CO2 certification, and it is offered to start the monitoring for the emission targets of 2025 and 2030 (Grigorato et al., 2019). In 2020,

the registered electric vehicle numbers were 1,325,000 units where it was only 550,000 units in 2019 (EEA, 2020). Road transport and especially road freight transport takes an important place on GHG targets. New legislation allows zero-emission trucks to weight up two more tonnes. This legislation plans to eliminate the disadvantage of battery electric trucks on payload capacity (EU Inno Energy, 2020).

According to the European Environmental Agency (EEA), road transportation is also the largest Nitrogen Oxides contributor and one of the biggest contributors of black carbon in 2015 (EAA, 2018).

Figure 2 shows the total number of vehicles registered in 2019 and 2020 of each country by fuel type.

Table 3. Percentage of each fuel type by countries (Source: ACEA, 2020)



On the other hand, in EU, the average distance between charging stations is 100km (Europa 2020) where it is optimal for new electric trucks that travel 200-300km with single charge.

4.2 Electric Truck Developments of Manufacturers

Companies are also believing that adopting the latest electric vehicle technologies will enhance their reputation on the customers' as being environmentally friendly (Steinhilber et al., 2013).

Many companies started their mass production or finished their R&D for electric trucks. Ford F-650 Super Truck (Ford, 2009), Smith Newton BET (Smith Newton, 2013), Toyota Mirai and Hyundai Tucson (Penton Media, 2019), The Renault Master Z.E (Renault Trucks, 2018), EMS 10,12,16 and 18 Series (EMOSS, 2019), Tesla SEMI (Tesla, 2017), Terberg electric trucks (Terberg Yard/Port Tractor, 2017). Mercedes- Benz (Mercedes-Benz Urban eTruck, 2017) and Volvo FL Electric trucks (Volvo, 2018) are examples for currently operating medium and heavy-duty electric trucks. Renault Trucks introduced their full electrified medium duty trucks 12 to 16 t segment at Guerlain, Stef in Carrefour, Nestlé and Delanchy. These trucks planned to have a range of approx. 200 km for distribution vehicles and 100 km for municipal vehicles (Renault Trucks, 2018).

Volvo Trucks also introduced battery electric truck for the delivery operations in Stockholm, Sweden. The trucks are designed to travel at the off-peak city distribution where the traffic is at the lowest level, so the trucks need to travel one third of the intraday operations DAF CF electric truck is a 4X2 tractor road transport up to 37 tons in urban areas. They are powered by 210 kW motors powered by 144 kWh lithium-ion batteries. The distance range of the CF electric trucks are 100km average (depends on the payload). The full charging of the batteries takes only one and a half hour.

Electric trucks are also in use or on purchase for many companies like Anheuser-Busch, PepsiCo and United Parcel Service Inc. are in force. Pepsi CO. currently reserved 100, UPS pre-ordered 125, and Loblaw Companies purchased 25 Tesla SEMI trucks (CNBC, 2018).

Tesla also started their development for charging stations which will be constructed on their customers' site. Tesla also promised to supply the energy (100% renewable sources) for their on-site charging stations (CNBC, 2018).

However, electrification of medium and heavy-duty trucks is more complex than

passenger cars. Electric trucks need to carry thousand kilograms of batteries while the passenger cars only need to carry hundreds. This problem might only seem to affect the TCO, however, since the heavy-duty trucks are mostly used as delivery trucks, they have limitations in terms of the total gross weight (own weight plus the weight of carried goods). Therefore, thousand kilos of batteries mean less loads to be carried suggested that governments should apply different policies for electric trucks, like excluding the battery weight on the total gross weight.

The current use of electric trucks is at early stage because they desire different technical and economic developments than electric passenger vehicles (Zhou et al., 2019). Therefore, for the current market, electric trucks do not represent immediate replacement for their counterparts (Çabukoglu et al., 2018). Yet they provide higher distribution speeds, lower operating costs, higher working convenience and customer satisfaction (Magsamen et al., 2015; Zhou et al., 2010).

CHAPTER 5: ELECTRIC TRUCK POTENTIAL OF TURKEY

Turkish economy is highly dependent on medium and heavy-duty trucks because main sectors in country are mining, transportation, and construction.

In terms of fuel consumption, Turkey is highly dependent on foreign sources. Therefore, adopting alternative technologies for conventional trucks are vital. Turkey is at the very early stage of battery electric vehicle technology. In terms of battery electric trucks, the case is even worse.

On the GHG emission side, there isn't enough legal boundaries to convince truck drivers and manufacturers to avoid using conventional trucks.

Current situation of medium and heavy-duty trucks needs to be studied to determine the potential of electrification of the trucks.

5.1 Current Truck Portfolio of Turkey

According to Turkish Statistical Institute, there are total of 23,153,556 registered vehicles in Turkey by October 2019. While 12,515,365 of them are vehicles, 3,322,867 of them are motorbikes and 65,076 are special purpose vehicles. It means that 7,250,248 of the registered vehicles in Turkey are medium and heavy- duty vehicles (minibuses, buses, small trucks, trucks, and tractors).

A survey by Turkish Statistical Institute demonstrates total sample of registered number of 12,515,365 vehicles. 3,035,365 of them are fuel (24,3%), 4,731,231 are diesel (37,8%), 4,699,190 are LPG (37,5%) and 12,749 (0,1%) are electric hybrid while 36,830 (0,3%) are unknown.

The weight limit, on the other hand, is a problem for developing battery electric truck technologies in Turkey. Turkey doesn't have any exceptions for electric trucks in terms of weight limit. Therefore, the trucks would carry less payload due to weight of the batteries. Table 3 shows the weight limit for each type of truck in Turkey where Table 4 shows the average millage by each vehicle type.

Table 4. Weight limits of each truck type (2020)

Truck Types	Dimensions	Loading Capacity
Normal Truck (With Awning or Open)	13.60 x 2.42 x 2.60 m (L x W x H)	20-24 tons
Maxima Truck (Towed Trailer)	13.60 x 2.44 x 2.80 m	20-24 tons
Mega Truck (Towed Trailer)	13.70 x 2.46 x 3.00 m	22-26 tons
Truck Trailer (Tilted Vehicles)	7.10 + 7.68 x 2.45 x 2.80 m	20-24 tons
Low Bed Trailer	13.60 + 6 x 2.55-3.00 x 3.00-4.00 m	25-80 tons
Hydraulic Trailer	13.00 + 13.00 x 3.00 -5.00 x 3.00-5.00	60-100 tons
Two Axle Trucks and Pickup Trucks	13.50 m	11-20 tons
Three Axle Truck	15 m	21-24 tons
Four Axle Truck (Centipede)	15 m	32-38 tons

Table 5. Average mileage by vehicle type (2020)

	Number of Vehicles	**Vehicles KM (million)**	**Average Year-KM**
Car	12.503.049	166.605	13.325
Minibus	493.373	12.155	24.637
Bus	213.358	9.622	45.098
Van	3.796.919	62.884	16.562
Truck	844.481	37.450	44.347
Motorcycle	3.331.326	12.839	3.854

5.2 Current Charging Stations

There are 6 companies in Turkey which provides charging solutions to electric and hybrid vehicles. This number increases to 11 companies when the foreign companies which started their investments. In addition to that, 18 companies currently holding their R&D operations to construct charging stations in Turkey.

Total number of charging stations is 3444, while it was 5 in 2015 (TEHAD, 2021). The number of charging stations in each city is listed on Table 5.

According to chairman of TEHAD, Berkan Bayram, 122 of the charging stations have fast charging technologies which can recharge a single vehicle by 80% in 45 minutes. However, the charging time increases to 5-12 hours for BETs. On-road charging and parking lots with charging technologies are also being developed in Turkey.

Table 6. Charging stations by cities (2021)

City	Number of Charging Station
İstanbul	1265
Ankara	320
İzmir	235
Antalya	162
Muğla	128
Bursa	123
Eskişehir	78
Konya	67
Afyonkarahisar	66
Diğer	1000

5.3 Potential for Electrification of Trucks

There are variety of factors that are affecting the potential of battery electric truck development as discussed below. The battery electric trucks offer GHG emission, reduction of fuel consumption and public approval. Turkey is a developing country which is at the very beginning of the battery electric truck development. Therefore, there are still uncertainties on the potential.

5.4 GHG Emission Reduction Potential

The electric generation in Turkey consists of %37.3 coal, %29.8 natural gas, 19,8% hydraulics, 6.6% wind, 2.6% solar, 2.5% geothermal and 1.4% other sources (Republic of Turkey, Ministry of Energy and Natural Resources, 2018). Since the GHG emission reduction of battery electric trucks highly rely on the energy mix, Turkey has a very

low potential to decrease the GHG emissions via adopting electric battery trucks. According to Turkish Statistical Institute, half of the medium and heavy-duty trucks are operating on the largest cities like Izmir, Istanbul, and Ankara. Therefore, the driving cycles are mainly including urban areas which battery electric trucks result better GHG emission reductions. Table 6 lists the percentage of resources used on electricity generation mix.

Table 7. Electricity generation mix of Turkey (2010-2019)

Year	Coal	Liquid fuels	Natural gas	Hydro	Renewable Energy and wastes
2010	26,1	1,0	46,5	24,5	1,9
2011	28,8	0,4	45,4	22,8	2,6
2012	28,4	0,7	43,6	24,2	3,1
2013	26,6	0,7	43,8	24,7	4,2
2014	30,2	0,9	47,9	16,1	4,9
2015	29,1	0,9	37,9	25,6	6,5
2016	33,7	0,7	32,5	24,5	8,6
2017	32,8	0,4	37,2	19,6	10,0
2018	37,2	0,1	30,3	19,7	12,7
2019	37,1	0,1	18,9	29,2	14,7

5.5 Fuel consumption Reduction Potential

Medium and heavy-duty trucks consume high volumes of fuel because of their gross weights. The fuel consumption also depends on the payload of the trucks. In terms of driving cycle, most of the medium and heavy-duty trucks operates on urban areas. Therefore, the potential of high fuel consumption of the trucks is very high.

5.6 Commodity Level Analysis

According to TUIK, biggest economic sectors in Turkey are mining, textile, road vehicles, machinery, and chemicals. Mining, road vehicles and machinery sectors are highly relied on trucks with high payload capacity (more than 22 tons), where textile relies on medium payload (between 10-18 tons) where chemicals rely different levels of payloads (Liimatainen et al., 2019).

The export operations of Turkey on the other hand are mainly to EU where GHG emission reduction is highly important (TUIK, 2020). The number of exported goods is listed on table 7.

Table 8. Exports by SITC (2021)

Total of 2021	
Food and live animals	14.459.179
Live animals	73.790
Meat and meat preparations	679.120
Dairy products and bird eggs	632.614
Fish, crustaceans, molluscs and aquatic invertebrates and preparations thereof	1.000.364
Fruits and vegetables	6.630.162
Sugar, sugar preparations and honey	740.668
Coffee, tea, cocoa, spices and manufactures thereof	758.021
Feeding stuff for animals	487.263

Table 8. Exports by SITC (2021) (continued)

Miscellaneous edible products and preparations	761.668
Beverages and tobacco	909.431
Beverages	336.460
Tobacco and tobacco manufacture	572.971
Crude materials, inedible, except fuels	4.863.793
Hides, skins and fur skins, raw	4.815
Oil seeds and oleaginous fruits	287.254
Crude rubber (including synthetic, reclaimed)	61.947
Cork and wood	87.087
Pulp and wastepaper	51.755
Textile fibres (other than wool tops) and their wastes	506.365
Crude fertilizers and crude minerals	1.542.720

Table 8. Exports by SITC (2021) (continued)

Metalliferous ores and metal scrap	2.038.523
Crude animal, vegetable materials	283.327
Mineral fuels etc	5.665.854
Coal, coke, and briquettes	8.598
Petroleum, petroleum products and related materials	5.382.301
Gas, natural and manufactured	130.651
Electrical energy	144.303
Animal and vegetable oils, fats, and waxes	1.359.537
Animal oils and fats	15.853
Fixed vegetable fats and oils	1.331.083
Processed animal or vegetable oils, etc.	12.601
Chemicals and related products	11.586.994
Organic chemicals	615.504
Inorganic chemicals	1.043.752
Dyeing, tanning, and colouring materials	779.951
Medicinal and pharmaceutical products	1.342.922

Table 8. Exports by SITC (2021) (continued)

Essential oils, resinoids and perfume materials; toilet, polishing	1.498.388
Fertilizers, manufactured	336.658
Plastics in primary forms	2.100.436
Plastics in non - primary forms	2.790.476
Chemical materials and products	1.078.907
Manufactured goods classified chiefly by material	45.750.016
Leather, dressed fur, etc.	230.565
Rubber manufactures	2.445.931
Cork and wood manufactures (excluding furniture)	963.880
Paper, paperboard and articles of paper pulp, of paper or of paperboard	1.980.974
Textile yarn, fabrics etc.	11.093.685
Non	4.352.262
Iron and steel - metallic mineral manufactures	13.364.636
Non -ferrous metals	4.367.170
Manufactures of metals	6.950.912

Table 8. Exports by SITC (2021) (continued)

Machineries and transport equipment	43.835.419
Power generating machineries and equipment	3.220.651
Machineries specialized for industries	3.424.790
Metal working machineries	683.574
General industrial machineries and equipment, and machine parts	5.626.689
Office machines and automatic data processing machines	129.755
Telecommunications and sound recording and reproducing apparatus and equipment	1.148.913
Electrical machineries, apparatus, and appliances, and electrical parts thereof	9.809.731
Road vehicles (including air - cushion vehicles)	17.451.201
Other transport equipment's	2.340.115
Miscellaneous manufactured articles	28.491.184
Prefabricated buildings; sanitary, plumbing, heating, and lighting fixtures and fittings	1.599.948
Furniture, bedding, mattress supports and cushions	2.983.464
Travel goods, handbags, and similar containers	175.527

Table 8. Exports by SITC (2021) (continued)

Articles of apparel and clothing accessories	13.692.879
Footwear	816.404
Professional, scientific, and controlling instruments and apparatus	915.958
Photographic apparatus, equipment and supplies and optical goods, watches and clocks	86.550
Miscellaneous manufactured articles,	8.220.454
Commodities and transactions not classified elsewhere in the SITC	4.029.467
Postal packages not classified according to kind	-
Special transactions and commodities not classified according to kind	1.931.939
Coins (other than gold), not being legal tender	2.039
Gold, non-monetary (excluding gold ores and concentrates)	2.095.489
Other goods not classified elsewhere	-

CHAPTER 6: EMPRICAL RESULTS

The results show that many companies share same concerns and motivations on adopting e-mobility. Economic pros and cons were the determining factor on almost every choice. There are several concerns and interests that the participants give more importance than costs, however none of them are reflecting actual operations – there are just personal opinions.

The logistics side is more concerned on environmental hazards than manufacturers. Manufacturer participants are less likely to adopt e-mobility because they have relatively higher concerns on high costs and driver acceptance. Reducing GHG has almost zero importance on manufacturers' operations. However, the participation from manufacturer side was relatively low, therefore there isn't enough data to make a sweeping statement for whole population. With that in mind, the results were listed as combined.

Question 1: Which sector are you working for?

In the first question, it has been seen that 75% of the participants were working for logistics sectors, where 25% of the participants were working for truck manufacturing.

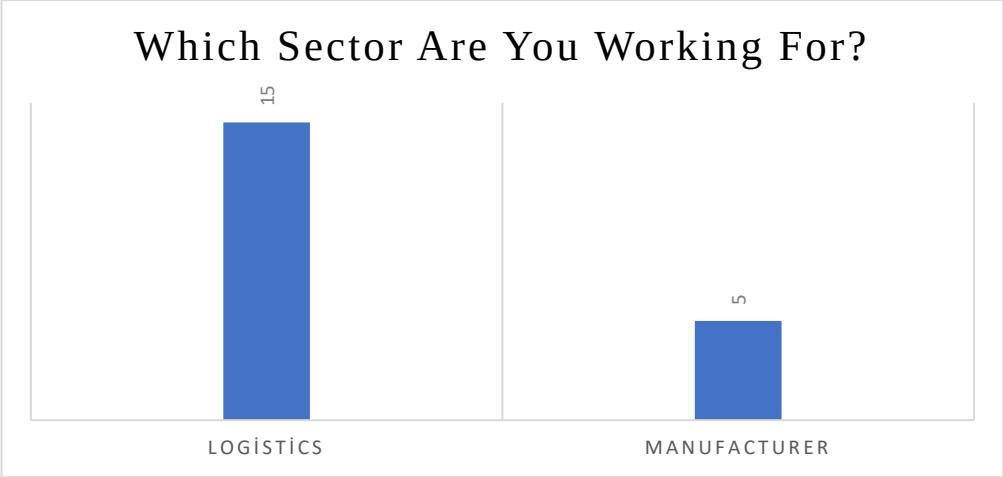


Figure 3. Distribution of Q1

Question 2: What is your role in the company?

55% of the participants are referred as *executives* or *managers.* It means that their decisions have potential to change the strategy of their companies. Therefore, it can be seen as a promising result.

The rest of the population are the specialist of their fields. Therefore, all the participants are well suited for the sample population.

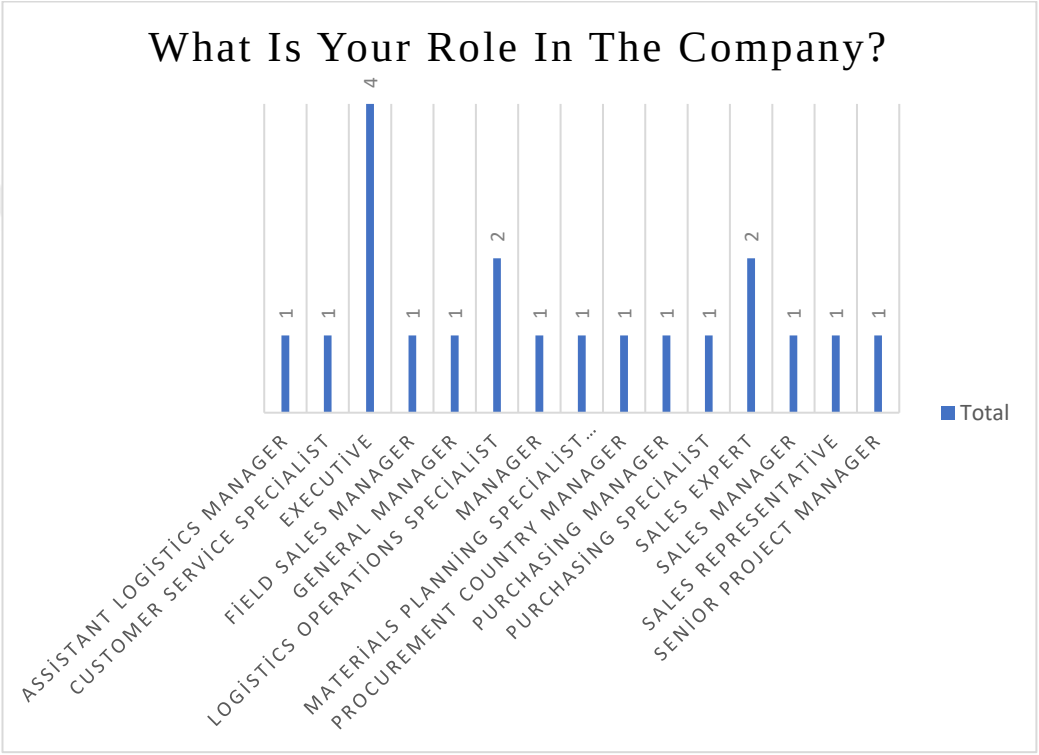


Figure 4. Distribution of Q2

Question 3: How many years have you been working in this industry?

The experience of the participants in the field is calculated by their working years at the related industry. Most of the participants (45%) are working in the related fields between 6-10 years. Only 1 participant is working more than 20 years. The second biggest portion of the participants have 1-5 years of experience with 30% share in total.

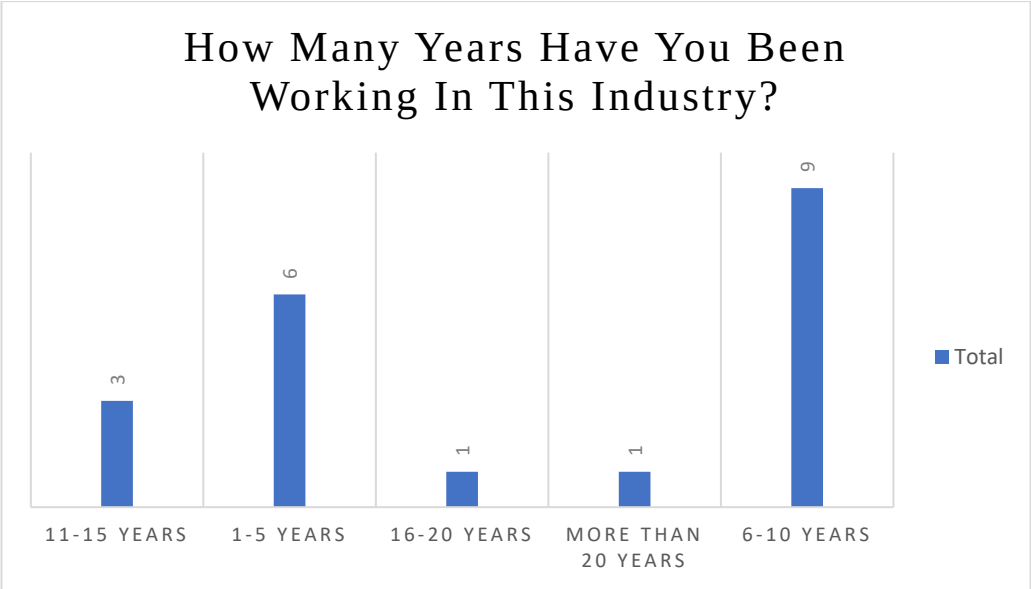


Figure 5. Distribution of Q3

Question 4: How many years has your company been operating?

80% of the companies were older than 10 years. 35% of total is older than 20% while the second biggest population is 30% with 11-15 years. Therefore, it can be concluded that most of the companies have been successfully operating for many years.

Figure 6. Distribution of Q4

Question 5: What is the size of the company you work for?

Q5 is the last question to determine the demographics of the company and participants. Only 1 company is a small company where 45% is a big, and the 50% is medium sized companies.

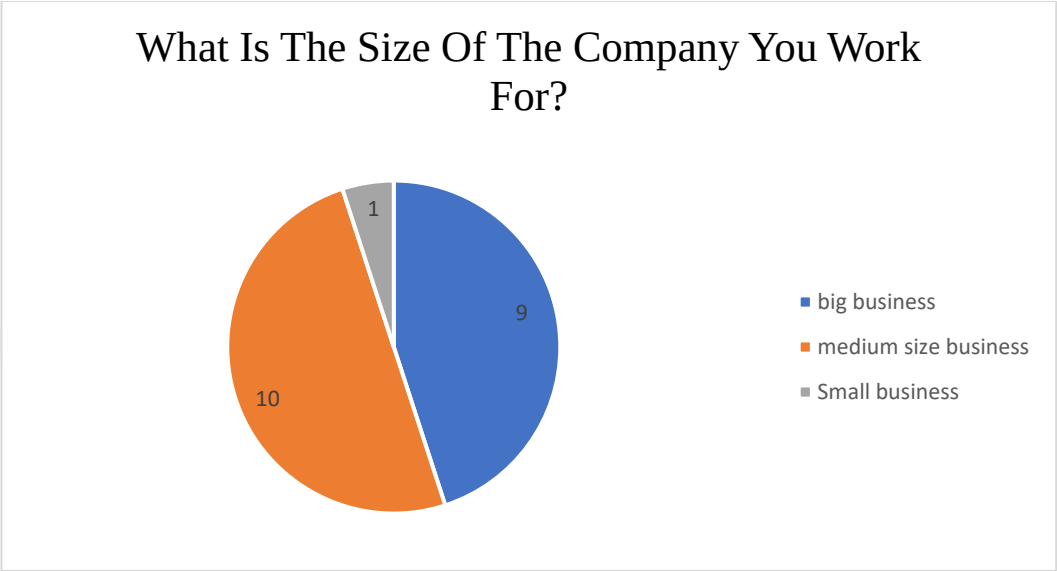


Figure 7. Distribution of Q5

First 5 question that asked to identify the characteristics of the companies showed that most of the participants are experts on their field where more than half of them are at or above manager level. The mainly show the logistics side but the manufacturer side is still big enough to affect the results. Most of the companies are older than 10 years old and big or medium sized companies so the possibility of having benefit from economies of scale is high.

Question 6: How many vehicles do you produce/use annually?

The economy of scale is only dependent on production or purchase amount of the trucks. Therefore, only one question has been asked to find the potential of companies to benefit from economies of scale. The question was multiple choice. 30% of the participant companies are producing more than 500 trucks, 20% producing/using 200-500, 25% producing/using 100-200, 10% producing/using 50-100 and finally, 15% of the participant companies were producing 50 or less trucks annually. Therefore, 75%

of the companies can benefit from economies of scale where 55% of them have very high potential with producing/purchasing more than 200 trucks annually.

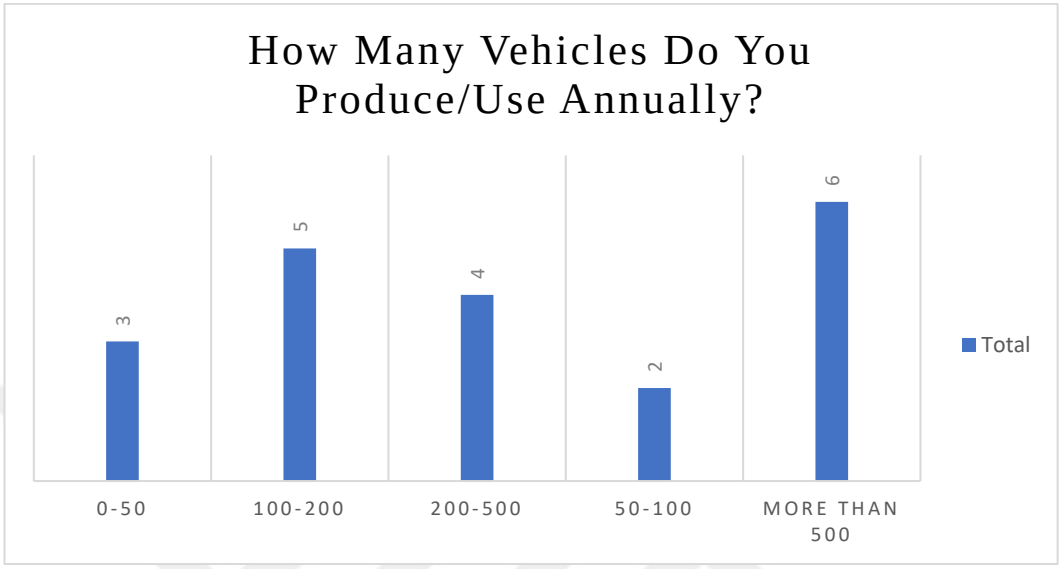


Figure 8. Distribution of Q6

Question 7: Which of the following is more important to your company?

Q7 was ranking question where the participants are asked to rank the most important factors for the company. The question can be related with "truck design" section. Yet it is indirectly related, so it is not grouped with other questions which are directly related with truck design.

50% of the participants selected "Low Fuel Consumption" as Rank 1 which makes the choice the most important factor. High payload capacity was selected as Rank 2 by 35% of the participants. The most selected factor for Rank 3, Rank 4 and Rank 5 were "long driving range", "low investment cost", and "low GHG emissions" by 50%, 35% and 55% of the participants, respectively.

The results show that one of the biggest advantage of BETs, which is decreasing fuel consumption, is the most important factor for supply and demand side. It highly increases the potential of adopting BETs. High payload capacity, on the other hand is one of the negative factors of BETs. However, it can be eliminated by new regulations.

"Driving range" and "low investments cost" are selected as "not very important". The only negative factor is the "GHG emission reduction" which is seen as the least important factor. It is the one of the main benefits of BETs. However, in general, corporal side acceptance is very high.

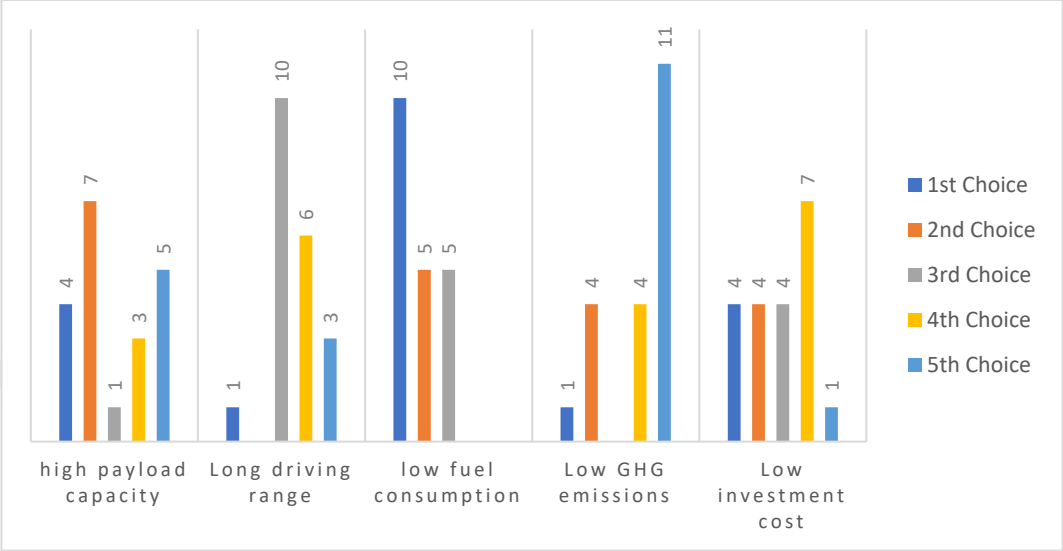


Figure 9. Distribution of Q7

Question 8 - What is your approach to electric trucks?

Questions between 8 and 18 are directly related with BET technologies. They include the battery trucks in general, charging stations and battery technologies.

Q8 shows that 80% of the participants are seeing BETs as positive (40% describes as highly positive). Only 20%'s approach was neutral where no one choose their approach as negative. This high percentage of acceptance is confirming the assumption made on Q7.

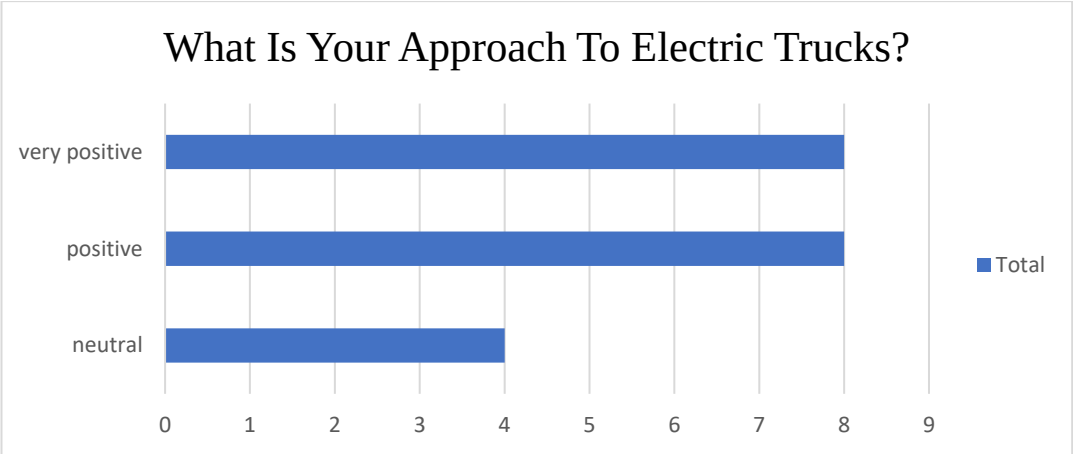


Figure 10. Distribution of Q8

Question 9: Would you prefer that the vehicles you manufacture/rent or buy are electric?

While none of the participants have negative approach on BETs, 30% of them wouldn't prefer them in their operations. 70% of the participants prefer to use electric trucks which shows that the purchase behaviour in general is highly positive. The motivations are detailed in Q10.

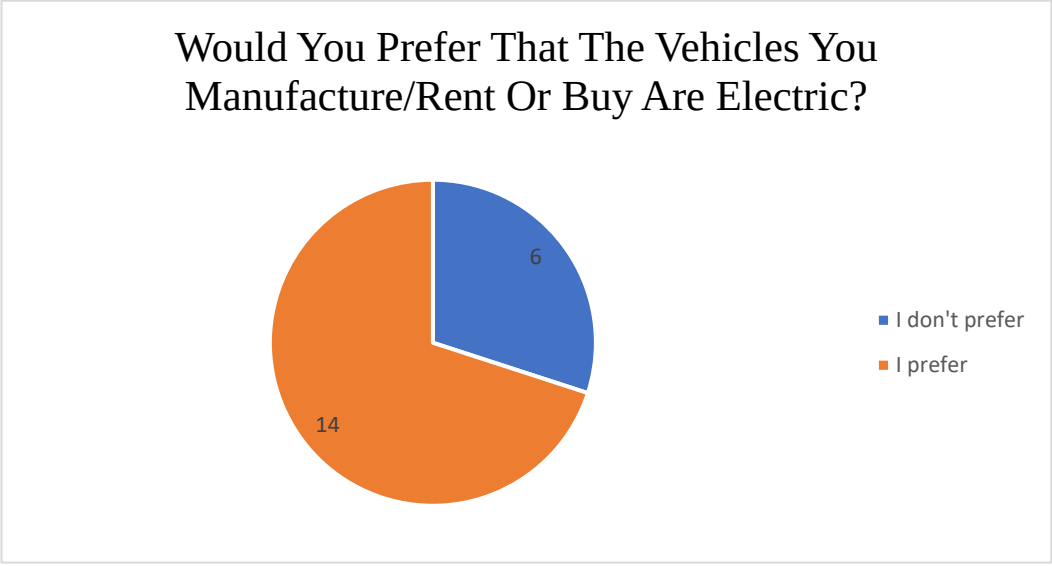


Figure 11. Distribution of Q9

Question 10: What is the reason for your choice?

Q10 shows that the environmental benefits of BETs were the main factor on choosing the technology. The second motivator is reflected as “decreasing fuel costs” which is also reflected on Q7.

5% of the participants do not prefer BETs because of the lack of infrastructure. The main barrier is shown as “lack of trust”. 25% of the participant’s classified BETs are “a new technology” and “not developed enough”. However, the answers of upcoming questions shows that the technology anxiety actually comes from lack of knowledge.

Table 9. Answers for Q10

Do you prefer?	**What is the reason for your choice?**
I prefer	Low consumption, more environmentally friendly use
I prefer	Fuel saving
I prefer	Sustainability, savings
I prefer	Environmental and material factors
I prefer	Increasing fuel costs and being environmentally friendly
I prefer	reduction in damage to the environment
I prefer	energy efficient technology, service-maintenance ease,
I prefer	Environment
I don't prefer	High cost and insecurity
I prefer	No fuel required
I don't prefer	Doesn't give confidence

Table 9. Answers for Q10 (continued)

I prefer	fuel alternative
I prefer	Decreasing the use of fossil fuel vehicles and leaving their place to cleaner energy sources.
I don't prefer	Lack of adequate infrastructure and efficiency
I don't prefer	a very new technology
I don't prefer	Technology is not enough
I prefer	Cost but I think it will be troublesome in the long way
I prefer	Economic and environmentalist
I don't prefer	Not yet developed enough
I prefer	environmentally friendly

Question 11 - Does the increase in incentives or new regulations related to electric vehicle technologies affect your choice?

Q11 shows that the incentives on BETs would affect the approach of 85% of the participants positively. On Q9, 70% of the participants states that they prefer BETs. It can be stated that the 15% of the participants would change their decisions positively if there are incentives on BETs.

Since the low investment cost was not a big factor on deciding the trucks and the high costs were not listed as a factor to negatively affect purchase behaviour on Q10, the incentive/regulation side can be characterized as incentives and regulations that positively affecting the operation side as payload or infrastructure.

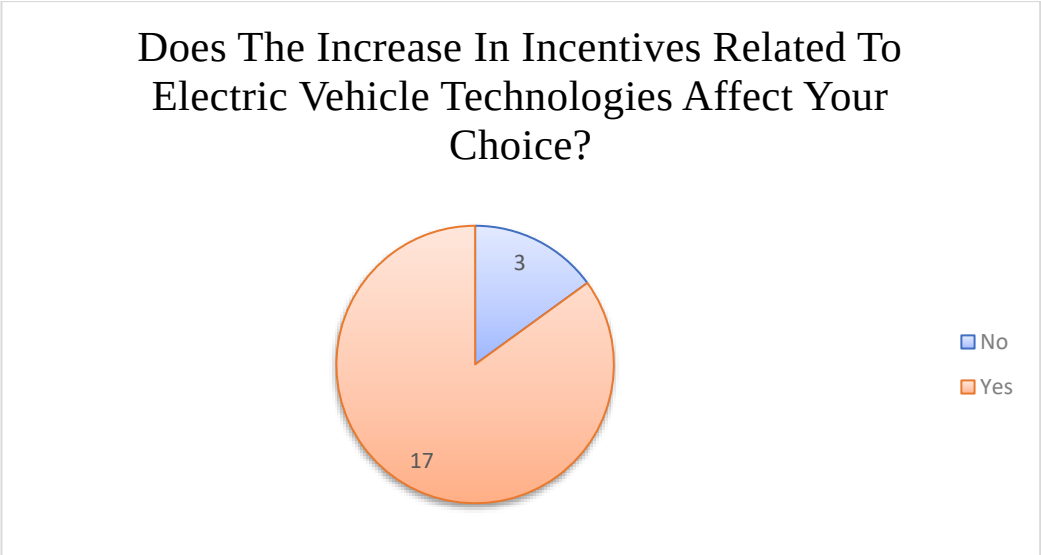


Figure 12. Distribution of Q11

Question 12 – Do you manufacture electric vehicles or use them in your operations?

85% of the participants do not manufacture or use BETs. Even if the motivation in general is high. It shows that even if the intentions are positive on the acceptance, they are not high enough to change purchase behaviour.

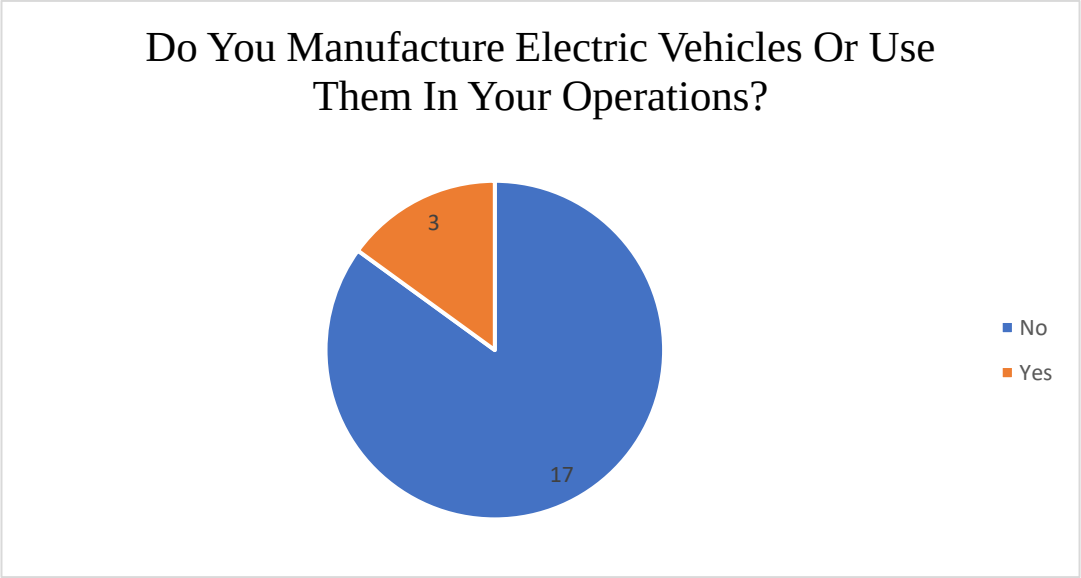


Figure 13. Distribution of Q12

Question 13 - If your answer is "yes", can you write how many trucks you produced/rented/purchased in 2021?

Only 3 of the attendants answer the question as yes and both considered electric passenger cars and forklifts. 2 of the attendant companies were using electric cars (10 cars) and one of the participants is using 2 electric forklifts. So we can clearly say that non-of the company's own BETs.

Question 14 - How many minutes do you think should be the optimal charging time for electric vehicles?

Most of the participants believe that optimal charging duration should be more than 15 minutes. Only 20% of the participants believe that optimal charging time should be less than 15 minutes, which is not possible even for the diesel trucks. Since the average charging time is more than 5 hours, the charging times should be an obstacle for the adoption of BETs in Turkey.

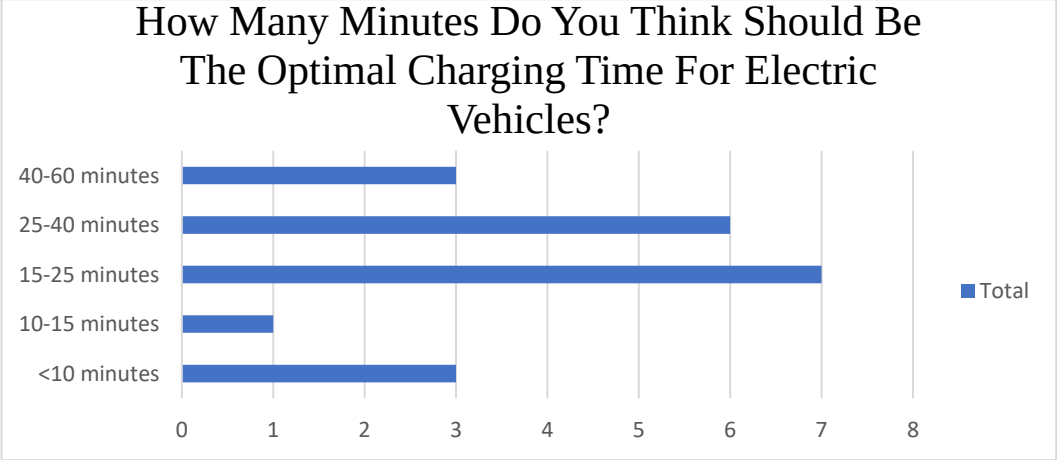


Figure 14. Distribution of Q14

Question 15 - Do you think there are enough charging stations for electric vehicles?

Even if the number of charging stations were increasing, all the participants said the charging stations in Turkey are not enough. So even if the answers do or do not reflect the reality, the approach to battery electric technology is still sceptical.

Question 16 - What should be the optimal average distance between charging stations?

30% of the participants believe that the average distance between charging stations should be less than 50km. However, 50% of them said average of 50km would be enough.

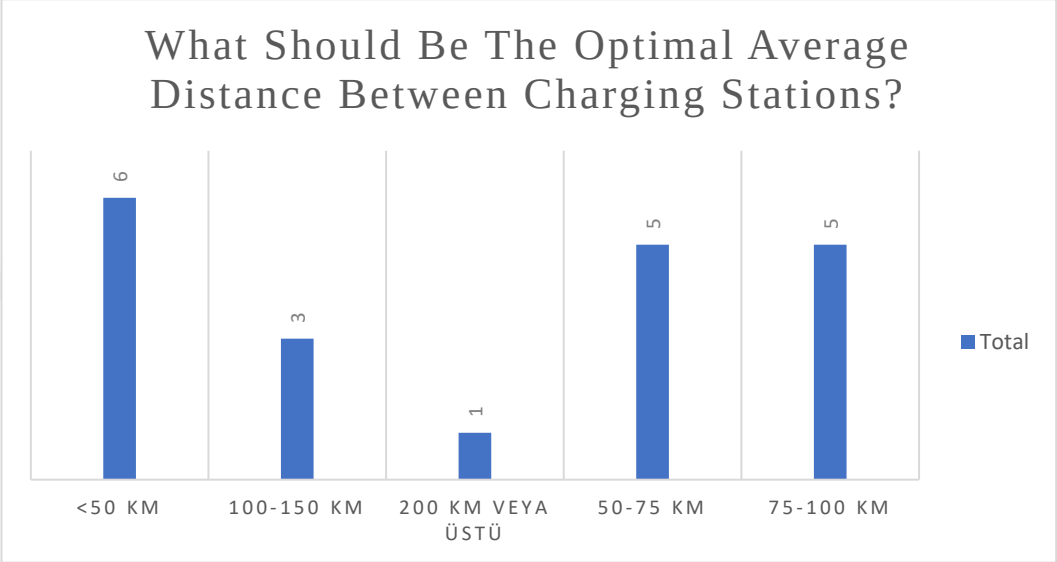


Figure 15. Distribution of Q16

Question 17 - With current battery technologies, how many kilometres should electric commercial vehicles travel in a single charge?

55% of the participants believe that the driving range should be more than 400 km. The state of art vehicles can travel more than 350km with a single charge however the costs are very high. Therefore, driving range is also an obstacle for Turkish companies. The latest battery technologies offer 400km of driving range. However, since the BETs suggested to recharge after using the 80% of the battery, the actual range is 320km. Therefore, the driving range of the current BETs meets the demand of 20% of the participants easily, where they barely meet the demand of 25% of the participants. However, the current technology doesn't meet the demand of 55% of the participants, which is the biggest obstacle before BETs that is determined in this article so far.

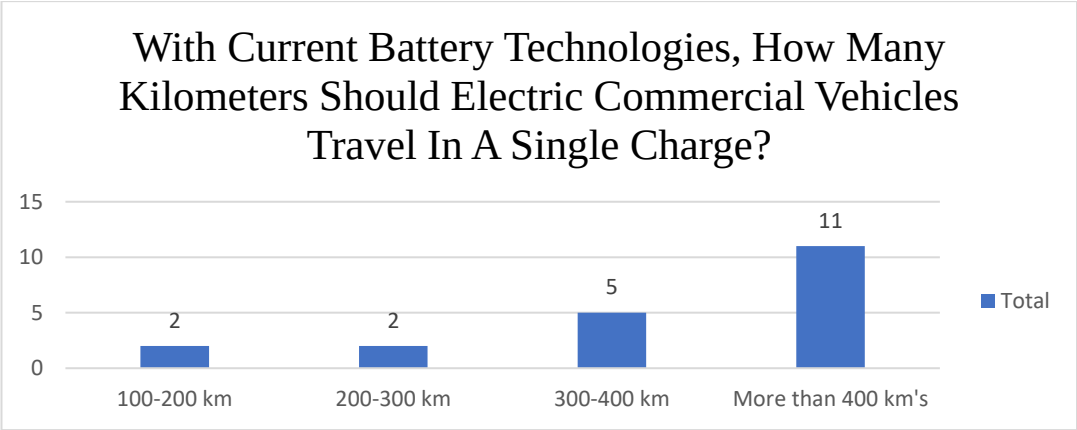


Figure 16. Distribution of Q17

Question 18 - Do you have greenhouse gas emission reduction targets in your company?

Questions between 18 and 24 are related with GHG emission reduction.

Q18 shows that 30% of the participant companies have GHG emission targets. It means that decreasing GHG would not affect the operations 70% of the participant companies as it mentioned before in this paper.

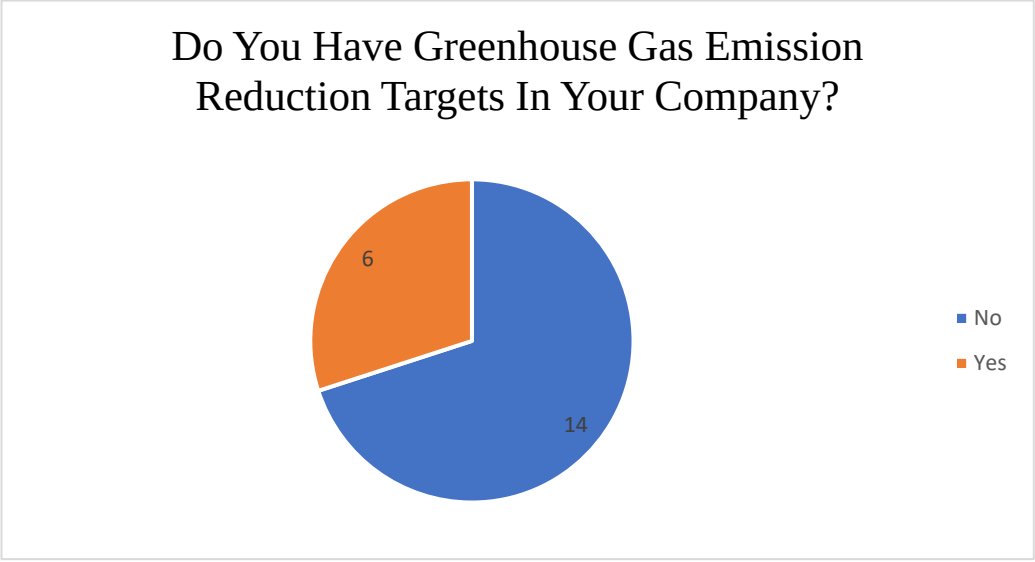


Figure 17. Distribution of GHG Reduction Q18

Question 19 - If your answer is "yes", what is your current goal?

Only 1 participant replied to the question as “to minimize the corporate carbon footprint by taking ISO 14064 Greenhouse Gas Training”.

Question 20 – Do you receive low emission truck requests from your customers?

35% of the companies are receiving low emission truck requests. However, only 30% of the companies set targets for their emission. It means that even if the participants receive demands for low GHG emission, they are not deterrent.

Figure 18. Distribution Q20

Question 21 – Does obtaining electricity from renewable sources in your region positively affect your perspective on electric vehicles?

Even if most of the participants doesn’t have obligatory demands on reducing GHG emission from their companies or customers, 70% of them said their acceptance would be higher if the electricity mix in their region would rely on renewable resources.

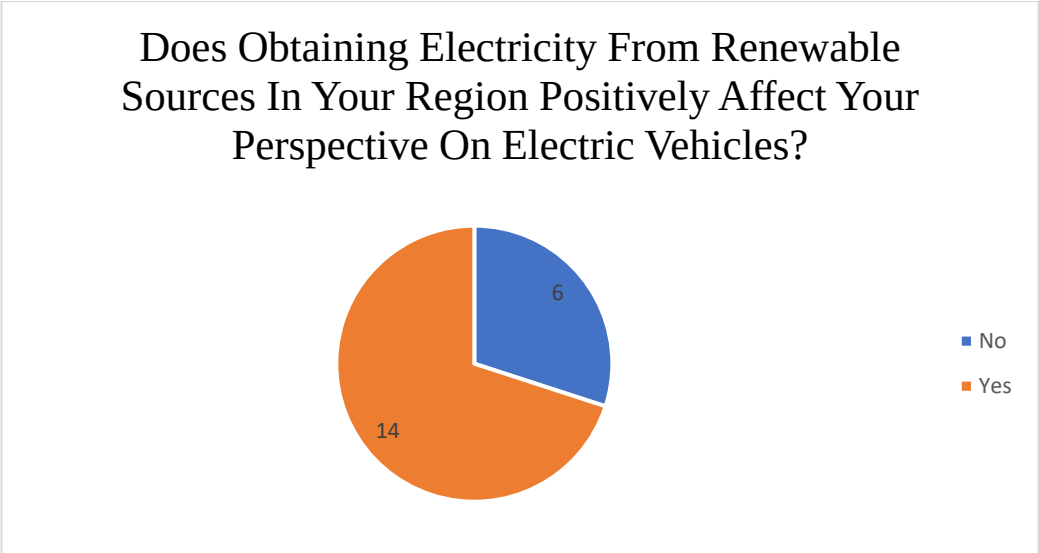


Figure 19. Q21

Question 22 – Do you calculate your GHG emissions?

Only 15% of the companies were calculating their GHG emissions. However, the information doesn't share with related fields as operations managers and specialists.

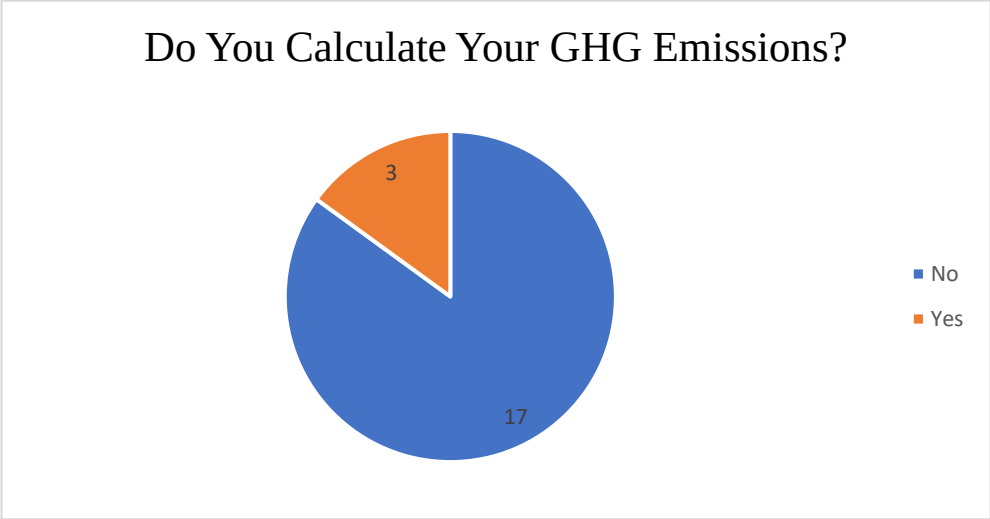


Figure 20. Distribution of Q22

Question 23 - If your answer is "yes", what was you emission levels in 2021?

None of the participants have information about their company's emission levels.

Question 24 - Would you consider taking steps to reduce GHG emissions by increasing some of their costs?

65% of participants are willing to reduce the GHG emissions of their companies even if it means to increase their total costs. This question once again showed that the higher costs are not negatively affecting the approach of participants on BETs.

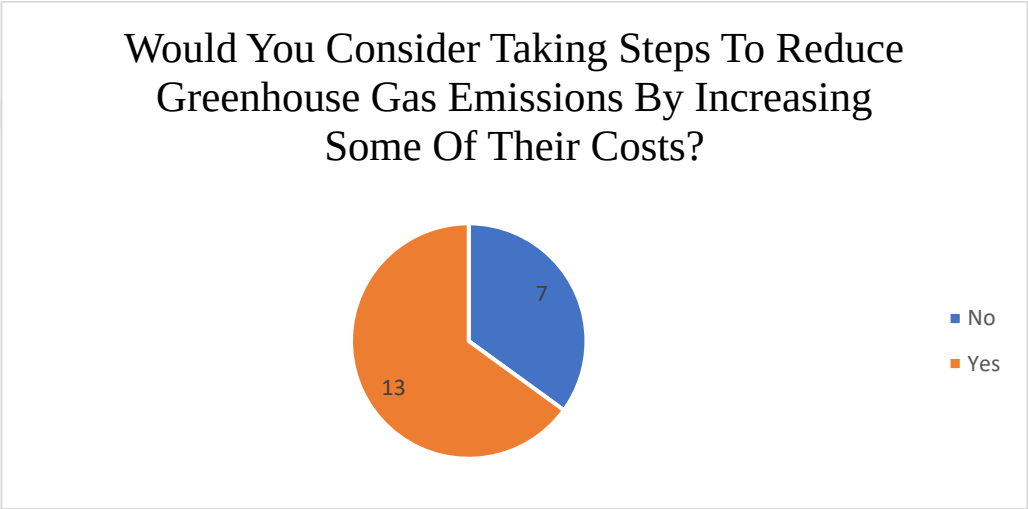


Figure 21. Distribution of Q24

Question 25 - What is the average target fuel consumption per 100 km for the vehicles you buy/rent/produce?

Questions 25 and 26 are related with fuel consumption cost. It is crucial because the fuel reduction is listed as the main factor on accepting the technology.

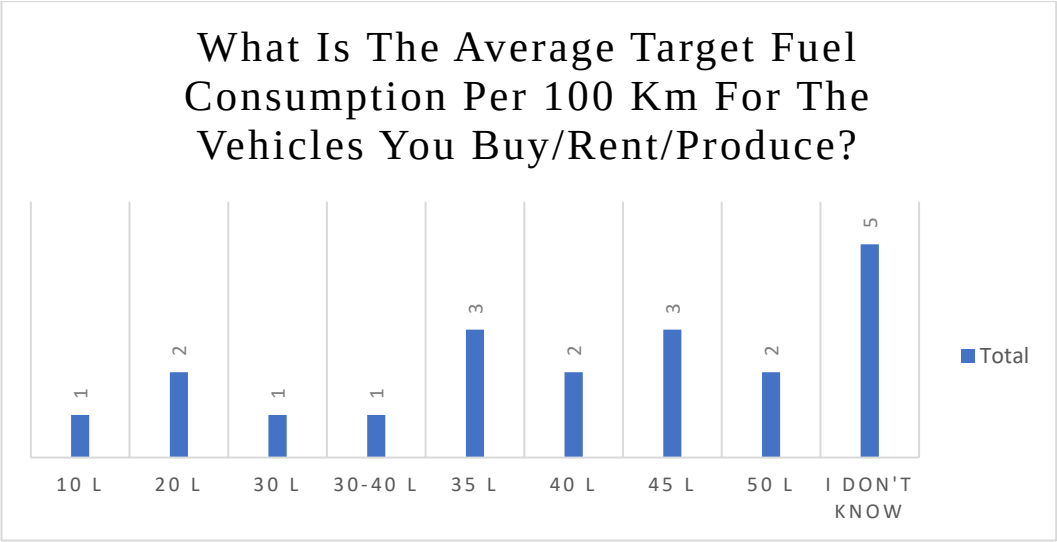


Figure 22. Distribution Q25

60% answers were between realistic range of 30-50L. However, most of them believe that the fuel consumption should be low where 25% have no idea about the fuel consumptions.

Question 26 – Are you looking for alternative fuels against the high increase in fuel prices?

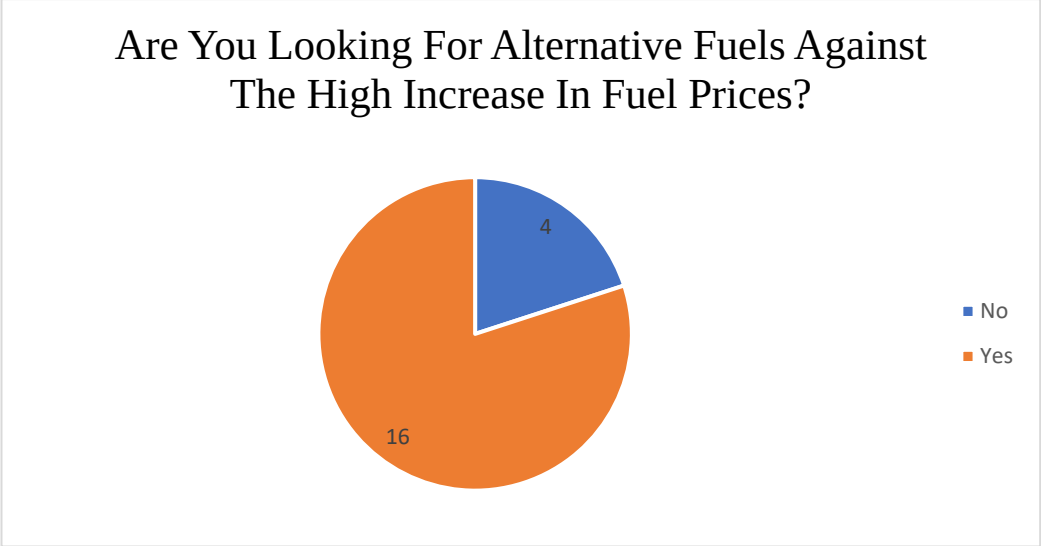


Figure 23. Distribution of Q26

Most of the participants are looking for an alternative for fuels because of the fluctuation in fuel prices. Only 20% percentage of the companies were not looking for an alternative. Q25 and 26 again confirmed that fuel consumption reduction of BETs

is giving them a great opportunity to be accepted.

Question 27 - In which industries do your customers generally work?

Q27 is related with commodity analysis. As it is mentioned in this article before, commodity analyses determine the dependency on payload capacity of the trucks.

Since the BET have lower payload capacity, they do not beneficial for mining, automotive, machinery, and some of the chemical sectors. The answered shows that BETs would be optional for more than %50 of the operations. Agriculture/food, furniture, textile, and some of the chemicals do not rely on high payloads, therefore low payload capacity of the BETs would not negatively affect them.

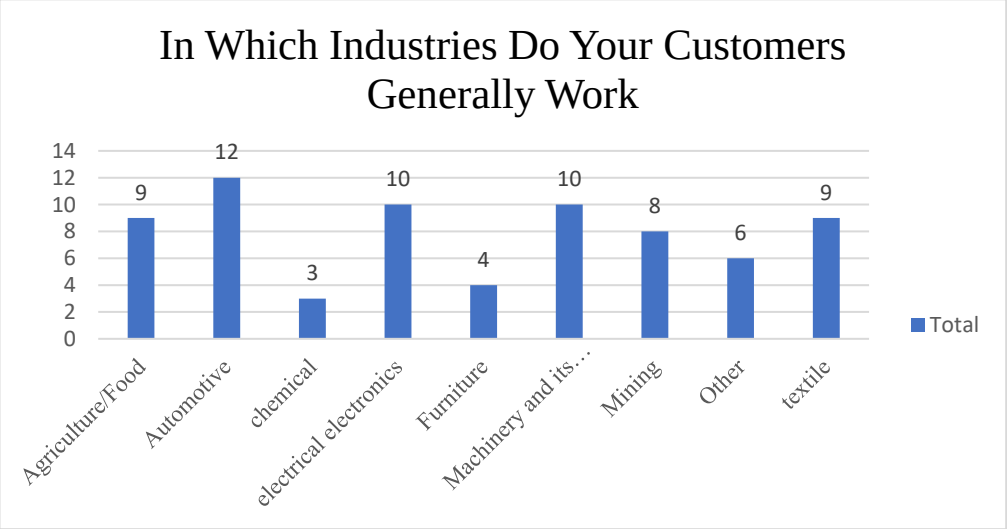


Figure 24. Distribution of Q27

Question 28 - Where is your main destination for international shipments?

Q28 is related with driving range. It is also important because the country or region of destination can affect the transportation mode or vehicle selection. For example, aviation's through are obligated to lower GHG emissions. 70% of the participants were working with EU companies so in some point, they would be forced to meet GHG emissions, mainly because of the 2050 climate goals of the EU. Therefore, the GHG emission reduction would be more dominant for those companies in the future, which would increase the potential of adopting BETs.

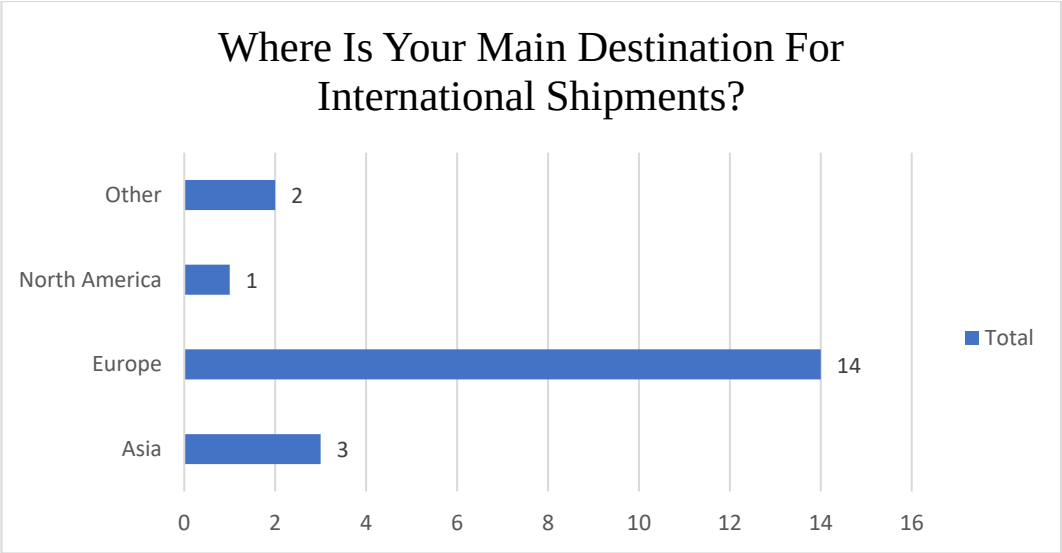


Figure 25. Distribution of Q28

Question 29 – Do you design the trucks, or do you prefer any design?

Questions 29 and 30 are directly related with truck design. 60% of the companies does not prefer any truck designs. All the manufacturing participants were interested in designs where only 2 of the logistics companies were interested in designs.

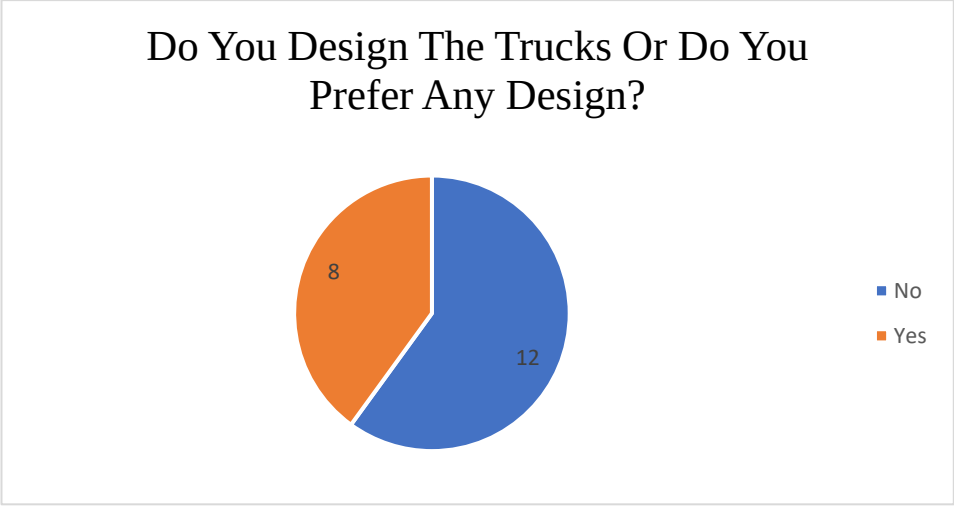


Figure 26. Distribution of Q29

Question 30 - What are the most important points for you in vehicle designs?

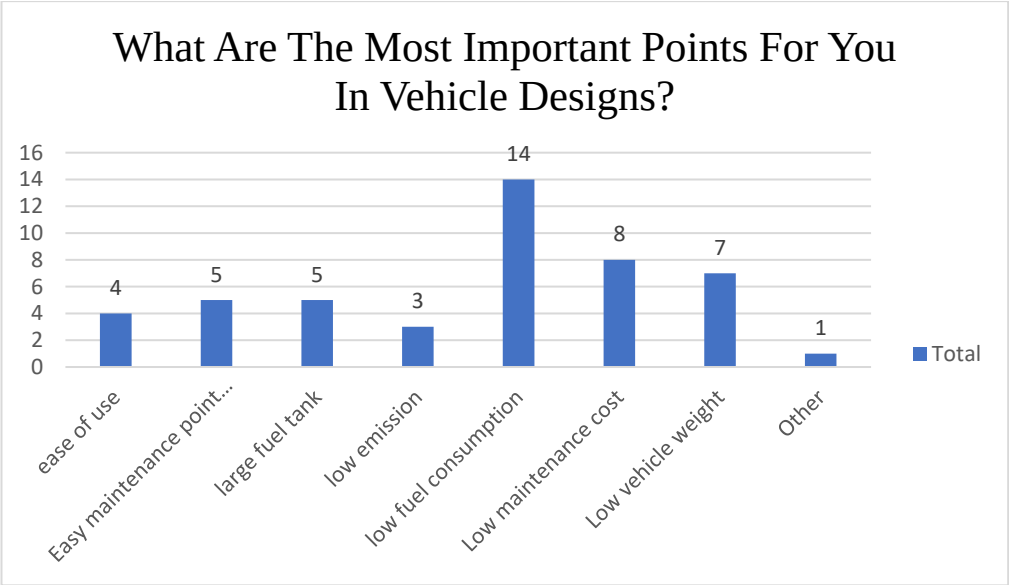


Figure 27. Distribution Q30

Question 30 shows one more time that low fuel consumption is the most important factor on deciding the trucks. However, second important thing on choosing the truck is the low maintenance cost where it is not an option for BETs at the moment because of the low know-how. The third factor that is affecting the design choice is low vehicle weight. As mentioned before, privileges to BETs are necessary because of the heavy weights of batteries. The low emission is again the least important factor if we exclude one answer as “other”.

CHAPTER 7. CONCLUSION

There were many parameters affecting the decisions on developing e-mobility. Through the literature review, 7 main parameters have been gathered.

The approach on BET's is both positive and negative on literature in terms on manufacturers side. Almost all of the articles are written in order to confute the negative approach of the end users. Many articles divided battery electric truck technology into truck types and determine the feasibility of each type. Yet all agree that the approach of manufacturers is relatively negative. Results of the survey is also shows that there are still concerns on BET technology on manufacturers side so the outcome is reflected as expected. The results are shown in Table 10.

Table 10. Expectations

	Expected Results	Unexpected Results	Both
1- Approach to BET's	+		+
2- Battery and infrastructure			+
3- Cost		+	
4- Emission Reduction		+	
5- Fuel consumption	+		
6- Public acceptance			+
7- Truck design	+		

The battery and infrastructure shown as a major barrier on literature. Driving range ang lack of charging infrastructure is a common issue. However, the latest research and articles shows that the battery and charging is not a major problem anymore. 55% of the participants says that the average millage on single charge should be more than 400kms. Also, 55% them believes that optimal distance between charging stations

would be less then 75km. When we combine those 2 approaches, it is clearly seen that most of the participants see battery and infrastructure as an obstacle on developing e-mobility. However, since there are divided opinions on battery and infrastructure on literature, both results were expected.

High capital cost and TCO also seen as an obstacle on literature. However, the 40% of the participants believes that low investment costs are their 4th or 5th priority. 20% them are also rated as 3rd priority so 60% of the participants does not see high investment costs as a major problem. Yet, the results don't seem to reflect the actions taken. Even though the participants don't seem to worry about the high costs, %90 of them don't have any operation electric vehicles. Therefore, the results only show the motivations, rather than intentions.

GHG emission reduction is the major benefit of e-mobility, and it is one of the main factors that is affecting the manufacturers and consumers opinion on developing e-mobility positively. However, 55% of the participants says that this is the least important factor that they are looking for choosing the truck on their operations. 20% of them also ranked GHG emission reduction as 4th. Even though Turkey lacks incentives and regulations in terms of reducing GHG emissions, this result is far away from expectations.

The general opinion on fuel consumption reduction, on the other hand, is positive as expected. Actually, it is more positive that what is expected. All of the participants are looking for an alternative for conventional fuel types. They are willing to accept all potential subsidiaries which will decrease their fuel costs.

Public acceptance is almost as expected. The information gathered on literature review shows that there are both positive and negative approaches on public acceptance. Environmental concerns are boosting the motivation towards adopting e-mobility. However, driving range, technology anxiety, high TCO and lack of infrastructure are still big concerns. The survey results also shows that while some of the participants are eager to accept e-mobility, some are still don't trust the technology.

Truck design is also important for participants as expected. Since the logistics companies are willing to carry more payload in order to increase revenues, they are highly interested in truck design. Truck load, battery weight and other factors which

are determined by the design is important for both manufacturers' and B2B customers.

Complete transitioning of battery electric trucks may not be a feasible option now because of the energy mix, current battery technology, TCO and technology anxiety. However, BET technology is improving each year. The important obstacles like driving range, battery weight and charging technologies are improving. Road transportation has high GHG emission. This issue takes the importance of many countries and companies because of air pollution and energy consumption targets. However, in Turkey, it is only important on personal interests. Even if the representatives of the truck manufacturing and logistics companies are mostly willing to decrease GHG emission, company targets do not support their ideas. The result of the survey shows that GHG is the least important factor on deciding the truck. However, Turkey's energy mix rely high GHG emitting resources. Therefore, even with the battery electric trucks, there won't be enough GHG reduction if the emission by generating electricity is included on total life cycle of GHG emission. The survey result shows that even if there are no corporal targets for lower GHG emissions, an electricity generation mix with renewable sources would positively affect the purchase behaviour of companies. In addition to that, there are no disincentives for GHG emissions that forces drivers and manufacturers to shift electric truck technologies in Turkey. Fuel consumption reduction on the other hand, gives the highest potential to BETs in Turkey. In any point of view, the results shows that the companies are mainly complaining about fuel consumptions, mainly because of the fluctuations on the prices. The diesel prices have increase from 6,43 TRY to 14,36 TRY per litre between January 2021 and January 2022. If the prices will increase in further months, the acceptance of BETs would increase highly. On commodity level, construction, mining, and transportation sectors are the main domestic economic factor in Turkey. Therefore, Turkish economy is highly relying on high payload in domestic. However, the main income of the country comes from exports which more than half of the exports are in textile, food, chemical and electric/electronics sector which payload is not important because of the lower weights. Therefore, the electrification of the trucks provides promising alternative.

Characteristics of driving cycles and road infrastructure seem unsuitable for electrification of trucks domestically. Most of the deliveries occur in urban areas in

Turkey. However, even if the trucks based on rural areas, they would eventually need to include the biggest cities (mainly Istanbul) to their driving rotations since it is the main route for export operations to EU. High purchase prices do not have big effect on big companies. However, the TCO which also includes maintained cost is still important. Low currency rates in Turkey enables further investments on Turkey by foreign countries. Ford Trucks, Mercedes and DAF already have facilities in Turkey (mainly including authorized body builders). However biggest portions of the facilities are manufacturing the trucks for EU market. The biggest factor that negatively affects BETs are technology anxiety and lack of infrastructure and charging technologies. Technology anxiety is common factor in all negative decisions on the acceptance of BETs. Also, the current charging times are 5 times higher than the optimal charging time that companies are willing to accept. To sum up, Turkey has great potential for production of electric battery trucks because of current truck manufacturing know-how. However, in terms of maintaining the battery electric truck technology in domestic market, the conditions in Turkey, in terms of infrastructure and purchase behaviour, seems highly unsuitable. Therefore, new incentives and legislations needs to be taken into an action in order to speed up the battery electric production and usage. Big and medium sized truck manufacturers and logistics companies that rely on exports on the other hand, has high willingness to adopt BETs. Even if the current demand and supply portfolio of trucks do not include BETs, the motivations are high.

POLICY SUGGESTION

There are plenty of articles regarding e-mobility. Most of them involving passenger cars, battery and vehicle design, feasibility analysis for countries or regions. The number of articles about medium and heavy-duty electric trucks have increased over recent years. However, they are yet not efficient. On the country and region side analysis, most of the articles are analyzing developed countries. For developing countries, it is an open discussion. Also, the corporate side analysis and demand side analysis is very few in numbers. Therefore, battery electric medium and heavy duty analysis on demand side can be a very promising subject, especially for other developing countries. Also, new methods for promoting e-mobility on countries with low GDP also a promising subject. Economies of scale used as a leverage for battery electric trucks on this article. There are many other concepts that can be considered in order to develop e-mobility on cost concerned countries.

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APPENDICES

Appendix A – SURVEY QUESTIONS

1. Which industry do you work in? Required to answer. single choice.

a) Logistics
b) Vehicle Manufacturer

2. What is your position in the company you work for? Required to answer. Single line text.

a) Enter your answer

3. How many years have you been working in this industry? Required to answer. single choice.

b) 1-5 years
c) 6-10 years
d) 11-15 years
e) 16-20 years
f) more than 20 years

4. How many years has your company been operating? Required to answer. single choice.

a) 1-5 years
b) 6-10 years
c) 11-15 years
d) 16-20 years
e) more than 20 years

5. What is the size of the company you work for? Required to answer. single choice.

a) Small business
b) medium size business
c) big business

6. Approximately how many vehicles do you produce/use annually? Required to

answer. single choice.

a) 0-50
b) 50-100
c) 100-200
d) 200-500
e) more than 500

7. Which of the following is more important to your company? Required to answer. Ranking.

a) low fuel consumption
b) Low greenhouse gas emissions
c) long driving distance
d) Low investment cost
e) High load carrying capacity

8. What is your approach to electric vehicle technology? Required to answer. Likert.

a) totally negative
b) Negative
c) I have no idea
d) Positive
e) very positive

9. Would you prefer that the vehicles you produce/rent or buy are electric? Required to answer. single choice.

a) I prefer
b) I would not choose

10. What is the reason for this choice? Required to answer. Multiline Text.

a) Enter your answer

11. Does the increase in incentives related to electric vehicle technologies affect your

choice? Required to answer. single choice.

b) Yes
c) No

12. Do you manufacture or use electric vehicles in your operations? Required to answer. single choice.

a) Yes
b) No

13. If your answer is "yes", can you write how many units you produced/rented/purchased in 2021? Single line text.

a) Enter your answer

14. How many minutes do you think should be the optimal charging time for electric vehicles? Required to answer. single choice.

b) <10 minutes
c) 10-15 minutes
d) 15-25 minutes
e) 25-40 minutes
f) 40-60 minutes

15. Do you think there are enough charging stations for electric vehicles? Required to answer. single choice.

a) Yes
b) No

16. What should be the optimal average distance between charging stations? Required to answer. single choice.

a) <50 km
b) 50-75 km
c) 75-100 km
d) 100-150 km

e) 200 km or more

17. With current battery technologies, how many kilometers should electric commercial vehicles travel in a single charge? Required to answer. single choice.

a) 50-100 km
b) 100-200 km
c) 200-300 km
d) 300-400 km
e) more than 400 km

18. Do you have greenhouse gas emission reduction targets in your company? Required to answer. single choice.

a) Yes
b) No

19. If your answer is "yes", what is your current goal? Single line text.

a) Enter your answer

20. Do you receive low emission truck requests from your customers? Required to answer. single choice.

a) Yes
b) No

21. Does obtaining electricity from renewable sources in your region positively affect your perspective on electric vehicles? Required to answer. single choice.

a) Effects
b) not affect

22.Do you calculate your greenhouse gas emissions? Required to answer. single choice.

a) Yes

b) No

23. If your answer is yes, how much emissions did you have in 2021? Single line text.

a) Enter your answer

24. Would you consider taking steps to reduce your greenhouse gas emissions by increasing some of your costs? Required to answer. single choice.

b) Yes
c) No

25. What is the average targeted fuel consumption per 100km for the vehicles you buy/rent/produce?Required to answer. Multiline Text.

a) Enter your answer

26. Are you looking for alternative fuels against the high increase in fuel prices? Required to answer. single choice.

b) Yes
c) No

27. In which industries do your customers generally work (you can tick more than one option)? Required to answer. multiple choices.

a) Mining
b) Textile
c) Machinery and its parts
d) Agriculture/Food
e) electrical electronics
f) Chemical
g) Automotive
h) Furniture
i) Other

28. Where is your main destination for international shipments? Required to answer. single choice.

a) Europe
b) Asia
c) Asia (Far East)
d) North America
e) South America
f) Africa
g) Other

29. Do you design trucks or do you prefer any design? Required to answer. single choice.

a) Yes
b) No

30. What are the most important points for you in vehicle designs? (more than one option can be selected)Required to answer. multiple choices.

a) Low vehicle weight
b) large fuel tank
c) low fuel consumption
d) ease of use
e) Easy maintenance point availability
f) Low maintenance cost
g) low emission
h) Other