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Analysis of HBE System Improvements to Aid Transportation Companies in the Transition to Electric Truck Fleet

by

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Abstract

In recent years, climate issues have been the focus of the international community. With the signing of a series of climate agreements, countries are also implementing various carbon emission policies or methods. The transportation industry is also developing in the direction of reducing carbon emissions. The electric truck market is also booming. This paper studies the gap between the current total cost of ownership of electric trucks and the total cost of ownership of diesel trucks. It also focuses on the relationship between the Dutch HBE market and the TCO gap through the establishment of the HBE-TCO model and correlation analysis and analyses how to improve the income of the HBE market and proposes solutions. At the same time, qualitative research and a series of interviews were used to verify the model and gain more knowledge of the market situation and future. The research shows that the HBE system can bring additional benefits to transport companies. HBE can contribute 6% to 32% to the TCO difference between electric trucks and diesel trucks with different conditions on HBE price, the number of trucks, average mileage of trucks and the green energy percentage.

Key words: renewable energy unit; total cost of ownership of trucks; renewable energy unit market; transition to low carbon emission

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COP: Conference of the Parties

EU ETS: EU Emission Trading System

EV: Electric Vehicle

GHG: Greenhouse Gas

HBE: Hernieuwbare Brandstofeenheden (Renewable Energy Unit)

ICE: Internal Combustion Engine

NEa: Netherlands Emission Authority

Red II: 2018 Renewable Energy Directive

REV: Netherlands Emission Authority's Transport Energy Register

TCO: Total Cost of Ownership

1 Introduction

With the intensification of the global climate problem, all countries have signed a series of climate documents, and all countries have put forward their own solutions to the climate problem. The focus of the climate problem is to control carbon emissions. The EU has established a carbon emission trading system for EU ETS (European Union Emission Trading System). The HBE (Hernieuwbare Brandstofeenheden, which means Renewable Energy Unit) trading system is built in the Netherlands to respond EU ETS. Dutch Emission Authority is also committed to achieving the long-term goal of carbon neutrality.

The Paris Climate Agreement is the agreement on global level. The European Green Deal will make the EU into a modern, resource-efficient, and competitive economy to solve environmental concerns. In order to make the EU's climate, energy, transportation, and tax policies suitable for decreasing net greenhouse gas emissions by at least 55% from 1990 levels by 2030, the European Commission has proposed a number of suggestions (European Commission, 2019).

RED II (Renewable Energy Directive II) aims to increase the use of renewable energy including the use in transport markets, which reduce dependency of transport of fossil fuels. It set the goal for that the EU's total consumption of renewable energy by 2030 should be increased to 32%. By 2030, member nations must demand that fuel providers deliver at least 14% of the energy used in road and rail transportation as renewable energy (European Comission, 2022).

HBE system is part of the Dutch implementation of EU policy. HBE forces energy supplier to increase the percentage of renewable energies provided to their customers each year until 2030. Additionally, HBE is traded on the HBE market between firms with surpluses and those with deficits.

HBEs might theoretically offer incentives to transportation firms who produce or utilize clean energy for their electric vehicles by installing their own charging stations (i.e., they are providing their own energy). If they adhere to the HBE regulations, they can earn HBE and sell them to other businesses, creating a new source of income. The benefit from HBE system can contribute to the Total Cost of Ownership of electric trucks and speed up the adoption of zero

emission transport. Similar to a diesel vehicle, an electric truck's total cost of ownership is determined. However, because electric transportation is a young business, there are a lot of unknowable variables. Although there are many unknown factors, the electric trucks have advantage in the total cost of ownership under certain situations (Envase, 2022).

1.1 Research Problem

The basic goals and principle of HBE trading system are to establish an appropriate trading mechanism to control carbon emissions and may also provide some incentives to primarily suppliers selling energy to the transport sector to enable them to make a transition to zero emissions.

In order to realize the transition to large-scale use of electric trucks, increasing revenue and reducing TCO (Total Cost of Ownership) will be the crucial goals, and HBE trading system can contribute to this goal. Transport companies that use electric trucks that are powered by green electricity (i.e., generated with clean energy) using their own charging infrastructure can generate credits in terms of HBEs. Because the TCO of electric trucks is higher than the TCO of diesel truck at the moment, the profit of HBE trading system can contribute to decrease the difference between TCO of electric trucks and TCO of diesel trucks.

While public transportation businesses using electric buses are benefiting from HBE, transport companies have not yet taken advantage of the HBE market to create additional revenue. Then why the transportation company has not used HBE and what conditions should be met to enable the transportation company to grasp the benefits of HBE will be the focus of the study. Transport businesses' lack of adoption of HBE may be due to a number of factors, including the following: (1) TCO is still too far away and HBE is ineffective yet; (2) many more requirements must be completed before companies can purchase trucks; (3) the HBE market itself is the issue.

1.2 Research Question

Under what conditions can the HBE trading system provide economic benefit to transport companies to the TCO of electric trucks of transportation companies and the transition to zero

emission?

Sub Questions:

1. What is HBE market/emission trading system?
2. How would transport companies use and benefit from HBE and how can transport companies use it at perfect/ideal situation?
3. What are the problems in the relationship between HBE trading market and the investment decision of a transport company to purchase EV?
4. What are the possible solutions to the problems that hinder transport companies to get benefit from HBE trading system?

1.3 Methodology

This study uses quantitative analysis and qualitative analysis methods. Based upon existing TCO models such as DANA Total Cost of Ownership Calculator (Envase, 2022) and TCO Freight model (Topsector Logistiek, 2022), the methodology of this study is to establish a model that can calculate the ten-year present value of HBE trading system profits and the ten-year present value of TCO of electric trucks and diesel trucks. It will study the impact of different variables on the present value of HBE trading system profits and the changes in the present value of TCO of two trucks. It can also provide suggestions to improve the HBE trading system or to transport companies on how to make better use of the HBE trading system.

The objective of qualitative research is to supplement some problems that cannot be understood from the literature in Chapter II Literature Review, so as to better establish a more appropriate model in quantitative research. Quantitative analysis is to find out the impact of key variables on the whole model through the established HBE-TCO model based on the result in the qualitative research and literature review.

Four Interviews with companies in the industry and government has been done to collect that on the applicability of the HBE. The respondents are transport companies, Dutch Emission Authority, Dutch researching institute of charging infrastructure and service company related to HBE.

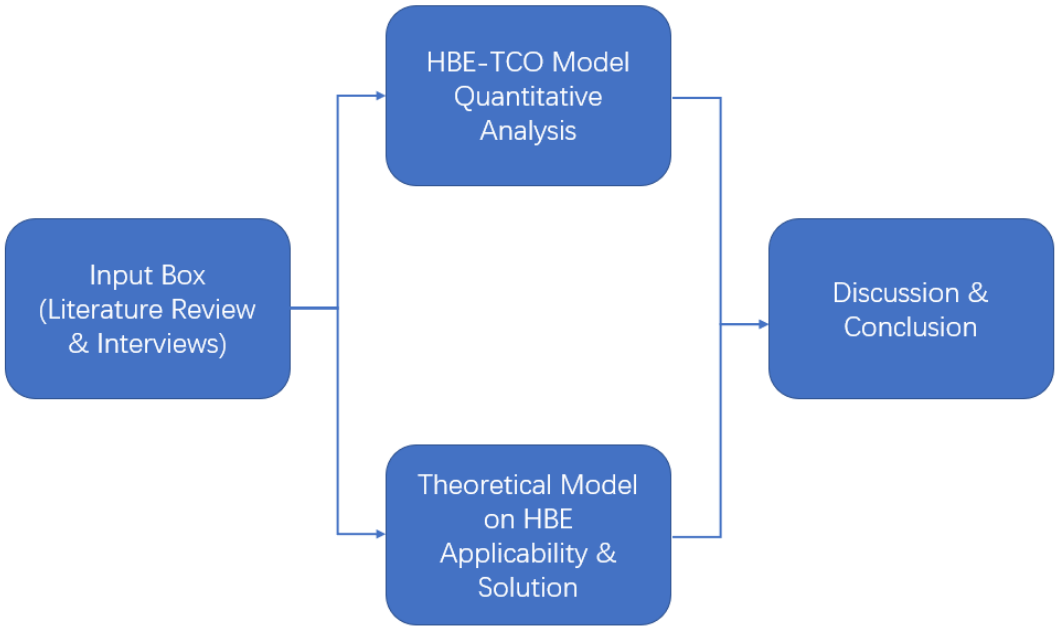


Figure 1 Methodology Flowchart

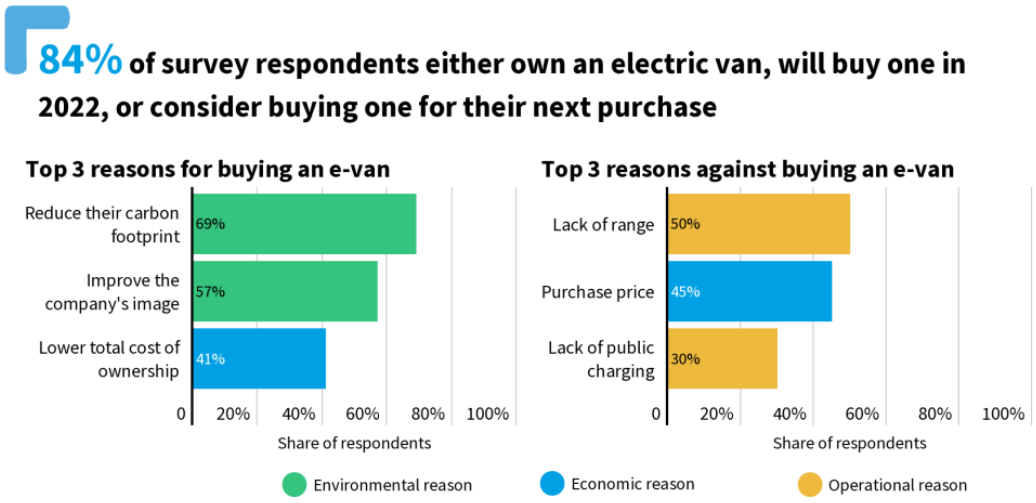


Figure 2 Questionnaire Feedback for Respondents Related to Electric Van, 2022

For the scope of research, the research focuses only trucks, but the research object does not include vans and buses. The public transport is already using HBE in their system because the buses are mostly already electric. In addition, vans are already economically viable, so there is no need to close gap of TCO. In the figure 2, although most electric van owners use it because

they want to reduce their carbon footprint and improve the company's image, 41% of respondents use electric vans because of the lower total cost of ownership compared to diesel vans (Transport & Environment, 2022).

1.4 Structure of Research

The structure of the research includes chapter 2 literature review, chapter 3 qualitative analysis, chapter 4 quantitative analysis, and chapter 5 the discussion on the research. The literature review introduces the background of the carbon emission control, TCO of trucks and HBE. In the methodology part, it introduces the HBE-TCO model. The quantitative analysis part discusses different scenarios in the HBE-TCO model. The qualitative analysis part gets feedback from different respondents in the industry such as electric fleet energy partner, transport companies, researchers of Dutch charging infrastructure and Dutch Emission Authority. The discussion on the research introduces quality of the research and the applicability of HBE.

2 Literature Review

2.1 Research Background-Global Level

Figure 3 shows that with the rapid growth of the global industrial system after World War II, the carbon dioxide emissions also increased rapidly. Under globalization, the world trade has increased, the transportation industry has become more prosperous, and the consumption of fossil fuels has also experienced unprecedented growth. From 1900 to 1940, the global carbon emissions from fossil fuels are only around 1,000 million metric tons, but it soared to 10,000 million metric tons in 2010s.

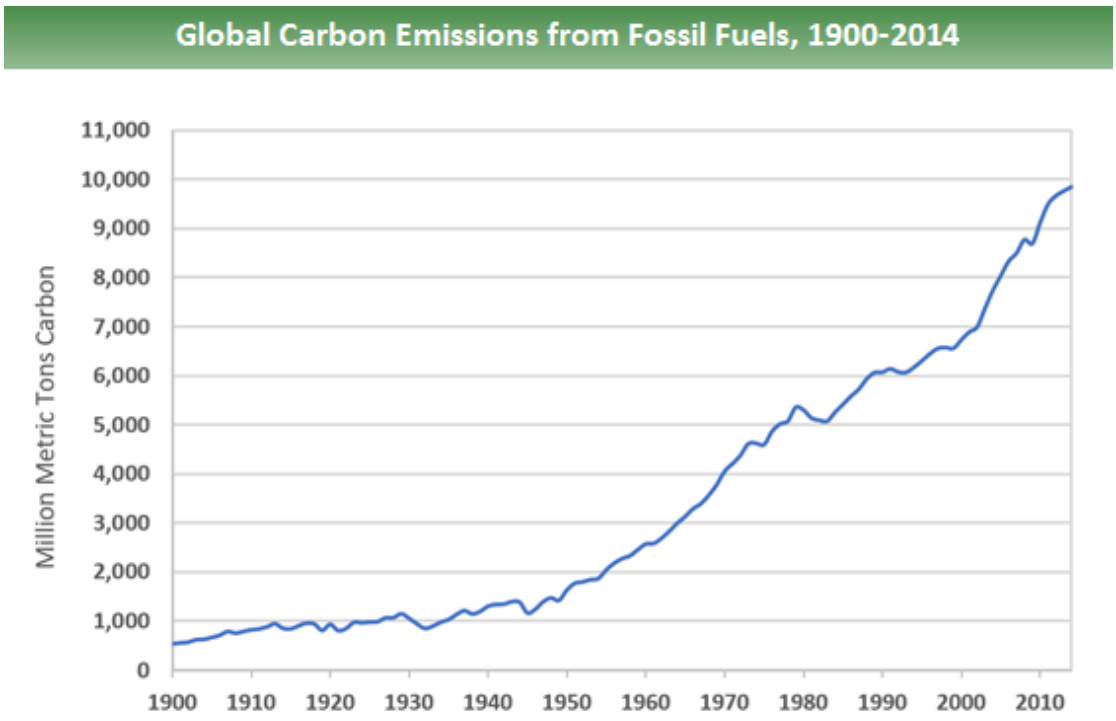


Figure 3 Global Carbon Emissions from Fossil Fuels, 1900-2014

Source: Boden, T.A., Marland, G., and Andres, R.J. (2017)

The Paris Agreement was adopted by 196 Parties at the 21st COP held in Paris on December 12, 2015, it entered into force on November 4, 2016. Compared with the preindustrial level, the goal is to limit global warming to far below 2 ℃, preferably 1.5 ℃. To achieve this long-term temperature target, countries aim to reach the global greenhouse gas emission peak as soon as possible, so as to achieve climate neutrality in the middle of this century. The Paris

Agreement is a turning point in the global fight against climate change because it is a legally binding agreement that for the first time unites all nations behind a shared goal and commits to making bold measures to combat the problem and prepare for its effects (UNFCCC, 2022).

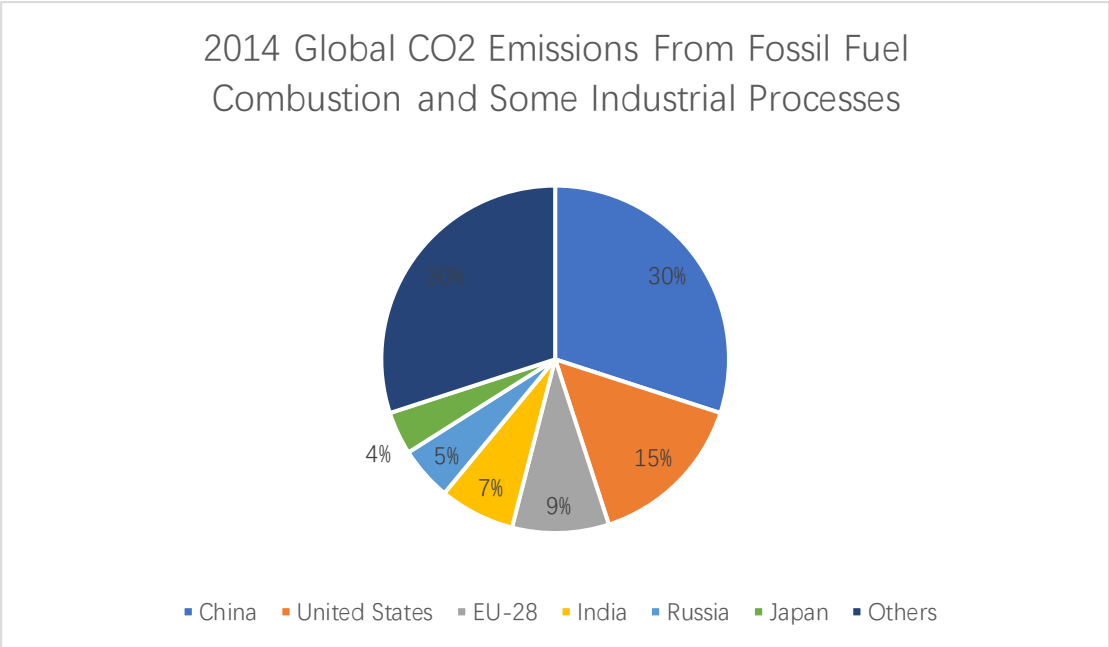


Figure 4 2014 Global CO2 Emissions by Country. Adapted from

Source: Boden, T.A., Marland, G., and Andres, R.J. (2017).

In figure 4, it can be found that the main carbon emissions in 2014 are from developing countries, which is very reasonable. The CO2 emissions from fossil fuel of China and others (mainly developing countries) can account for 60% of the global CO2 emissions from fossil fuel. The United States and EU-28 account for 24% of the global CO2 emissions from fossil fuel in 2014. Developing countries need a lot of energy in the process of carrying out a large number of infrastructure, transportation and other industrial projects, and this energy usually comes from the combustion of fossil fuels. The consumption of a large number of fossil fuels will lead to a high carbon dioxide emission. However, the industrialization of developed countries such as Europe and the United States has been gradually completed a long time ago. With the globalization of the world, many manufacturing industries in Europe and the United States have relocated to countries with lower labor costs and site costs, which further reduce the carbon emission level of developed countries. However, this is still far from enough.

To support the transition from fossil fuels to cleaner energy and, more specifically, to meet

the EU's commitment to reducing greenhouse gas emissions under the Paris Agreement, the EU undertook a thorough reform of its energy policy framework in 2019. The consumer, the environment, and the economy will all gain significantly from the new regulations. The Act further emphasizes the EU's leadership in combating global warming by coordinating these reforms at the EU level and significantly advances the EU's long-term goal of carbon neutrality (net zero emissions) by 2050 (European Commission, 2021).

The deployment of renewable energy has increased annually since the 2009 implementation of the Renewable Energy Directive (2009/28/EC), and it reached more than 22% by 2020. However, it also demonstrates that the EU's competitive position in the global renewable energy market can be further strengthened. The study of "EU's Global Leadership in Renewable Energy" in 2022 confirmed that the EU has taken the lead in the development and deployment of renewable energy technologies. These ideas attempt to develop an energy recycling and conservation system based on renewable energy, promote electrification based on renewable energy, and encourage the use of renewable and low-carbon fuels, including hydrogen, in areas where electrification is not yet practical, like transportation (European Commission, 2022).

Since it was revised in 2018, the Directive has undergone substantial revisions. Utilizing at least 32% renewable energy by 2030 is the new Renewable Energy Directive II (RED II) goal. The EU's package plan, “Fit for 55 package”, intends to cut greenhouse gas emissions in the EU by 55% by 2030. In July 2021, the European Commission put out the proposal. The law-making process has sped up, so the proposal may be passed by 2022. The initiatives include more funding for renewable energy and clean transportation, as well as a "Carbon Boundary Adjustment Mechanism" tax that attempts to cut the greenhouse gas emissions of imported high-carbon products from nations with inadequate carbon emissions (Carbon Brief, 2021).

2.2 HBE

2.2.1 Background of HBE Market

Regulations in Europe have promoted the use of biofuels since 2003. The European Renewable Energy Directive (RED) went into effect in 2009. As a result, the EU mandates that member nations boost the proportion of renewable energy in new fuels for road transportation.

The Netherlands charges national gasoline providers with this duty (annual obligation to transport renewable energy). This annual obligation can be explained as a kind of tax. In fact, it will require the national gasoline provider to buy the renewable energy unit to stimulate them to become more environment friendly. Red II took the place of RED in 2018, because with the publish of “Fit for 55 package”, the RED I is not sufficient to the target of reduce greenhouse gas emission. As a result, fuel providers are compelled to use 14% renewable energy in transportation by 2030. The target of the obligation regulation is to reduce the carbon emission in the transportation.

Operators of renewable energy sources must meet standards in order to be eligible for inclusion in the REDII goal. The specifications apply to the overall supply chain greenhouse gas emissions for all fuels. For biofuels, sustainability standards have also been established. In 2025, the updated REDII (REDIII) will go into effect. The EU's "Fit for 55 package" (which aims to cut emissions by 55% by 2030) includes REDIII.

Since this law's 2009 adoption, RED III has undergone three revisions of this type. In order to reduce the contribution of crop-based biofuels to the road transport energy portfolio, the Commission depends on out-of-date and unreliable justifications at each milestone. For instance, the Commission's frequent worry about "food and fuel" has long been known, and the tricky problem of indirect land-use change emissions has been handled by the phase-out of palm oil (Emmanuel, 2021).

Focusing on the greater objective of renewable energy is necessary for RED III to be effective. The potential of crop-based ethanol will be unlocked now that the sustainability issue has been resolved (as the Committee itself consistently confirms in its yearly renewable energy progress report); Additionally, promote the usage of advanced biofuels (Emmanuel, 2021). According to the RED II and “Fit for 55 package”, they only regulate the target of reducing carbon emission until 2030. The situation of these regulations after 2030 is not clear.

Dutch government is also responsive to the series of Renewable Energy Directive. The Dutch Government wants to cut greenhouse gas emissions in the country by 49 percent compared to 1990 levels by 2030 and by 95 percent by 2050 in order to combat climate change. The 28 May 2019 climate legislation stipulates these goals. Policies and actions to accomplish

these climate goals are included in the Climate Plan, the National Energy and Climate Plan (NECP), and the National Climate Agreement (Ministerie van Economische Zaken, Landbouw en Innovatie, 2019).

In the Netherlands, there are various policy instruments used, like restricted access to city centers for non-zero emission vehicles and subsidies. Besides these policy instruments, one of the other ways to reduce the carbon emission is that market mechanisms are used to achieve the objectives of raising the proportion of renewable energy in transportation and lowering greenhouse gas emissions from transportation fuels.

The Netherlands has established goals for reducing greenhouse gas emissions from transportation fuels and using renewable energy in the transportation sector. By 2025, fuel suppliers to the transportation sector must utilize 16.4% renewable energy. Additionally, by 2025 compared to 2015, they must cut greenhouse gas emissions from the fuels they provide by 6% (NEa, 2021).

2.2.2 HBE System

The HBE trading system is the Dutch implementation of the EU Directive such as RED II. An EU directive is a European Law that each country should adopt in their own legislation. The whole system is under the supervision of the Netherlands Emission Authority (NEa). Companies that supply fuel for transportation must account for a rising percentage of fuel that is made of renewable energy, which comes from naturally regenerating resources including biomass, wind, hydropower, and sun. The HBE system is addressing the energy suppliers to the transport sector and enforces to increase the share of renewable energies (NEa, 2021).

The HBE system is a market-based mechanism that enables importers and providers of fossil fuels to buy HBE in order to meet their yearly renewable energy targets. The first step is that providers of fuels should have a level of HBEs based on the annual requirements. The annual requirement is defined by the Dutch Emission Authority. The providers of fuels can either buy renewable energy sources and mix them with their gasoline or sell them directly as low emission or zero emission fuels. If the providers of fuels have not met the required level of HBEs, they can try to buy HBE from companies that have a surplus (NEa, 2021).

In accordance with the volume of renewable fuel sold on the Dutch market, fuel importers

and providers may acquire HBE, but they need register in the HBE market first and then they will have the rights to make transactions in HBE market. For entering the system, the registration must be done with verification, which will generate the audit fee (NEa, 2021).

HBE trading system is an emission trading market. These HBEs are listed in the energy transport register and obtain biofuels from fuel providers. These HBEs can subsequently be sold to fuel providers with yearly requirements. The HBE system has two roles. All registered energy providers must prove they have sufficient HBEs in the system. The second role is a trading register allowing matching of surpluses and shortages. The companies that do not trade in a relatively short period will remain in the HBE register and may keep their surplus before the checking date (Trinomics,2021).

Type of HBE	**Created by claiming delivery of**	**Further description**
HBE Advanced (HBE-A)	Liquid or gaseous advanced biofuel	Biofuel produced from feedstocks mentioned in Annex IX, part A of the Renewable Energy Directive
HBE Gas (HBE-G)	Liquid or gaseous renewable fuel	Fuel where the energy-content comes from renewable energy sources other than biomass
HBE Conventional (HBE-C)	Liquid or gaseous conventional biofuel	Biofuel produced from agricultural and energy crops
HBE Other (HBE-O)	Other liquid or gaseous biofuel	Biofuel produced from feedstocks mentioned in Annex IX, part B of the Renewable Energy Directive
		Biofuel produced from feedstocks NOT mentioned in Annex IX of the Renewable Energy Directive and which do NOT come from agricultural and energy crop
	Electricity	The renewable part, based on the European determined forfait

Figure 5 HBE Types

In figure 5, it shows that there are 3 types of HBE: HBE Advanced, HBE Conventional and HBE Other. HBE Advanced is created by claiming delivery of liquid or gaseous advanced or renewable fuel, such as biofuel produced from feedstocks and fuel where the energy-content comes from renewable energy resources other than biomass. HBE Conventional is that biofuel produced from agricultural and energy crops. HBE Other includes other liquid or gaseous

biofuel and electricity (NEa, 2021).

The Dutch government uses a trading system for the energy transport compliance system, which is basically a system that use the market mechanism to stimulate the providers of fuels to purchase HBEs to reduce their carbon emission. The HBEs are functioning as a tax here, because the fuel suppliers have to buy HBE units to reach the goal of their annual requirements assigned by NEa. However, the benefit from HBEs will be allocated to the supplier of HBEs, who are the companies responding to the environment protection policies such as the company used electric trucks. They have the option of purchasing HBE to meet their obligations or delivering and requiring the delivery of renewable energy to produce HBE themselves (NEa, 2021).

The Dutch Emission Authority has established such a system to control carbon emissions. Although NEa is the organizer of this system, the transaction of this system is bilateral between the buyers and sellers in the system. Hence, the HBE market is a free market. There are suppliers, such as some transport companies using electric trucks or other green gases, and demanders, such as traditional energy companies, such as ExxonMobil and other oil companies. They are required to master the specified number of HBE units, and they usually obtain HBE units by purchasing from suppliers and increasing the proportion of green energy in the energy they sell (NEa,2021).

2.2.3 Price Development of HBE

The HBE market is a free market. HBE's demand to some extent comes from the plan of the Dutch Emission Authority, but the transaction and HBE's supply are spontaneous market behaviors. Therefore, the price of HBE is also determined by the relationship between supply and demand (NEa,2021).

Therefore, the price of HBE is not fixed. Any factor that can affect the supply and demand of HBE can affect the price of HBE, such as the problem of European energy supply caused by the conflict between Russia and Ukraine, and the decline of electric truck TCO caused by technological progress (Barthel, 2022).

Due to the increased demand for road gasoline, HBE prices have increased over the three months in 2021, going from 13.30/GJ in April to 15.60/GJ in June (Barthel, 2021).

According to market players, advanced biofuels utilized in maritime transportation are providing an increasing amount of HBE-G supply. As a result, HBE-G trading has dominated the market's liquidity, and the price has decreased from an average of 18.60 euros per GJ in April 2022 to 17.75 euros per GJ in June 2022. Because the HBE that generated from the electric trucks only accounts for 3% of the HBE market, the price of HBE is mainly decided by the HBE-G market (Barthel, 2022).

In the case of granting a substantial number of HBE to the marine fuel business, the price of HBE compliance credit will fall dramatically in most of 2022. On November 24, the price of HBE was 12.50 euros per gigabit joule, almost 36% less than it had been in early January, according to broker statistics. Late last week, the cost of category "B" was around 11.75 euros per gigabit joule, down 8.25 euros or 41% for the entire year (McGarrity, 2022).

Additionally, the market transfers 1 billion euros annually from fossil fuel businesses to green ones. Between 2% and 3% of energy/HBE will be produced by electricity by 2021. As a result, just 3% of the market is represented by all the charging stations in the Netherlands as well as all the fast-charging stations operated by Tesla and Fastned. This is due to the market's significant share for gasoline. The party that manufactures green gas and green biofuels thereby controls 97% of the market, making them the dominant product. This implies that the market for HBE will increase even if fossil firms need to purchase 10% to 20% more annually. The price will surely climb as the market for HBEs becomes scarcer (Gunsing, 2022).

In order to encourage more businesses to install charging stations, the Dutch Parliament passed the Grinwis resolution, which mandates that the Dutch government investigate various plans to make small businesses more economically desirable to participate in the HBE system (Trinomics, 2021).

The price of HBE and the proportion of renewable power in the Netherlands both affect the tipping point for small companies to ear benefits from HBE market. If the price of HBE unit increase, the economic benefit from HBE system will increase as well. The proportion of renewable power in the Netherlands in the network will affect the percentage of the clean energy in the electricity power network. For now, the percentage of clean energy in the electricity power network only accounts for 26%, so only 26% of the power from the electricity power

network can be counted for the HBE conversion. It will increase with the increase of the proportion of renewable power in the Netherlands (Trinomics, 2021).

2.3 TCO

TCO is total cost of ownership (TCO), which is used to describe the sum of a product's direct and indirect expenses. In this context, the term applies to trucks. Budget and planning, asset life cycle management, vehicle selection, supplier selection, and lease and buy decisions may all benefit from considering TCO (Manutan, 2022).

The TCO model examines not only the vehicle's purchase price but also the total cost of ownership, which includes infrastructure for charging, subsidies, depreciation, maintenance, etc. By entering parameters, the user may see how their changes would affect the cost per kilometer. Consider the durability of vehicles, the size of the subsidies, or the cost of electricity or diesel (Manutan, 2022).

Companies need positive TCO for investment, but currently the gap between the TCO of electric trucks and the TCO of diesel trucks is big. As shown in the following figure, the heavy-duty diesel truck purchase cost is 105,000 dollars, but the heavy-duty electric truck purchase cost is 380,500 dollars, which is much higher than diesel truck. According to the figure, the purchase cost of electric trucks will decrease to 177,000 dollars in 2030. Although it is still higher than diesel trucks, it is more affordable for transport companies.

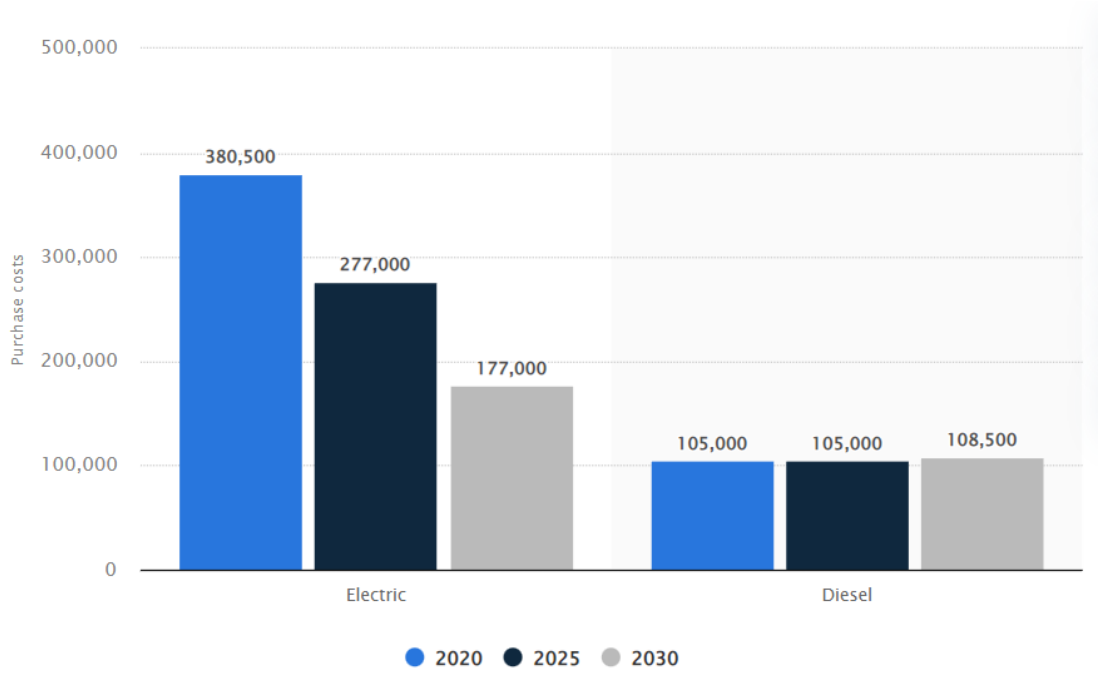


Figure 6 Projected heavy-duty truck purchase costs between 2020 and 2030, by fuel type (in U.S. dollars), Statista 2020

Compared to diesel and natural gas vehicles, electric trucks also lose value more quickly. The largest upfront cost of electric trucks is caused by the high cost of batteries. More than 30% of the cost of a vehicle is made up of light and medium trucks, while more than 55% is made up of heavy trucks. Because an electric truck loses 50% of its value in just five years, the initial owner is responsible for paying around 60% of the total cost of ownership (ReportLinker, 2021).

Besides higher purchase cost and higher depreciation cost, the investment of purchasing electric trucks includes the investment to the charging infrastructure, which will increase the TCO of electric trucks further.

The HBE system also helps to electrify transportation, but due to administrative and budgetary constraints, this potential is not completely realized, especially for small firms (Trinomics, 2021).

2.4 The Problems for Small Companies to Generate Benefit from HBE

Small businesses will encounter considerable obstacles if they want to take advantage of HBE, and the reasons are obvious. Because small enterprises usually do not own many electric trucks, when the number of electric trucks does not exceed two, it is difficult for the company

to obtain profits from the HBE trading system.

In order to participate in the use of HBE system, each company also needs to pay an audit fee every year, and the company also needs to have its own charging facilities to earn more HBE. For small companies, the purchase of electric trucks has been a big expense, while the construction of their own charging facilities further increases the burden.

A considerable amount of power qualified to earn HBE may not be recorded due to the administrative and verification requirements of taking part in the HBE system, notably electricity supplied by small businesses (Trinomics, 2021).

The problem of small enterprises participating in the HBE market is about all kinds of cost. Small enterprises usually do not own more than two electric trucks, because the TCO of electric trucks is still much higher than that of diesel trucks (Gunsing, 2022). Based on Gunsing's statement, it can generate profit when the number of trucks is over two, but the current purchase price of electric trucks is much higher than the purchasing price of diesel trucks. Therefore, small companies cannot afford two electric trucks. However, the verification fees required to enter the HBE market are the same for each company, which means that small enterprises are more difficult to gain benefits from the HBE market (Trinomics, 2021).

The plausible ways to make small participants' bookings more financially appealing under the existing legal framework are to take steps to lower the cost per subscription. The first solution is the parent company's executive summary input, input via authorisation to the service provider, and standardization of papers needed for registration, which can lower the expenses that the subscriber must incur within the parameters of current laws and regulations. Adjusting or removing the verification criteria for small players is another choice that makes it more financially feasible for them to register (Trinomics, 2021).

The factors that influence HBE benefits to transport companies can be divided into 4 kinds of factors. They will influence the accessibility to HBE, revenue of HBE, costs of HBE and financial risk of HBE market respectively.

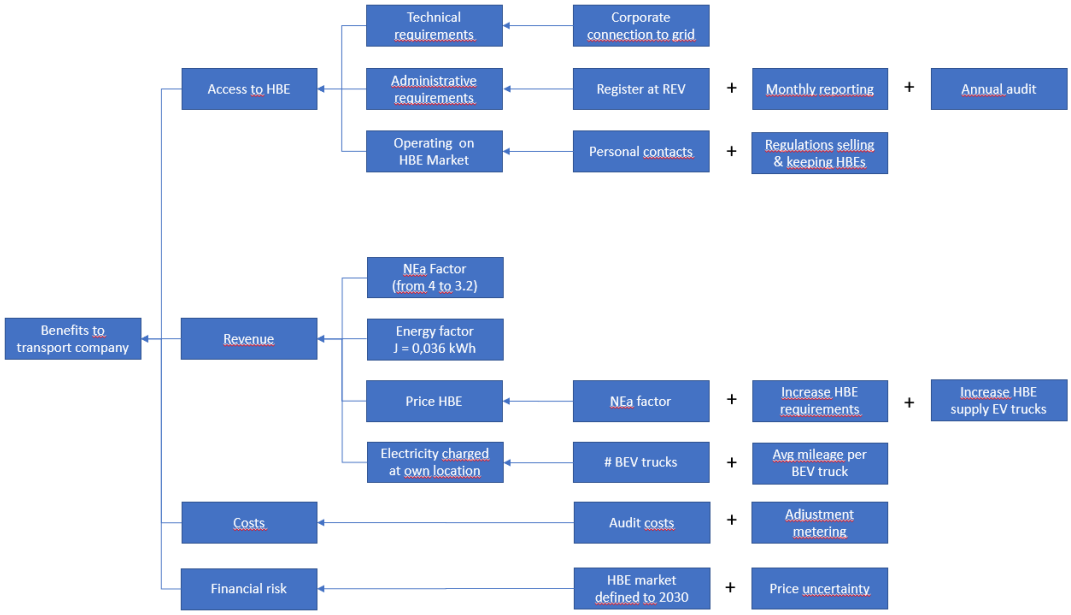


Figure 7 The Overview of Factors for HBE Benefit

There are three aspects including technical requirements, administrative requirements, and operation on HBE market. The technical requirements are mainly about the power connection to grid. The administrative requirements include registration at REV, monthly reporting, and annual audit. These are all the administrative costs that could happen in the operation in the HBE market. Last but not least, some details of the operation of on HBE market will affect the accessibility to HBE such as contract types (personal contracts or broker) and regulations for selling and keeping HBE units.

For the parameters that will affect the revenue include energy factor, NEa factor, the price of HBE and the electricity charged at own location, which is the electricity power consumption. For the cost part, there are audit costs and adjustment metering. The main financial risk is the HBE market is currently only defined to 2030 and the price of HBE is also uncertain as discussed in the previous section.

2.5 Literature Review Conclusion

In response to global warming, the European Renewable Energy Directive (RED) promotes the use of renewable energy. Road transport is a major source of greenhouse gas emissions. The Netherlands also imposes obligations on gasoline suppliers for road transport, which can be understood as a tax. The European Renewable Energy Directive is also being updated. In 2018,

RED II replaced the previous RED, and the updated RED III will come into force in 2025.

In response to the EU renewable energy directive, the Dutch government has established the HBE trading system, which regulates the market of traditional fuel suppliers (HBE demanders) and transport companies using electricity energy (HBE suppliers) based on the mechanism of free market trading.

The HBE system can control the carbon emission by the market mechanism. The price of HBE unit is not fixed and it is constantly changed because of the relationship between the supply and demand of HBE units since it is a free market. The trends of the price of HBE unit will go up according to Gunsing's statement.

The RED III will be implemented in 2025. It will increase the reduction target of carbon emission further. It is assumed to increase the demand of HBE units.

There are four kinds of factors that influence the HBE benefit to the transport companies. Four kinds of factors are in four aspects including the access to HBE, revenue, costs and financial risk.

The access to HBE is affected by technical requirements, administrative requirements and operating on HBE market.

Technical requirements include two parts, corporate connection to grid and certified meter charging system. These two will help transport companies to successfully get HBE units without any technical issues. In the meanwhile, it will lead to some costs if transport companies do not have the qualified charging infrastructure.

Price of HBE is decided by NEa factor and the supply and demand of the HBE market. With increasing HBE requirements from NEa and the increasing HBE supply by electric trucks, the HBE market scale will expand as well. Electricity charged at own location will be affected by the number of electric trucks and the average mileage per electric truck.

Costs include audit costs, adjustment metering and brokerage costs. Transport companies have to pay for annual audit or verification service to be qualified to register in the HBE system. Adjustment metering cost happens when the charging infrastructure of transport companies are not in accordance with standard to gain HBE units. Brokerage fee is needed to be paid, because the register and transaction of HBE unit are all operated by agents for now according to

Gunsing's statement.

Financial risk includes two factors. One is HBE market is only defined to 2030, because the current regulations was only defined to 2030. The price is also uncertain because of all HBE price is affected by HBE demand and supply. Supply of HBE can be affected by the electricity vehicle policy and the TCO development of electric trucks. HBE demand is decided by the NEa. They set the HBE requirements for fuel suppliers.

The market mechanism is not clear yet. The length of contracts and how the transaction happens. The detail information of contract and transaction can help to build the quantitative model correctly. The contract can reduce the uncertainty of the HBE market. The sustainability of the HBE market is also uncertain because the current RED II and "Fit for 55 package" only regulates the carbon emission to 2030.

Although the factors that can influence the benefit to transport companies are sorted out, the HBE-TCO model that built to provide an overview of various factors influencing the benefits and access of transport companies to HBE system can still be improved to be more considerate, after the qualitative analysis that can provide more information about those factors.

With the conclusion from literature review, some part of research questions can be answered, and some questions' answers are still unclear.

HBE market is well explained in the literature review. HBE market is a Dutch renewable energy unit market. One of the important parts in the system is the HBE market about electricity energy, which is the focus of the paper. The demand of HBE market is determined by NEa for the traditional fuel suppliers. The supply of HBE market is fulfilled by transport companies with electric trucks. HBE prices is determined by the relationship between demand and supply of HBE market.

Transport companies can gain additional benefit from HBE system by earning HBE units and sell them. The ideal situation for transport companies to gain benefit from HBE system is the research direction for qualitative and quantitative analysis.

The problem in the relationship between HBE trading market and the investment decision of a transport company to purchase electric trucks is that the TCO of electric trucks is still high compared to the TCO of diesel trucks. Although the HBE trading market can bring additional

benefit to transport companies, the benefit still hardly compensates the gap between the gap between TCO of electric trucks and diesel trucks.

For the possible solutions to tackle with the problems that hinder transport companies to get benefit from HBE trading system, based on the Trionomics' article, some small companies can register in the HBE system as a group of companies to save the audit fee and the charging infrastructure cost.

3 Qualitative Analysis

3.1 The Design of Qualitative Analysis

The process of qualitative analysis is first to confirm the respondents. The respondents of this qualitative analysis and research are respectively transport companies, transport consultant, researchers of Dutch charging infrastructure, and Dutch Emission Authority. These respondents can represent the main parties in the research questions. Besides the interviews, there is a Dutch podcast about HBE and electric trucks. It discussed a lot of factors for calculating HBE.

Dutch Emission Authority can provide more information about the HBE market policy and explain the sustainability of HBE market from their perspective. Transport companies are the main research object for the HBE market. They are the suppliers in the HBE market, and the main goal of this research is to find a plausible solution to the problems that hinder transport companies to get benefit from HBE market. Transport consultants know the detail about HBE market better than transport companies. They cooperate with many transport companies that have electric trucks and help them gain benefit from HBE market. They have better knowledge about the transaction and how the profit is. Researchers of Dutch charging infrastructure can provide the information about the electricity grid.

The objective of the interview is to get the answer to questions, which are supplements to the conclusion of literature review. The interviews with respondents provide a more diversified and comprehensive perspectives of HBE. The topics and questions of the interview are based on the conclusion of literature review. It is mainly about the cost of the HBE trading system, the future of the HBE market, and the details of the registration and trading process in the HBE trading system. The qualitative analysis is expected to supplement some missing information to provide reliable data and information for quantitative analysis.

For the validity and robustness, these interviews with relevant respondents are sufficient for the research, because the respondents are all from the relevant areas of HBE market. Although the number of interviews is not many, there are few transport companies using electric trucks, and even fewer transport consultants at HBE. Since the market size is not so large, and the HBE market is relatively new, the situation of each transportation company is similar, therefore interviews are representative.

All interviews are completed online. The interviews with transport consultant were done with Robert Gunsing from Mobilyze for three times. The interviews are respectively on July 15, September 29, and November 4. The interview with researchers of Dutch charging infrastructure (Elaad) was done on September 19. The transport company (Den Hartogh) took the interview on November 7. Dutch Emission Authority took the interview on November 16.

To Transport Companies that have electric trucks:
1. Why did some of they have electric trucks, but choose not to register in the HBE system?
2. Why do they start to use electric trucks when the price of electric truck is still relatively higher than diesel trucks?
3. If they are using it, how is the economic benefit?
4. Will they use scale economy to make more profit from the HBE system? Why or why not?
To NEa (Dutch Emission Authority)
1. What are the costs of HBE system for transport companies want to use HBE system to generate additional revenue?
2. What do they examine in the audit?
3. How is the price of HBE unit determined?
4. How does a transaction happen? What is the process of a transaction?
5. How do they register the transactions?
6. Do they analyze the transactions in terms of prices and quantities and duration of transactions between parties?
7. Is the price set by NEa or is it a market prices?
8. How long HBE market will be in place? It shows on NEa website that current legislation only sustain to 2030.
9. If HBE price is a market price, how do supply and demand meet each other for an HBE transaction?
10. uncertainty about benefits - it is possible to get a 7-to-8-year contract with a buyer and what will the future price be if only short-term contracts are possible?
To Mobilyze
1. What kind of service are they provide?
2. How do they make money for the service, since the economic benefit of HBE system to transport companies is limited.
To Elaad
1. What is your opinion on HBE market and electric trucks?
2. How is the sustainability of HBE market from your perspective?
3. How is the comparison of the cost per kilometer between diesel trucks and electric trucks?

Figure 8 Questionnaire

The figure above is the questionnaire for the series of interviews. The interviews are based on the questionnaires. Questions are related to the HBE market mechanism, HBE transaction, and uncertainty issue of HBE market. The feedback from interviews can be good supplements to help create quantitative model correctly. A lot of additional information is covered in the answers of respondents.

During the interview, the interview was recorded with the permission of all the respondents. The main method of analysis is to extract key information from interviews by transcribing, and then sort out and classify the information to obtain results. Cross compares the contents of the interview report and abstract with the data in the literature to validate the report. The interview

time for different interviewees is staggered, so the data obtained from all interviewees have also been verified by other interviewees.

3.2 Interview with Transport Consultant

The transport consultant for HBE that took the interview is Robert Gunsing from Mobilyze. Mobilyze is a service company dedicated to helping transport companies transform from diesel trucks to electric trucks. As a project developer, Mobilyze supervises the implementation of charging infrastructure, solar panels and grid connection, and helps link the charging facilities of transport companies to the HBE trading system to earn HBE units. Robert Gunsing has always been interested in mobility, sustainability, and mobility. To help businesses use mobility and automobiles more efficiently and sustainably, Robert had established his future plan before graduating. His goal is to found Mobilyze (Mobilyze, 2022).

Mobilyze basically helps transportation companies to make use of the HBEs system without their clients being involved. For instance, for a Mobilyze registered the client to the Dutch Emission Authority, but what they do is they measure all the energy streams for them. They measured the solar roof; They measure the charging stations, and They combine those data in in our data system. Then they do the audit for their clients. Mobilyze does the contact with the Dutch Emission Authority, and they sell the HBEs, and they prepare the materials for the audit.

Due to the limited economic benefit from the HBE system, the situation of making profit from the HBE system by providing such transport services is unclear. The feedback from Robert is that when there is not much profit, they do not earn that much either. Although Robert did not explain how much Mobilyze can make from their services, it is fine because the research focuses on the current situation of HBE system. The profit for transport companies depends on how much electricity they use. Basically, it is around between 2,000-8,000 euros per truck. To reach 8,000 euros, they are fully charged by locally produced solar or wind energy. However, the clients of Mobilyze seldom choose to use the solar or wind energy.

According to Robert Gunsing, the trucks that are using natural gas etc., the revenue from HBE system can barely cover any costs. However, for the clean energy trucks that are using

electricity, it can cover 10-40% of CAPEX and OPEX. The CAPEX (Capital Expenditure) is the total cost of investment of electric trucks and the charging station install cost, which is 170,000 euro. The OPEX (Operational Expenditure) is the total cost of energy cost, electric truck and charging station maintenance cost and miscellaneous cost (such as driver's wage and audit cost for the truck etc.). Therefore, the OPEX shown in the model is 189,000 euro. The total revenue of 1 electric truck with 50,000 kilometers mileage in 10 years is 40,290 euro, which accounts for 11.22% of the CAPEX and OPEX, which reach the minimum of the range that Robert Gunsing mentioned. The cost percentage that HBE income can cover can be increased by using more electric trucks and trucks with higher annual mileage if a higher percentage of capital expenditure and operating expenditure must be covered by the income of the HBE trading system.

However, there are also some problems in the HBE trading system, which hinder the transformation of transportation companies. Based on the interview with Robert Gunsing, HBE market is unstable, because some current rules and regulations only continue until 2030. For enter the system, transport companies need audit every year, and audit service is expensive compared to the revenue from HBE system. The revenue of the HBE system can cover the audit, but the profit within the HBE system is limited.

Based on the HBE-TCO model, the revenue of one electric truck with 50,000 kilometers annual mileage is 4,029 euro and the annual audit fee is 3,500 euro. After deducting the audit cost, there is only 500 euro profit each year. If calculating the net present value of the total HBE profit in 10 years with the same condition, the net present value of the total HBE profit in 10 years is only 2,833 euro.

3.3 Interview with Researchers of Charging Infrastructure in the Netherlands

The Netherlands' knowledge and innovation hub for intelligent charging infrastructure is called ElaadNL. Grid operators are prepared for the future of electric cars and sustainable charging thanks to ElaadNL's shared engagement. Their goal is to make sure that everyone can charge sensibly. They coordinate the link between the grid and the public charging infrastructure and keep an eye on the EV charging infrastructure. In the Netherlands, the Elaad Foundation has built a network of more than 3,000 public charging stations for electric vehicles since 2009

(ElaadNL, 2022).

In the interview with Rien Krol from ElaadNL, the focus of this interview is on the barriers for the transport companies to participate in the HBE trading system, the uncertainty of the HBE market to be in the place in the future. The main barriers for transport companies to participate in the HBE trading system is that the decision to use electric trucks is not economically attractive enough.

As Rien said, in the current situation, the income of HBE does not greatly help the transition from transport companies to electric trucks. After covering the annual audit fees, the income from HBE trading system is only about 1,500 Euros per electric truck per year. However, in addition, transportation companies need a lot of cash flow to purchase electric trucks and they also need to configure charging infrastructure for electric trucks in case to get higher benefit. For transportation companies, they have an incentive to use electric trucks instead of diesel trucks. Compared with the price of diesel consumed per kilometer, the price of electricity per kilometer is still cheaper. Although there will be a large investment in the early stage, it is in line with economic interests in the long run. As a future trend, electric trucks will have more advantages in environmental protection.

The amount of fuel a truck uses per kilometer depends on its size, its cargo, and whether it drives intercity or in an urban setting. Diesel vehicles typically consume 30 to 40 liters of fuel per 100 kilometers. 38 liters can be consumed every 100 kilometers for heavy vehicles with a weight of around 23,500 kg. The diesel cost per liter is around 2 euro, therefore the cost of diesel per kilometer is around 0.76 euro (B.V. Bridgestone Mobility Solution, 2020). The cost of electricity per kilometer is close to the diesel price in 2021 and 2022. The cost of per kilometer is 0.6258 euro.

In the interview, Rien claimed that although the current status of the HBE market has limited contribution to narrow the gap between TCO of diesel trucks and the TCO of electric trucks, the HBE market is still a very potential means to control carbon emissions. Environmental protection is still the major trend in the future. The transition to electric trucks will also happen slowly in the foreseeable future. HBE will reach a perfect balance between supply and demand at a certain node in the future. Rien believes that as more transport

companies transition to electric trucks in the future, there will be a lot of room to grow for the supply of HBE, because the demand is currently remaining the same large size each year. Currently, the HBE market mainly focus on other new energy like biofuel. The HBE units generated in the electricity grid only accounts for a small group of HBE units. The scope of participants in the current HBE trading market has several limitations, and it is likely to expand the access scope of this market in the future.

3.4 Interview with Dutch Emission Authority

The NEa is an autonomous national agency tasked with establishing and overseeing market instruments that benefit society and the environment. The EU emissions trading system is put into place in the Netherlands by the Netherlands Emission Authority. The initial step is issuing emission licenses. To do this, businesses must be able to demonstrate that they have accurately and consistently assessed emissions. After that, they keep an eye on it. Additionally, they looked at whether the Netherlands' 400 ETS firms were distributing enough emission rights annually. In order to do this, they looked into the business, participated in the survey, and looked into and examined additional information that the business is required to produce (NEa, 2021).

Anthea Tiesma from Dutch Emission Authority (NEa) accepted the interview. The focus of the interview with Anthea is on the sustainability of HBE trading system and HBE trading process. Anthea claimed in the interview that at present, the HBE trading system is operating well. In the report in July 2022 (NEa, 2022), the total number of HBE saved has reached 10.6 million, but this is the total number. However, the HBE points earned through power infrastructure mentioned in the paper are only a small category of HBE-O. HBE-O also accounted for only 5.2% of the transport energy register (NEa 2021). In the future, NEa will also try to broaden the interaction between the power part of HBE-O and other HBE systems.

If transport companies want to use HBE system to generate additional revenue, on the Dutch Emission Authority side, there is no cost. The main cost aspect is the verification cost, which is the audit cost. It is about 3,000 euro per company per year. Beside the verification cost, sometimes there is a cost for charging station compliance. The situation for AC charging stations is unclear.

The right measurement tools are already in place at this moment in DC charging stations.

Sometimes transport companies need to retrofit some energy meters. However, the cost of compliance can vary from 100 to couple of thousands of euros. It really depends on the situation and that that makes it difficult, but for a new AC and DC charging stations, there is barely any other additional cost.

For the HBE system, there are 3 companies that have the certificates to do the verification, but only two of those companies are registered to validate electricity in the system. One is QS Quality Service and the other one is Dekra. They are exercising a risk management for the verification. They want to analyze the risks of that, the, the, the amount of kilowatt hours, amount of diesel that is put in the mission targeting system was valid. Therefore, there will be doing some measurements about the energy meters, about the systems used, about the protocol that transport companies use to validate all the measurements. In another word, they are basically doing risk analysis.

The transaction is like a bilateral exchange. That is how the price of HBE unit decided. The transactions happen all the time during the year, but they have a final moment in February. Dutch Emission Authority is not active in the pricing of the HBEs. It is a free market. Transport companies do not analyze the transactions in term of prices and quantities and duration of transactions between parties. The transport consultants company help transport companies to make use of the HBE system. There is no transport company do it by itself at this moment. For the current characteristics in the contracts, the market for transportation companies is completely new this year. This is the first cycle, which will only last to 2025.

For the sustainability of HBE market, at this moment, it is only defined until 2030. It probably will be longer, but there is no definite message. The reason why the year 2030 was selected is that it is based on the Real Energy Directive, II, and European legislation. The end of that legislation is 2030. There is no certainty that HBE system will be in place after 2030.

In the HBE market, the transaction of HBE unit is bilateral. For instance, a transport company has a list of all a lot of buyers from oil companies that need HBEs. Then, the transport company just call them. However, there are also some brokers who can do some matchmaking.

3.5 Interview with Den Hartogh

One of the top companies offering logistics services is Den Hartogh Logistics. With

offices/offices in 50 sites in 27 nations, it conducts business everywhere in the world. Over 2,000 people work there. More than 24,000 tank containers, 5,750 dry bulk containers, unique dry bulk trailers, 350 tank trailers, and 650 vehicles make up today's equipment (Den Hartogh, 2021).

Patrick de Kok has accepted my interview request. The main focus of the interview with Den Hartogh Logistics is to know the motivation for transport companies to use electric trucks at this moment, since the TCO of electric trucks is higher than the TCO of diesel trucks. Patrick said Den Hartogh only has one 50-tonne electric truck, which means that it is hard for Den Hartogh to make profit from HBE system. Therefore, they did not register in the HBE system.

Den Hartogh Logistics chose to purchase such an electric truck at this moment because it can improve the brand image. Many companies will also have their own ESG strategy so that they prefer transport companies that are more environment friendly. Although the cost of electric truck is much higher than traditional diesel truck now, they still choose to deploy such an electric truck at this moment, because not everything is business case driven. At this moment, like Albert Heijn or IKEA are pushing their contractors to move forward towards electric trucks. And they are paying more for those electric trucks because they say our clients, consumers want more sustainable deliveries of their stores.

3.6 Podcast about HBE and Electric Trucks

The podcast was produced by electrictruck.nl on December 11, 2022. The host is Johnny Nijenhuis and the guest is Robert Gunsing from Mobilyze. The podcast introduced conditions that determine the benefits to transport companies in the future. Most of these issues are related to the demand and supply balance. The podcast covers the following topics: HBE market scale, the change of charging infrastructure regulations for HBE, the market development of electric trucks, and HBE calculation formula factors.

The HBE market also transfers 1 billion euros every year from fossil companies to green companies. By 2021, the share of energy generated by electricity in HBE will be between 2% and 3%. Therefore, all charging stations in the Netherlands and all fast-charging stations in Tesla and Fastned account for only 3% of the market. Therefore, 97% of the market is the

political party that produces green gas and green biofuels, so they constitute the largest part of the market. Even though fossil companies must buy 10% to 20% more each year, if the power market doubles in the near future to meet the growing demand, this is unlikely to happen, which means that the demand for HBE will grow. The shortage of HBEs market will increase, so the price will undoubtedly rise.

There is some positive change about the charging infrastructure. Before January 1, 2022, HBE can only be obtained by all parties charging vehicles under the condition of grid connection, and the grid connection must be used exclusively for charging electric vehicles. However, most companies have grid connection, and the office needs power supply. It is almost impossible to have a grid only for charging electric vehicles. However, as of January 1, 2022, the Netherlands Emission Administration said that if you charge the electric truck in the logistics center of the office, or if you input part of the energy of the electric truck, and the measurement is good, the transport company can obtain HBE.

The market for electric trucks is also expanding. Since the past six months, it can be seen that some transport companies in the Netherlands have started to own more than two or three electric trucks. Until January, February and the year before last, transportation companies usually had only one or at most two electric trucks.

The benefits to transport company are affected by many factors. The factors that will affect the revenue include energy factor, NEa factor, the percentage of green energy in grid. NEa factor is a control lever that NEa to control the number of HBE generated. They now set it to 4, because they say that the energy efficiency of electric vehicles per kilometer is four times that of diesel vehicles. This green energy percentage is based on the average value of CBS renewable energy in the Dutch power structure. As a result, electricity in the Netherlands is produced in many different ways: natural gas, coal, a little bit of sunshine and wind. The sustainable quantity of the whole portfolio is currently 26%. Because the proportion of renewable energy will increase with the increase of solar energy and wind energy. The trend is that the share will be slightly higher each time. For example, it will be 30% next year and 34% or 35% by 2024. There was calculation of HBE benefits in the podcast. The formula is as following.

HBE Benefit = Energy Factor x NEa Factor x HBE Amount x HBE price x Green Energy Percentage – (Audit Costs + Adjustment Metering + Brokerage Cost)

The technical requirements for gaining HBE include corporate connection to grid and certified meter charging system. Before January 1, 2022, HBE can only be obtained by the parties who charge vehicles if the transportation company has a grid connection, and the grid connection must be specifically used to charge electric vehicles. However, most companies have a grid connection, offices need power supply, and maybe warehouses other than electric vehicles. This will not be possible for a long time, but as of January 1, 2022, the Netherlands Emissions Authority said that if the transport company still charges the electric truck in the logistics center of the office, or the transport company invests part of the energy of the electric truck, and the measurement is good, the transport company will also obtain HBE.

If the transportation company generates energy in its own location (solar energy, wind energy, you happen to have a biomass power plant), because it does not contain 26% of sustainable energy like grid power, it is of course 100% of sustainable energy. So, the transportation company can almost multiply by 4.5 cents by 4. Therefore, if the sustainable energy generated by the transportation company itself is put on the truck, the transportation company has nearly 18 cents of sustainable energy per kilowatt-hour. This is almost 50 euros per fully charged electric truck. However, there is a problem. For example, those solar panels that generate energy between 12 and 4 p.m. must be charged at the same time. Therefore, if the truck is not at the charging station and only arrives at 5 p.m., it cannot be used.

3.7 Conclusion of Qualitative Analysis

In the qualitative analysis, four respondents are respectively from four related fields of HBE market, which are transport consultant, researcher of charging infrastructure in the Netherlands, Dutch Emission Authority and transport companies. From the transport consultant side, the current revenue of HBE system is relatively limited. When the transportation company only owns one or two electric trucks, the revenue generated by HBE system is difficult to bring

actual economic benefits to the company. When the number of electric trucks is more than two, additional revenue can be generated.

The revenue from HBE system for electric trucks is estimated relatively conservative by researchers of charging infrastructure in Netherlands compared to the estimation of transport consultant. However, they are still optimistic about the prospects of HBE. The reason is that HBE market is a market worth 1 billion euros. However, the HBE generated by electricity only accounts for 2-3% of it. According to the ESG strategy, many companies should reduce 50% of carbon emission by 2030 with a baseline of 2020. The increase of supply is expected not be able to fulfill the need of HBE in the foreseeable future. Although there are uncertainties, for example, all the current contents of the HBE market will only last until 2030, and what changes will take place after 2030 is uncertain, but the scale of the market will expand. This means the demand of HBE units will increase, but supply may not increase as far as demand. The only conclusion that can be drawn is that experts think the price will rise, but clear evidence or quantitative estimates how the market of HBE will emerge are not provided. Therefore, it remains very speculative.

From the Dutch Emission Authority side, HBE market is a free market. It is a bilateral transaction for the supplier and demander of HBE unit. The cost for HBE system is only the audit cost. The cost for the compliance of charging infrastructure depends on the condition of the charging infrastructure, but there will not be any additional cost in most cases. For the future situation of the HBE market, everything is uncertain, because the current market is only defined until 2030 according to the Real Energy Directive, II, and European legislation.

Transport company explained some facts about electric trucks. The current transport companies with electric trucks are difficult to make profits from the HBE system because there are few transport companies with more than two electric trucks. However, many companies still choose electric trucks that do not have cost advantages because of environmental protection, brand image and other reasons. Electric trucks are supposed to be more attractive to transport companies in the future because the purchasing cost of electric trucks is expected to decrease in the future and the HBE market scale is expected to increase so that the HBE system will become more profitable.

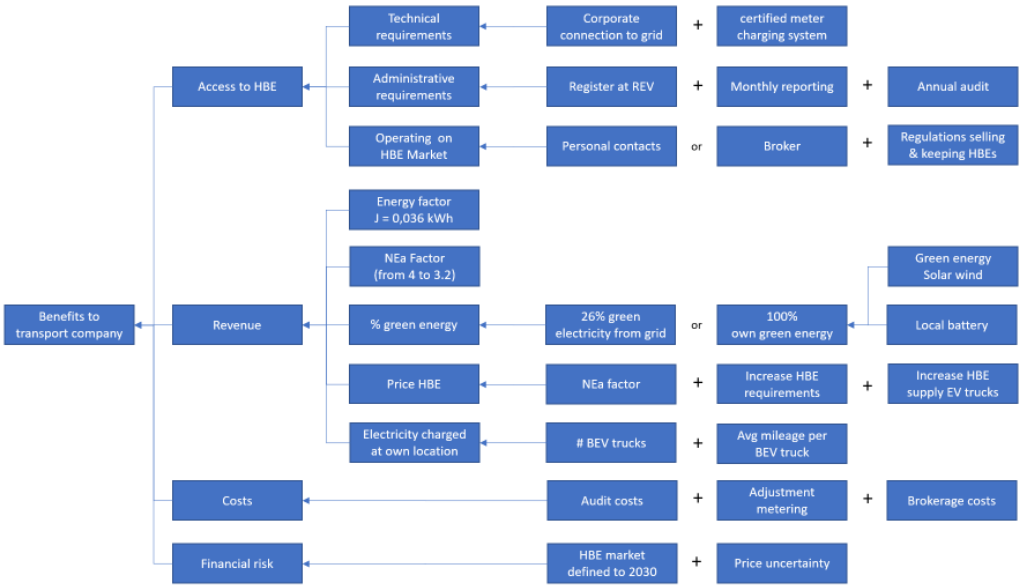


Figure 9 The Revised Overview of Factors for HBE Benefit

The figure above is the revised overview of factors for HBE benefits. The factors that can influence the benefits to transport companies can be divided into four types. It has been introduced in literature review as factors affect access to HBE, Revenue, Costs and financial risk. With the qualitative analysis, there are some factors can be added to the overview of the factors. First, the certified meter charging system is required by NEa so that transport companies can gain benefit from HBE system successfully. The percentage of green energy from the grid or produced by the transport companies themselves can have a significant influence on revenue. If transport companies charge electric trucks with power in grid. Then they can only transform 26% of the consumed energy to earn HBE units, because only 26% of energy in grid is green energy. The energy can also be generated by transport companies themselves. If they utilize solar power and wind power, they can utilize 100% energy to earn HBE units. For the costs part, brokerage cost is necessary for earning HBE units, because based on Robert's statement, for now, there is no transport company proceed the registration and audit by themselves.

The key to answer the research question is to figure out all factors and drivers that determine how and to what extent transport companies can use and participate in HBE. Based on literature review and qualitative analysis, sub research questions can be answered.

HBE market is a free market that HBE price is determined by the supply and demand of HBE. The annual requirements for transport companies are determined by NEa, but the supply

of HBE by electric trucks are responsive to the demand of HBE demand.

The HBE benefits is an additional economic benefit with the conversion to electric trucks. Currently, the TCO of electric trucks are much higher than the TCO of diesel trucks. HBE benefits can contribute to narrow the gap of TCO between electric trucks and diesel trucks. Due to the big gap between TCO of electric trucks and diesel trucks, the contribution of HBE is not great. The ideal situation of using HBE system is when transport companies have more than two electric trucks. Based on the interview with Den Hartogh and Gunsing from Mobilyze, the situation when transport companies have more than two electric trucks are recommended to register in the HBE system to gain additional benefit.

The main problems in the relationship between HBE trading market and the investment decision of a transport company to purchase electric trucks are as followings. Firstly, the purchasing cost of electric trucks are much higher than diesel trucks at the moment, it is difficult for transport companies to afford more than two electric trucks. The result of the lack of number of electric trucks is that transport companies with limited truck numbers hardly gain any profit from HBE system. Secondly, the current battery condition for electric trucks cannot support for long distance transport and the charging infrastructures are not enough to support the electric truck transport, which hinder the investment decision of transport companies for electric trucks. The uncertainty of HBE market also hinder the entering of transport companies to HBE system.

For the possible solutions to tackle with the problems that hinder transport companies to get benefit from HBE trading system, with more electric trucks and higher average mileage of trucks, transport companies can earn more HBE units. It seems reasonable to increase the number of electric trucks and average mileage of trucks to increase the revenue of HBE system. It can be verified in the cost-benefit analysis in the next chapter.

4 Quantitative Analysis

4.1 The Objective of Quantitative Analysis

The objective of quantitative analysis is to do the cost-benefit analysis in this section to check the cost-benefit relationship in different scenarios so that to quantify the influence of factors that affect the HBE benefit. To answer the research question, it is expected to get the quantified influence of several controllable variables such as the number of electric trucks and average mileage of trucks. Based on the literature and qualitative research, the investment on electric trucks is only profitable when transport companies own more than two electric trucks. The HBE benefit is not only decided by the two controllable variables. The factors from four aspects including the access to HBE, revenue, costs and financial risk will affect the HBE benefit, the influence of all these factors need to be checked and analysed with a quantitative analysis.

4.2 HBE-Revenue-Cost Model

In the HBE-Revenue-Cost model, it contains two parts, which are the calculation of net present value of HBE benefit in 8 years and the calculation of net present value of total cost of ownership of electric trucks and diesel trucks in 8 years.

For the calculation of HBE benefit, the formula to calculate HBE revenue is as following.

HBE benefit = HBE price / 1 GJ support mileage x Average mileage of trucks x number of Trucks x NEa factor x green energy percentage

HBE costs is a total all in cost including brokerage cost, administration fee and audit fee. For the calculation of TCO of both types of trucks, the costs include purchasing cost (investment cost), energy cost (fuel cost), maintenance cost, miscellaneous cost (including tax and driver wages).

In the model, all quantitative factors mentioned in the overview can be input with the latest value to adjust the results. The key output of the model is the HBE benefit and the difference between the TCO of diesel trucks and TCO of electric trucks. It can show on what level, the

HBE benefit can contribute to narrow the gap between TCO of both types of trucks.

Here is an example of calculating of the HBE revenue. The main revenue from the HBE trading system comes from the sale of HBE points. When the charging station outputs 1GJ energy, that is, 277KWh energy, 1 HBE can be obtained at a price of about 15.5 euros (Price on July 15, 2022). The energy of 277 KWh can be used to drive an electric truck for about 192.36 km (ViriCiti, 2020). Therefore, the revenue of HBE per kilometer is 0.0806 euro. The costs of HBE system include annual audit cost, brokerage cost and administrative cost, which are around 3,000 euros plus the 15% of the HBE revenue (Gunsing, 2022).

Because it is necessary to predict and evaluate the HBE market, the model calculates the net present value of HBE's income for 8 years. 8 year was selected because the RED II will be in place from 2022 to 2030. The updated European Renewable Energy Directive (RED II) and the Dutch Climate Agreement will be partially implemented by the updated transport energy legislation and regulations, which went into effect on January 1, 2022 (NEa 2021). The price of HBE has been increasing recently. From 13.30 euros per GJ in April to 15.60 euros per GJ in June (Barthel, 2021).

TCO model can help to do the quantitative analysis by simulating the scenarios to find out the conditions for transport companies to generate benefits from HBE and when it is worthwhile in terms of costs and benefits. TCO model is also used to evaluate, compare, and contrast the TCO of diesel trucks and electric trucks. The main input and output parameters are as following table. In the TCO model, the net present value is also used to analyze the TCO of trucks in the next eight years. The model only simulates eight years because the current regulations are only valid until 2030. The situation of HBE market can be different after 2030. Combined these two models together, it can be used to find the contribution of HBE trading system to the total cost of ownership of electric trucks.

In the model, we can take various TCO costs into account. The important factors that affect TCO also include many parameters that will affect HBE system revenue. We can compare them by estimating the present value of TCO and future annual operating costs and calculating the present value of annual HBE system revenue to determine what investment strategy is the best strategy.

Input Parameters			Output Results	
Diesel Truck	Electric Truck	HBE Market	Diesel Truck	Electric Truck
Number of Trucks	Number of Trucks	HBE Price	TCO of diesel truck without HBE	TCO of electric truck without HBE
Mileage per year (Kilometer)	Mileage per year (Kilometer)	NEa Factor	TCO difference without HBE	
Fuel cost per kilometer	Electricity cost per kilometer	Audit Cost	TCO of diesel truck with HBE	TCO of electric truck with HBE
Vehicle diesel fuel efficiency	Vehicle Electricity fuel efficiency	Adjustment fee for metering	TCO difference with HBE	
Diesel truck investment cost	Electric truck investment cost	Brokerage Costs		
Diesel truck maintenance cost	Electric truck maintenance cost	Energy Factor		
Residual value of diesel truck	Residual value of electric truck			
	Charging station investment cost			
	Charging station maintenance cost			
Miscellaneous cost for both (including tax, driver wage etc.)				

Figure 10 Input and Output Parameter Table

There are several existing TCO models such as DANA TCO model (Autocar Professional, 2019) and the TCO model built by company Topsector Logistek (Topsector Logistek, 2022). However, for the DANA TCO model, is used for the imperial system and many parameters are not well explained. Therefore, it is helpful to build a HBE-TCO model to do the quantitative analysis. The HBE-TCO cost benefit model is calculating the TCO of both diesel trucks and electric trucks and the HBE benefit of electric trucks in eight years. Although it is still an idealized model, it can still to evaluate different variables' effect on the HBE benefit for filling the gap of TCO under different certain conditions.

In the following figure, it shows the calculation of HBE revenue per kilometer and HBE cost. In the HBE model, the most essential parameters are the mileage of the electric trucks for one year and number of the electric trucks. Because the more mileage can lead to a larger amount of revenue and more electric trucks can share the HBE cost. In this model, the HBE price is the real-time price on July 15, 2022. The data of the annual audit cost and the additional cost for charging station are from the interview with Robert Gunsing from Mobilyze.

The difference between the present value of cash inflow and the apparent value of cash flow over time is known as net present value, or NPV. To evaluate the profitability of anticipated

investments or projects, NPV is used in capital budgeting and investment planning. A computation result called NPV is used to determine the present value of a future payment stream. When comparing the return rates of various projects or comparing the anticipated return rate to the minimal return rate necessary to authorize the investment, NPV considers the time value of money (Fernando, 2022). Therefore, NPV is a calculation tool that considers the time value of money and can more accurately reflect the current value of costs or benefits.

An investment, project, or other set of cash flows can be valued using NPV analysis. Because it accounts for all revenue, expenses, and capital costs related to its free cash flow (FCF) investments, this indicator is comprehensive. The time of each cash flow is taken into account in addition to all revenue and expenses, which may have a big influence on the investment's current value. For instance, it is preferable to have quicker cash inflow and outflow than the contrary (CFI Team, 2022).

HBE Revenue	
HBE Price (euro/GJ) (July 15, 2022)	15.5
1 GJ = 277 kWh	
Average energy cost per kilometer for an electric truck (kWh)	1.44
The distance of an electric truck that 1 HBE energy can support	192.3611111
The revenue of HBE per kilometer without NEa factor etc.	0.080577617

Figure 11 HBE Revenue Calculation Results

In the figure above, it shows how the revenue of HBE per kilometer calculated based on HBE price on July 15, 2022. 1GJ is equal to 277kWh, and the average energy consumption per kilometer for an electric truck is 1.44 kWh. Therefore, 1 HBE energy, which equals to 1 GJ, can support an electric truck go the distance of 192.36 kilometer. Therefore, the revenue of HBE per kilometer is equal to the 1 HBE price divided by the distance that 1 HBE energy support.

Input Box (All costs are in euro)	
Diesel	
Mileage per year (Kilometer)	Independent Variable 1
Number of Trucks	Independent Variable 2
Fuel Cost per kilometer	1.5
Diesel Truck Investment Cost	98,466
Diesel Truck Maintenance Cost	9,570
Residual Value	(3,000)
Electricity	
Mileage per year (Kilometer)	Independent Variable 3
Number of Trucks	Independent Variable 4
Electricity Cost per kilometer	2.1
Electric Truck Investment Cost	361,000
Electric Truck Maintenance Cost	4,600
Charging Station Investment Cost	30,000
Charging Station Maintenance Cost	375
Residual Value	(3,000)
Miscellaneous cost for both Electric and Diesel	80,000
HBE Market	
Energy Factor	J=0.036 kWh
Brokerage Cost	2,000
Nea Factor	4
HBE Price per GJ	15.5
Renewable Energy Ratio in the Dutch Electricity Mix	26%

Figure 12 Input Box for HBE-TCO Model

In the input box for HBE-TCO model, the main variables are the mileage per year of electric trucks and diesel trucks and the number of diesel trucks and electric trucks. Other parameters are from reliable sources on the Internet. Jorgensen calculated in his article for trucks under imperial system. The fuel cost per kilometer for diesel trucks is 1.5 on average (Jorgensen, 2019). Diesel engines have energy efficiency of 30% typically (U.S. Department of Energy, 2013). According to the data from Statista shown in literature review chapter, the electric heavy-duty truck purchase costs is 361,000 euro after conversion and the diesel heavy-duty truck purchase costs is 98,466 euro after conversion (Statista, 2020). The cost of diesel energy is 80% expensive than the cost of electricity energy for heavy-duty trucks (Euronews, 2022). The maintenance cost of electric trucks is around 4,600 euro (Miller, 2021).

There are three levels of EV charging station. Level 1 can only fulfil home charging need. The level 2 is used for public charging station with 240 volts. Level 3 can be up to 480 volts, which is also DC charger with faster charging speed. In general, the cost of the Level 2 charger

ranges from 1,127 to 5,637 euros, while the price of the Level 3 charger ranges from 28,186 to 75,165 euros. For the charging station that can fulfil the need of transport companies, the cost should be 30,000 for a charging station, because the ideal choice is level 3 charger (Wattlogic, 2022). The experts from U.S. Department of Energy suggest the maintenance cost for charging station is 375 euro after conversion (EV Connect, 2022). Miscellaneous expenses include utility fees, insurance fees, transport tax, safety inspection, tire expenses, engineering maintenance materials, drivers' salaries, and toll payment. They account for 51% of the total trucking expenses (Pogotovkina, 2015). For the brokerage cost, the maximum will account for 15% of HBE revenue, but it will drop to 4% if transport companies have enough trucks. This fee will include the administration fee and validation fee (Gunsing, 2022).

In the following two figures, it shows the net present value calculation of TCO of diesel truck and electric truck. In the example below, the number of trucks is one and the mileage per year is set as 45,000 kilometers. The calculation is based on the data in the input box.

TCO Cost of Diesel Truck									
Year	1	2	3	4	5	6	7	8	Total NPV
Investment	**€ 98,466**								
Energy	€ 67,500	€ 67,500	€ 67,500	€ 67,500	€ 67,500	€ 67,500	€ 67,500	€ 67,500	
Maintenance Cost	€ 9,570	€ 9,570	€ 9,570	€ 9,570	€ 9,570	€ 9,570	€ 9,570	€ 9,570	
Miscellaneous	€ 80,000	€ 80,000	€ 80,000	€ 80,000	€ 80,000	€ 80,000	€ 80,000	€ 80,000	
Residual Value								(€ 3,000)	
Total	€ 255,536	€ 157,070	€ 157,070	€ 157,070	€ 157,070	€ 157,070	€ 157,070	€ 154,070	
NPV	€ 255,536	€ 145,435	€ 134,662	€ 124,687	€ 115,451	€ 106,899	€ 98,981	€ 89,898	**€ 1,071,550**

Figure 13 NPV Calculation of TCO of Diesel Truck

TCO Cost of Electric Truck									
Year	1	2	3	4	5	6	7	8	Total NPV
Investment	**€ 361,000**								
Energy	€ 37,350	€ 37,350	€ 37,350	€ 37,350	€ 37,350	€ 37,350	€ 37,350	€ 37,350	
Charging Station Install Cost	€ 30,000								
Charging station maintenance cost	€ 375	€ 375	€ 375	€ 375	€ 375	€ 375	€ 375	€ 375	
Electric truck maintenance cost	€ 4,600	€ 4,600	€ 4,600	€ 4,600	€ 4,600	€ 4,600	€ 4,600	€ 4,600	
Miscellaneous	€ 80,000	€ 80,000	€ 80,000	€ 80,000	€ 80,000	€ 80,000	€ 80,000	€ 80,000	
Residual Value								(€ 3,000)	
Total	€ 513,325	€ 122,325	€ 122,325	€ 122,325	€ 122,325	€ 122,325	€ 122,325	€ 119,325	
NPV	€ 513,325	€ 113,264	€ 104,874	€ 97,106	€ 89,913	€ 83,252	€ 77,085	€ 69,625	**€ 1,148,444**

Figure 14 NPV Calculation of TCO of Electric Truck

In the figure below, it shows the calculation of net present value of HBE benefit for one electric truck in eight years. The results can also be different when the number of trucks and mileage per truck change. The following is an example of HBE benefits calculation.

	1	2	3	4	5	6	7	8	Total
HBE Revenue	€ 3,771	€ 3,771	€ 3,771	€ 3,771	€ 3,771	€ 3,771	€ 3,771	€ 3,771	
Total all in cost (including brokerage cost, administration fee and audit fee)	€ 3,565.65	€ 3,565.65	€ 3,565.65	€ 3,565.65	€ 3,565.65	€ 3,565.65	€ 3,565.65	€ 3,565.65	
HBE Profit	€ 205.38	€ 205.38	€ 205.38	€ 205.38	€ 205.38	€ 205.38	€ 205.38	€ 205.38	
NPV	€ 205	€ 190	€ 176	€ 163	€ 151	€ 140	€ 129	€ 120	€ 1,275

Figure 15 NPV of HBE Benefits Calculation

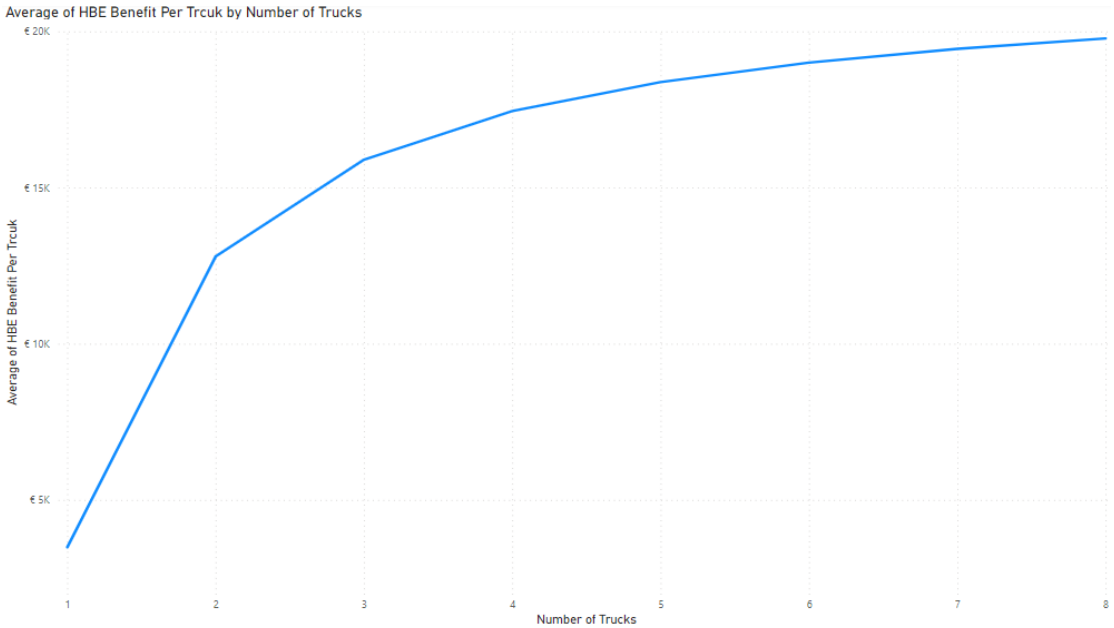
4.3 Quantitative analysis

The figure below is the output box of total net present value of TCO in different scenarios. In this table, it shows that the TCO of diesel truck and TCO of electric truck under the condition that the number of trucks is one and the mileage is 45,000 kilometers. Therefore, the net present value of HBE benefits in 8 years is 1,275 euros, which is 160 euros on average. Although the HBE benefit is positive, such limited benefit from HBE system cannot make contribution to narrowing the gap between TCO of electric trucks and TCO of diesel trucks.

Output Box	Without HBE (NPV)	With HBE	Difference HBE
TCO of diesel truck	**€1,071,550**	**€ 1,071,550**	**---**
TCO of electric truck	**€ 1,148,444**	**€ 1,147,169**	**€ 1,275**
TCO difference	**€ 76,894**	**€ 75,619**	**€ 1,275**

Figure 16 Output Box

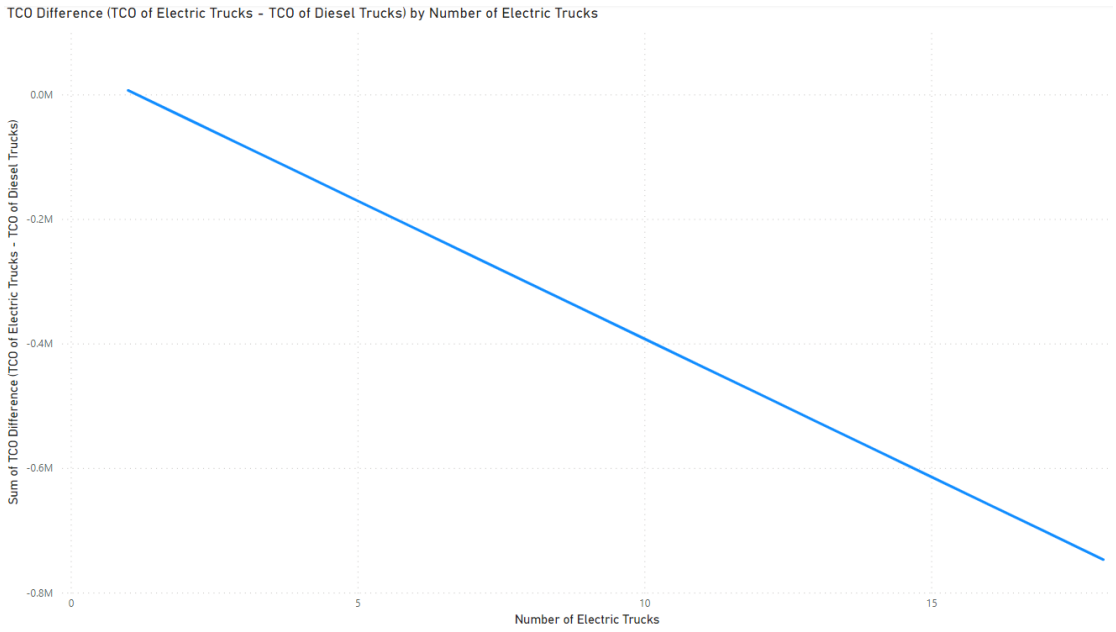
4.3.1 Case Scenario 1 - The Influence of the Number of Trucks



Number of Trucks	HBE Benefit	HBE Benefit Per Trcuk
1	€ 3,485	€ 3,485
2	€ 25,589	€ 12,795
3	€ 47,693	€ 15,898
4	€ 69,797	€ 17,449
5	€ 91,901	€ 18,380
6	€ 114,005	€ 19,001
7	€ 136,109	€ 19,444
8	€ 158,213	€ 19,777

Figure 17 HBE benefit per truck by number of trucks (Mileage is 50,000 kilometers per year）

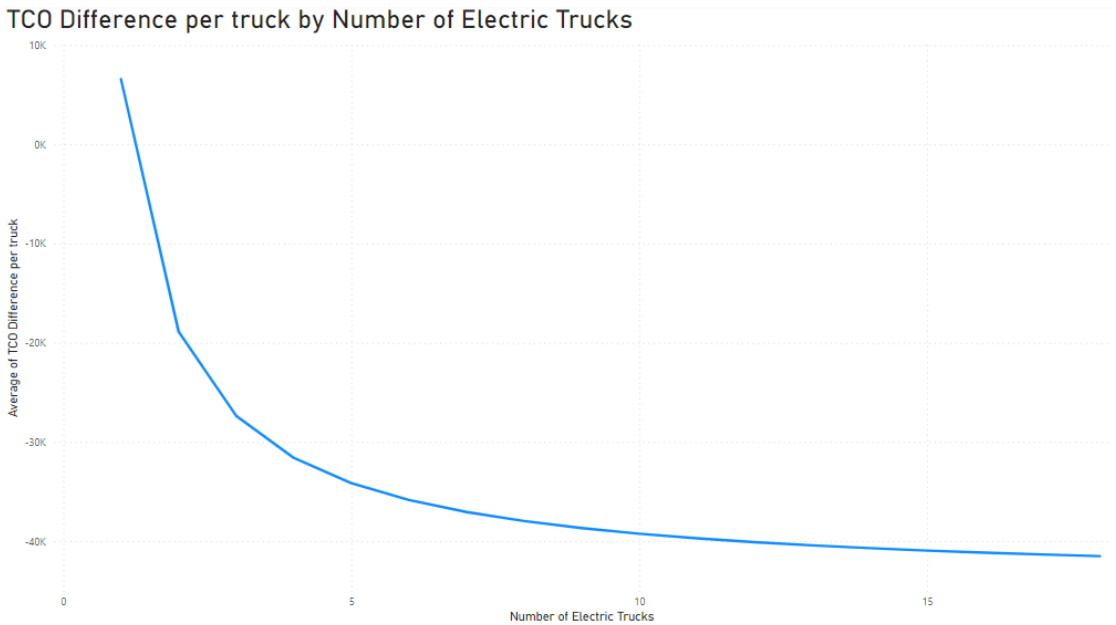
In the figure above, it shows the change of HBE benefit per truck with the increase of number of electric trucks with 50,000 mileage per year. Under this circumstance, the increase of electric trucks will increase the HBE benefit per truck. However, the HBE benefit per truck is the net present value of the new HBE benefit, which means the average of HBE benefit per truck is 435 euros per year. This is a result that is not consistent with Robert Gunsing's prediction. He claims that it is profitable when there are more than two electric trucks in a transport company. Although the HBE benefit per truck is not great at the one electric truck level, it is still can bring some benefit to contribute to the gap between TCO differences. When the number of electric trucks is higher than two, it is truly more profitable than there is only one electric trucks in the transport company. The HBE benefit per truck is 12,795 euros at the two trucks level. When the number of trucks is over 5, the increase of HBE benefit per truck is small.



Number of Electric Trucks	TCO Difference (TCO of Electric Trucks - TCO of Diesel Trucks)	HBE Benefit
1	€ 6,614	€ 7,906
2	(€ 37,719)	€ 34,431
3	(€ 82,052)	€ 60,956
4	(€ 126,384)	€ 87,481
5	(€ 170,717)	€ 114,006
6	(€ 215,050)	€ 140,531
7	(€ 259,383)	€ 167,056
8	(€ 303,715)	€ 193,581
9	(€ 348,048)	€ 220,106
10	(€ 392,381)	€ 246,631
11	(€ 436,714)	€ 273,156
12	(€ 481,046)	€ 299,681
13	(€ 525,379)	€ 326,206
14	(€ 569,712)	€ 352,731
15	(€ 614,045)	€ 379,256
16	(€ 658,377)	€ 405,781
17	(€ 702,710)	€ 432,306
18	(€ 747,043)	€ 458,831

Figure 18 TCO Difference between Electric Truck and Diesel Truck with HBE by Number of Electric Trucks （Mileage is 60,000 kilometers per year）

In the figure above, the TCO difference is decrease with the increase of electric trucks with 60,000 kilometers mileage. When the number of electric trucks is two, the TCO difference turns to negative 37,719 euros, which means that when the mileage is 60,000 kilometers and the number of trucks is two, the TCO of electric trucks is less than TCO of diesel trucks. It is profitable to invest two electric trucks at the 60,000-kilometer-mileage level.



Number of Electric Trucks	TCO Difference (TCO of Electric Trucks - TCO of Diesel Trucks)	TCO Difference per truck	HBE Benefit
1	€ 6,614	€ 6,614	€ 7,906
2	(€ 37,719)	€ -18,859	€ 34,431
3	(€ 82,052)	€ -27,351	€ 60,956
4	(€ 126,384)	€ -31,596	€ 87,481
5	(€ 170,717)	€ -34,143	€ 114,006
6	(€ 215,050)	€ -35,842	€ 140,531
7	(€ 259,383)	€ -37,055	€ 167,056
8	(€ 303,715)	€ -37,964	€ 193,581
9	(€ 348,048)	€ -38,672	€ 220,106
10	(€ 392,381)	€ -39,238	€ 246,631
11	(€ 436,714)	€ -39,701	€ 273,156
12	(€ 481,046)	€ -40,087	€ 299,681
13	(€ 525,379)	€ -40,414	€ 326,206
14	(€ 569,712)	€ -40,694	€ 352,731
15	(€ 614,045)	€ -40,936	€ 379,256
16	(€ 658,377)	€ -41,149	€ 405,781
17	(€ 702,710)	€ -41,336	€ 432,306
18	(€ 747,043)	€ -41,502	€ 458,831

Figure 19 TCO Difference per truck by Number of Electric Trucks at 60,000-kilometer-mileage level.

In the figure above, with the increase of the number of electric trucks, the TCO difference per truck will decrease all the time. The TCO difference is 6,614 euros when the number of electric trucks is one. When the number of electric trucks is two, the TCO difference per truck is turning into negative 18,859 euros, which means the TCO of electric starts to be less than TCO of diesel trucks.

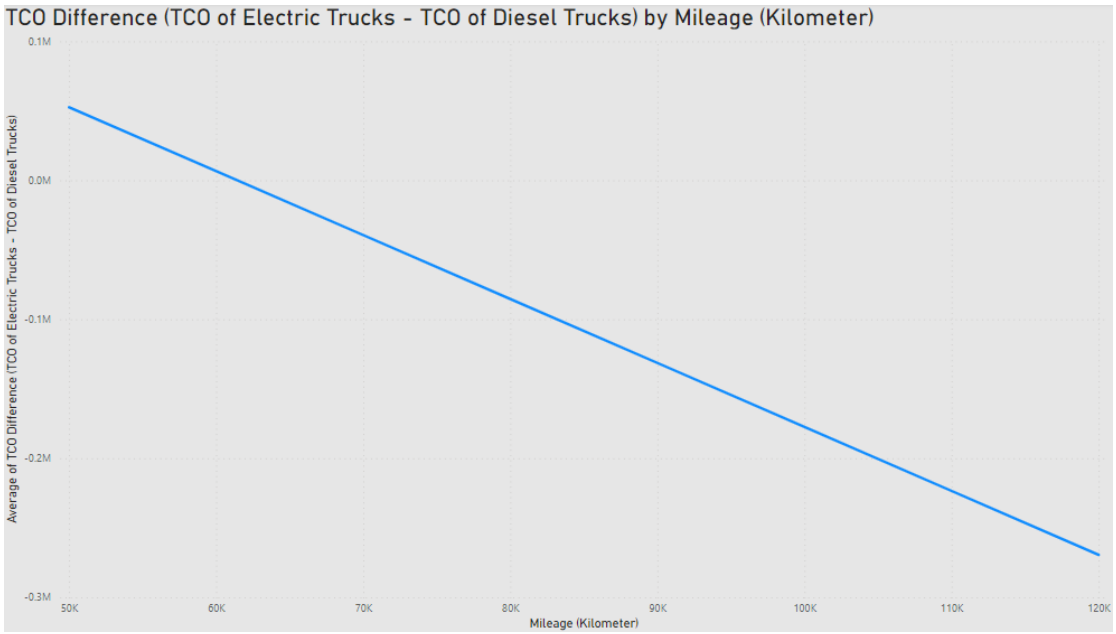
However, the trend is that when the number of electric trucks increases from 1, the TCO difference per truck will decrease quickly, because of the diminishing marginal utility. When the number of electric trucks continues to increase, the TCO difference per truck will decrease much more slowly. As shown in the figure above, the decrease of TCO difference per truck is getting slower. When the number of electric trucks is six, the decrease of TCO per truck can only be 485 euros in total. Compared to the initial investment for electric trucks, the benefit for purchasing another electric truck is very limited when the number of trucks is six. The conclusion from the case analysis above can answer research question about how transport companies utilize HBE system to get benefit from it and under what circumstances, the investment in electric trucks is better than investment in diesel trucks.

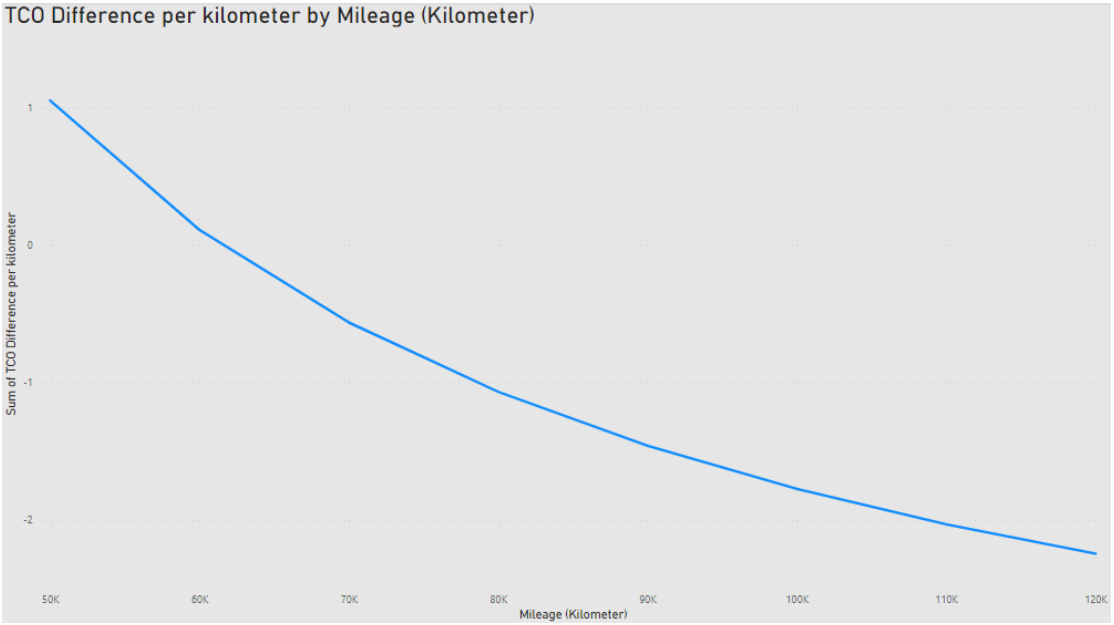
From the case analysis above, there is a minimum mileage per truck per year for transport companies to gain more benefit with the increase of number of electric trucks. The turning point for the TCO difference (TCO of electric trucks – TCO of diesel trucks) is when the mileage is around 61,500 kilometers. The best number of electric trucks is 6. The TCO difference decreases sharply when the number of electric trucks increases from 1 to 6, but its decreasing

speed turns slow with more electric trucks. In the next case, the influence of mileage will be analysed. It is better to combine the two cases together to make a comprehensive conclusion. The two variables are not completely independent from each other.

4.3.2 Case Scenario 2 – The Influence of the Mileage of Trucks

In addition to the number of electric trucks of transportation companies, another key parameter that can determine the economic benefits of HBE trading system is the mileage of trucks every year. Mileage can determine the number of HBE units that can be exchanged for the energy consumed by electric trucks in charging stations. A larger mileage naturally means that more electricity is consumed, which means that transportation companies can earn more HBE revenue. In addition to truck depreciation and other factors, in an ideal state, a larger mileage means that the cost of HBE trading system can be amortized to the cost of mileage per kilometer as much as possible. The greater the mileage, the lower the cost per kilometer.





Mileage (Kilometer)	TCO Difference (TCO of Electric Trucks - TCO of Diesel Trucks)	TCO Difference per kilometer	HBE Benefit
50000	€ 52,617	€ 1.05	€ 3,485.07
60000	€ 6,614	€ 0.11	€ 7,905.90
70000	€ -39,390	€ -0.56	€ 12,326.74
80000	€ -85,393	€ -1.07	€ 16,747.57
90000	€ -131,397	€ -1.46	€ 21,168.41
100000	€ -177,400	€ -1.77	€ 25,589.24
110000	€ -223,404	€ -2.03	€ 30,010.08
120000	€ -269,407	€ -2.25	€ 34,430.92

Figure 20 TCO Difference per kilometer by mileage of Electric Trucks at one electric truck level

In the figure above, it shows the trend of TCO difference (TCO of electric trucks – TCO of diesel trucks). TCO difference decreases with the increase of mileage, which means that the mileage is larger, and the TCO of electric trucks will decrease. When the mileage is around 61,437 kilometers, the TCO difference is equal to 0. Whether transport companies choose to buy electric trucks or diesel trucks, the TCOs of two choices are the same, which means that the decision to invest in electric trucks or diesel trucks has almost the same benefits. The best mileage of electric trucks is 80,000 kilometers. The TCO difference decrease is relatively sharp when the mileage of electric trucks increases from 50,000 to 80,000 kilometers, but its decreasing speed turns slow with more mileage, and mileage is not unlimited. The mileage of 80,000 kilometers is almost maximum in the reasonable range for mileage.

Combining case 1 and 2 together to get the answer to research questions, the ideal number of electric trucks and mileage should be 6 electric trucks with 80,000 kilometers mileage per year. For some of small transport companies, it is hard for them to afford more than one electric trucks. When the number of electric trucks has a better chance to gain benefit from the

investment in electric trucks. The solution mentioned by Trinomics is plausible based on the analysis for the influence of number of electric trucks and mileage of electric trucks. If small transport companies can collaborate with each other by sharing the charging infrastructure at a compromised location and registering in HBE system as one company.

4.3.3 Case Scenario 3 – The Influence of Different Mileage-Truck-Number Combination to TCO Difference

In order to intuitively display the difference between the TCO of electric trucks with HBE and diesel trucks under various combinations of different numbers of electric trucks and different mileage of electric trucks, the corresponding values are found through the HBE-TCO model and sorted into a table.

The TCO difference of the data marked in red is greater than € 30,000, which means that the TCO of electric trucks with HBE is at least € 30,000 higher than that of diesel trucks. The data marked yellow means that the TCO of electric trucks with HBE is higher than that of diesel trucks in the range of 0 - € 30,000. The data marked in blue, and green are that the TCO of electric trucks with HBE is lower than that of diesel trucks within € 30,000 and that the TCO of electric trucks with HBE is lower than that of diesel trucks in the range of € 30,000 - € 50,000. The data without any color is that the TCO of electric truck is lower than that of diesel trucks at least € 50,000.

Mileage (Kilometer)						
90,000	€ -131.4	€ -313.7	€ -496.1	€ -678.4	€ -860.8	€ -1,043.1
85,000	€ -108.4	€ -267.7	€ -427.1	€ -586.4	€ -745.8	€ -905.1
80,000	€ - 85.4	€ -221.7	€ -358.1	€ -494.4	€ -630.8	€ -767.1
75,000	€ - 62.4	€ -175.7	€ -289.1	€ -402.4	€ -515.7	€ -629.1
70,000	€ -39.4	€ -129.7	€ -220.1	€ -310.4	€ -400.7	€ -491.1
65,000	€ -16.3	€ -83.7	€ -151.1	€ -218.4	€ -285.7	€ -353.1
60,000	€ 6.6	€ -37.7	€ -82.1	€ -126.4	€ -170.7	€ -215.1
55,000	€ 29.6	€ 8.3	€ -13.0	€ -34.4	€ -55.7	€ -77.0
50,000	€ 52.6	€ 54.3	€ 56.0	€ 57.6	€ 59.3	€ 61.0
45,000	€ 75.6	€ 100.3	€ 125.0	€ 149.6	€ 174.3	€ 199.0
40,000	€ 98.6	€ 146.3	€ 194.0	€ 241.6	€ 289.3	€ 337.0
Number of Electric Trucks	1	2	3	4	5	6

Figure21 Table of TCO Difference under Different Combination of Number of Electric Trucks and Mileage of Trucks (in thousand)

In the output table above, it can be seen from the above figure that there are also great opportunities to obtain positive benefits from the investment in electric trucks. As long as the mileage is above 60,000 kilometers and the number of electric trucks is better above 2, the investment in electric trucks can bring good financial benefit to the transport companies.

4.4 Conclusion of Quantitative Analysis

The HBE-TCO model has two independent variables, which are mileage of trucks and the number of trucks. According to the research results of the model, the greater the number of electric trucks and the annual mileage of trucks, the more benefits HBE system can generate.

Although the results of HBE-TCO model are quite positive, the HBE-TCO model is in an ideal state. In order to observe the influence of the two independent variables including the number of trucks and the mileage of trucks, the uncontrollable variables remain the same in the model. However, they also have great impact on the benefit of the investment for electric trucks. For example, the electricity price can be fluctuated in the future because of complex factors such as energy supply crisis caused by Russian-Ukrainian Conflict. NEa factor will also respond to those changes in other uncontrollable factors.

During the actual operation of electric trucks, some factors that have not been considered in this model may be encountered. For example, the charging infrastructure of electric trucks is still imperfect, which lead to problems in the long-distance transportation of electric trucks. The most demanding long-distance transportation is not yet ready, mostly due to a lack of public charging infrastructure, a slightly small battery capacity, and a small charging power for vehicle (Engdahl, 2022). This will cause the trouble for electric trucks to earn more HBE unit from the system furtherly.

When companies start to use HBE, they can earn an additional benefit from the HBE system. Although the benefit is relatively small when transport companies only have one electric trucks, it will increase with the increase of the number of electric trucks. When the number of trucks is above two, the HBE benefit per truck is around 20,000 euros, which means that each truck can contribute 20,000 euros to narrow the gap between TCO of electric trucks and TCO of diesel trucks.

Compared to diesel trucks, the TCO of electric trucks is still higher than diesel trucks. The contribution of HBE benefit to narrow the gap between the TCO of both types of trucks is from 6% to 54%. It was expected that HBE will solve the TCO problem for transport companies in the near future. Therefore, the more average mileage of trucks and a greater number of electric trucks can both lead to enlarge the contribution percentage of HBE benefit. Currently the green

energy percentage is 26%, if transport companies can generate its own solar and wind power that connected to the grid, it will almost quadrate the HBE benefit.

5 Conclusion

HBE market can provide economic benefits to transport companies by narrowing the gap between TCO of electric trucks and TCO of diesel trucks under certain combination of mileage and number of electric trucks. One of the biggest barriers for transport companies is that the lack of understanding of how the HBE market works and how it can benefit transport companies. Additionally, the investment cost of purchasing electric trucks is still too high for transport companies, and the expected returns from participating in the HBE market may not be sufficient to justify the investment.

In the study, the key findings on the economic benefits of HBE market to transport companies are the revenue generated by HBE for transport companies with one or two electric trucks is relatively limited, but with more electric trucks, additional revenue can be generated.

Despite uncertainties about the market after 2030, experts are optimistic about the prospects of HBE due to the growing demand and limited supply. However, the profitability of the HBE system for transport companies may increase as the purchasing cost of electric trucks is expected to decrease in the future, and the HBE market scale is expected to increase.

The HBE-TCO model shows that the greater the number of electric trucks and the annual mileage of trucks, the more benefits HBE system can generate. When transport companies utilize HBE system, HBE system can bring additional benefit to transport companies to contribute to narrowing the gap between TCO of electric trucks and TCO of diesel trucks. When the number of electric trucks is more than two, the HBE benefit per truck in 8 years is around 20,000 euros. Under different conditions, the contribution percentage of HBE benefit (HBE Benefit/TCO difference between electric trucks and diesel trucks) can vary from 6% to 54%.

The study fills a gap in the literature of the relationship between HBE market and the TCO gap between electric trucks and diesel trucks. In this study, the qualitative analysis was finished in the method of interview with four respondents. The qualitative analysis includes insights from experts in transport consulting, charging infrastructure research, Dutch Emission Authority, and transport companies. The qualitative analysis supplements the information about HBE market in the literature review, and these supplementary contents are also valuable for future research on HBE market. The quantitative analysis part combines HBE's profit with the

TCO model to create the HBE-TCO model, which is unique in the study of the HBE market.

This study has some limitations. Because the research only studied the relationship between the electric truck field and the Dutch HBE trading system, the actual HBE trading system includes not only the electric truck field but also many other new energy trading systems except electricity. At present, the HBE-TCO model also has some deficiencies such as cost factors, because the HBE-TCO model is designed based on ideal situation.

Future research can focus on the specific development prospects and stability of the HBE market and improve the HBE-TCO model to better evaluate the impact of the HBE market. Some rules and policies of the HBE market in the future may change, and the TCO of electric trucks in the future will also change due to the development of technology and other factors. Future research can also focus on analysing the impact of these new changes on the HBE market.

This study shows that under some conditions, the profit of HBE market can be considerable for narrowing the gap between TCO of electric trucks and diesel trucks. The research conclusion is of positive reference value for transportation companies to purchase electric trucks and whether to use HBE system.

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