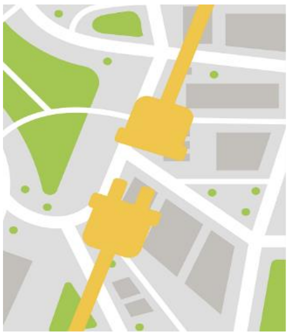

ELECTRIC TRAVELLING

Platform to support the implementation of electromobility in Smart Cities based on ICT applications

Deliverable 7.2.

Results from the Netherlands Case Study: the city of The Hague

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1 Executive summary

Electric travelling is intended to ease the implementation and further development of e-mobility in urban and suburban areas. The final products of the project ETSys help travellers in choosing their travel mode, travel route, and supports local authorities in the definition of appropriate directions for the development of e-mobility. In this report, the ETSys will be tested in a simulation model under different scenarios in the city of The Hague in the Netherlands.

Using the data of The Hague collected in WP2 T2.4: Database of key data for implementation partners (cities), we established 10 scenarios to compare the simulation results of using electric vehicles (EVs) to feed the travel demand between demand zones in the city area. These 10 scenarios are based on three dimensions: travel demand formulated as OD-matrix; optimal charging locations based on the results from WP4 T4.3: Optimal allocation of charging infrastructure for EVs; EV distribution in the fleet meaning the percentage of petrol vehicles, diesel vehicles, PHEVs, and BEVs in the fleet of urban vehicles.

In this report, we present the results of the optimal location of charging stations in The Hague in the target year 2020. The results of all the scenarios will be shown based on the indicators including direct and indirect emissions, monetary travel cost, and energy consumptions. Based on the simulation results, we establish the scenario comparisons and analyse the comparison results. The comparisons are illustrated by graphical figures regarding direct and indirect emissions, noise, and energy consumptions. We conclude that the usage of EVs will decrease the traffic emissions, noise, and energy consumption to some extent. However, the increasing travel demand of travellers in the following years will increase these at the same time which limits the effects of the EVs. In general, evoking the EV market will prevent or decelerate the deterioration of the traffic environment.

This report is organized as follows. Firstly we introduce the information of system input and scenario description in chapter 2. Then the simulation results according to different scenarios are shown in chapter 3. Chapter 4 presents the analysis of the scenario comparison. The report ends with conclusions and recommendations in chapter 5.

2 Scenario descriptions

The Hague is a city located on the western coast of the Netherlands and the capital of the province of South Holland. With a metropolitan population of 1 million, it is the third-largest city in the Netherlands. Currently, The Hague has installed more than 500 charging stations. Most of these stations are with two charger points with 11 kW output[1].

The scenarios in this report are set with three dimensions of inputs: charging demand formulated as OD matrix; charging station; fleet distribution including petrol vehicles, diesel vehicles, battery electric vehicles (BEVs) and plug-in hybrid electric vehicles(PHEVs). We use the current current data in the year 2020 of charging stations and charging demand as the input. Based on this, the travel demand is exported from OmniTRANS which is a multimodal transport planning software package. The charging station information for current scenarios is based on the reality provided by the Municipality of The Hague[2] and Over Morgen. The information includes the longitude and latitude, charging type, power output, capacity, and which company it belongs to. The third dimension of establishing a scenario is the fleet distribution based on the vehicle power type. We set the vehicles running on the road network based on 5 categories: petrol vehicle Euro-5, petrol vehicle Euro-6ab, diesel vehicles Euro-5, diesel vehicles Euro-6ab, pure battery vehicle (BEV), and plug-in hybrid electric vehicle (PHEV).

According to the statistics[3], the total number of passenger vehicles with electric power has reached 227,906 by July 2020 in the Netherlands, in which 55.5%, 0.1%, and 44.4% are BEVs, FCEVs, and PHEVs respectively. Besides the EVs, 76% of the registered vehicles in the Netherlands are with petrol power and 21% are with diesel power Therefore we use this data as the fleet distribution in the simulation running of current scenarios.

Some research and policy institutions in the Netherlands have predicted the EV distribution in the future[4]. In general, the number of EVs on the market is expected to reach 120 million by 2030 in Europe. As the global leaders in electric mobility, the Netherlands are foreseeing a significant EV uptake in the following decades. The government of the Netherlands plans by 2030 to have all cars being sold in the Netherlands emissions-free. According to the literature, we assume that in the future scenarios (2030), the EV fleet distribution is set as following: 13%PHEV and 15% BEV for the conservative situation; 17% PHEV and 20% BEV for the optimistic situation. The fleet distribution including petrol vehicles, diesel vehicles, and EVs for current and future (conservative and optimistic situation) is shown in FIGURE 1FIGURE 2 and FIGURE 3.

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1 An Optimization Model to Upgrade the Charging Network of Electric Vehicles, Dawei Fu, 2020

2 https://www.denhaag.nl/en.htm

3 Statistics Electric Vehicles and Charging in The Netherlands (up to and including May 2020), Netherlands Enterprise Agency, 2020
Composition and payload distribution of the on-road HD-fleet in NL, TNO, 2016
2016 Transport and Mobility, Statistics Netherlands,2016

4 Inputs considerations for estimating large scale uptake electric vehicles in Dutch passenger car fleet up to 2030, TNO, 2018

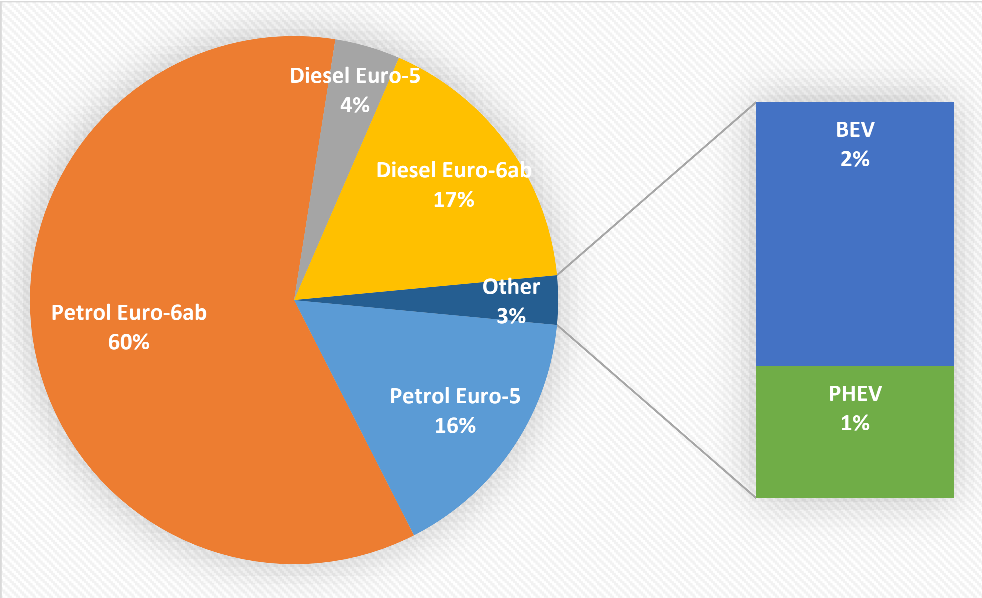

FIGURE 1 EV distribution in the current pattern

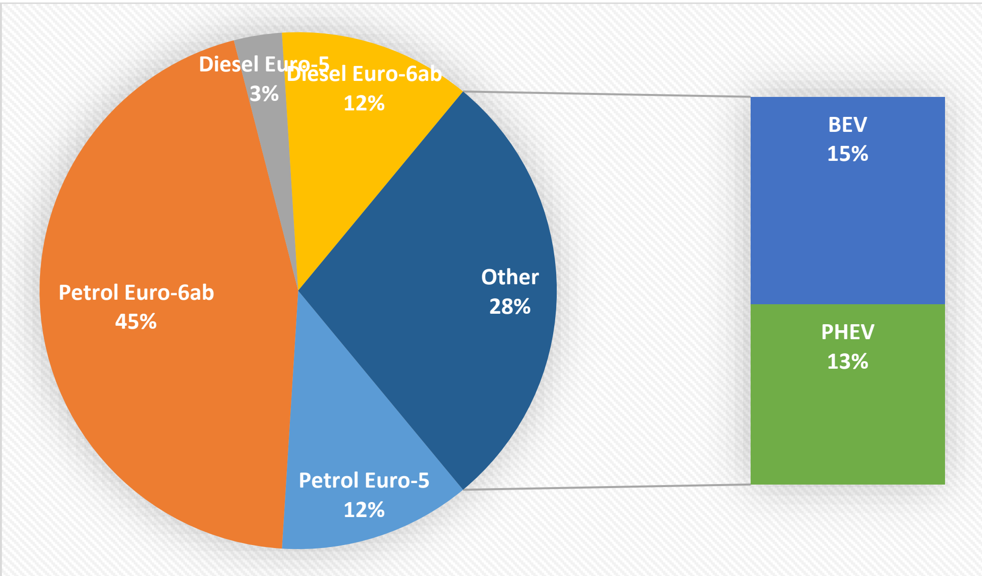

FIGURE 2 EV distribution in future 1 pattern (conservative situation)

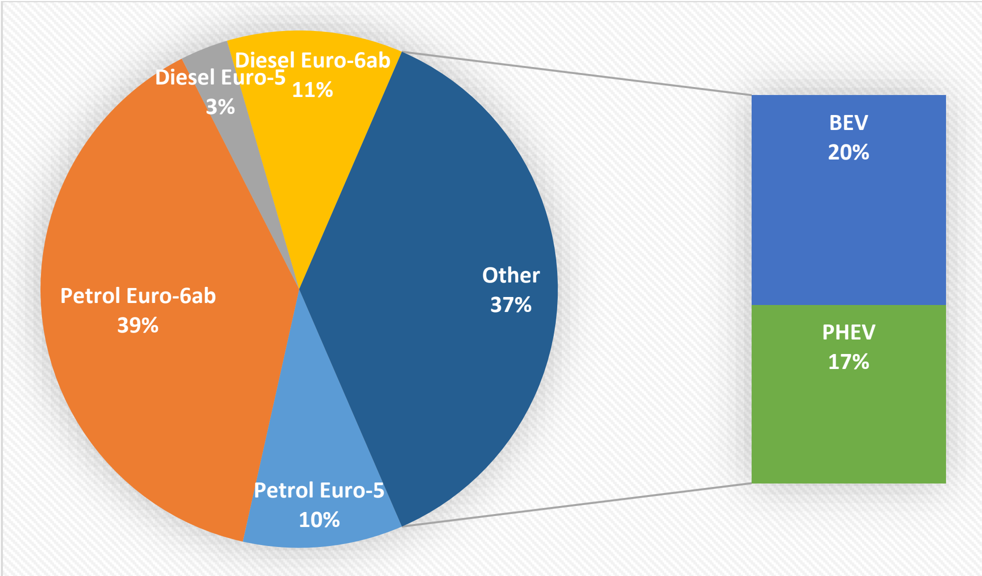

FIGURE 3 EV distribution in future 2 pattern (optimistic situation)

The settings of demand, charging station network and fleet distribution for 10 scenarios are shown in TABLE 1. We vary the OD-matrix as travel demand from current to the future where the future demand is predicted based on a 2% annual increase rate. The charging station distribution for the future scenario is generated by the ET tool in this project based on the current pattern of charging facilities in The Hague area. The detailed information of these results will be shown in section 3.1 in this report. All PHEV and ALL BEV fleets are established to compare with other fleet distributions to analyse the impact of introducing EVs to replace all the Internal combustion engine vehicles on the market.

TABLE 1 Scenario settings

Scenario	**Demand**	**Charging station**	**Fleet distribution**
1	Current	Current	Current
2	Current	Current	Future 1
3	Current	Current	Future 2
4	Current	Current	All PHEV
5	Current	Current	All BEV
6	Optimal	Future	Current
7	Optimal	Future	Future 1
8	Optimal	Future	Future 2
9	Optimal	Future	All PHEV
10	Optimal	Future	All BEV

3 Simulation results

3.1. Results for optimal charging location

FIGURE 4 indicates the location and density of charging facilities in The Hague based on dividing the selected area into several hexagons. This is the result of the tool "optimal allocation of charging infrastructure for EVs" in T4.3 of this project. The prediction year is set as 2030 meaning that to this year an expected growth curve is applid to the number of expected EVs.

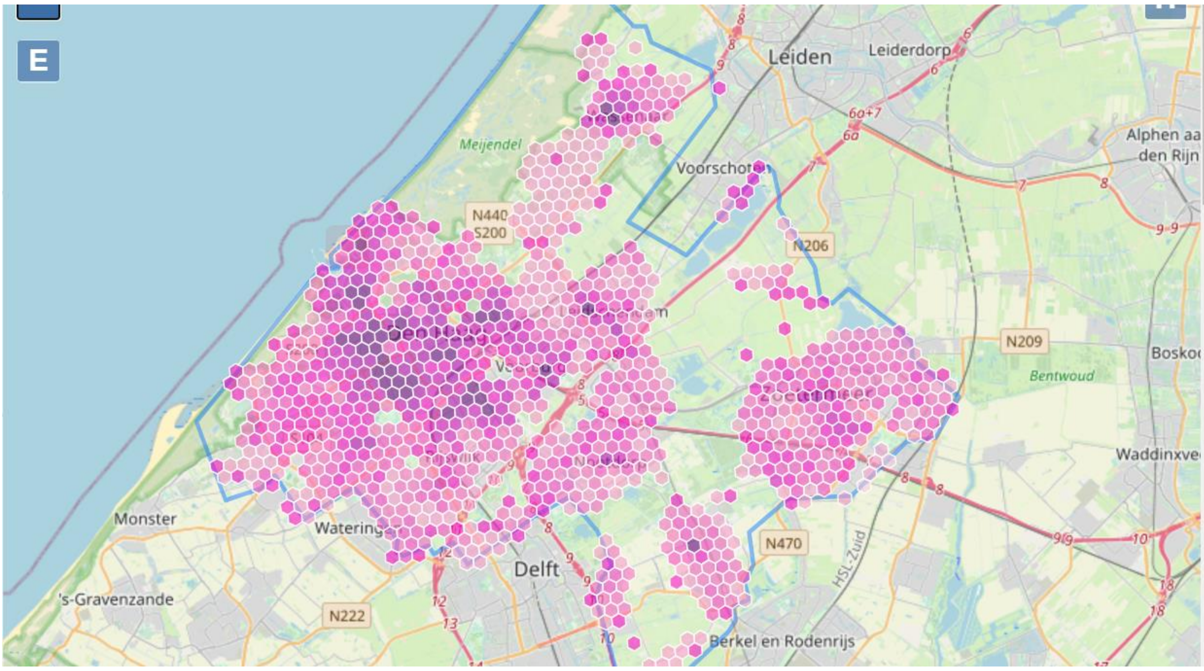

FIGURE 4 Optimal charging facility distribution for The Hague

FIGURE 5 shows optimal points in the city centre area of The Hague. Each hexagon is around 2 km2 containing from 1 to 7 charging facilities. The outskirts areas have relatively low demand for charging which can be seen in the northeast and southwest area of the city. On the contrary, the charging demand in the city centre is larger, leading to a higher density of the charging locations varying from 4-7 per hexagons.

FIGURE 5 Optimal charging facility distribution the city centre area of The Hague.

3.2. Results for all the scenarios

TABLE 2 gives an overview of all the scenarios. 10 scenarios, with different OD matrices, charging station networks and fleet distribution, are tested in the simulation model. The first 5 rows present the scenarios with the current OD matrix, current charging stations and 5 different fleet distributions. The last 5 rows present the scenarios with optimal OD matrix and future charging stations. The emission and energy consumption are given in the last four columns of the table.

It is clear that with a higher proportion of PHEV and BEV, both the level of emissions and energy consumption will drop. If the total proportion of EV increases from 3% to 28%, then the direct emission and energy consumption will drop by 14% and 18% with usual OD matrix and current charging stations. The drop will be 17% and 19% when the optimal OD matrix and future charging stations are considered. If all vehicles are replaced by PHEV, then the direct emission and energy consumption reduction will be 36% and 75% with usual OD matrix and current charging stations (41% and 77% with optimal OD matrix and future charging station). The BEV vehicle could reduce the direct emission and energy consumption by 99% and 89% regardless of the OD matrix and charging stations settings.

We also notice that when the proportion of the EVs increases while the demand and charging stations remain the same, the emission and energy consumption level will drop. This means that the charging station is not the limiting factor for the EV fleet. The simulation results also indicate that if the proportion of the EVs remains the same, the higher travel demand in the future will result in higher emission and energy consumption.

TABLE 2 Results for all the scenario

Scenario	OD matrix	Charging station	Fleet distribution	Global direct Emission gCO2	Global indirect emission gCO2	Electric energy consumption MJ	Other energy consumption MJ
1	Usual	Current	Current	3,283,199,992	709,677,604	42,962,776	952,441
2	Usual	Current	Future1	2,830,211,109	546,497,456	35,092,225	950,257
3	Usual	Current	future2	2,650,214,453	527,645,286	33,638,748	950,315
4	Usual	Current	All PHEV	2,100,581,558	11,506,149	10,651,831	948,854
5	Usual	Current	All BEV	29,133,362	11,508,967	5,052,694	949,243
6	Optimal	Future	Current	4,247,051,029	927,169,206	55,614,402	1,132,262
7	Optimal	Future	Future1	3,526,478,168	728,550,738	44,972,616	1,139,965
8	Optimal	Future	future2	2,394,271,869	393,673,999	27,829,149	1,138,597
9	Optimal	Future	All PHEV	2,520,816,602	13,808,093	12,782,657	1,138,635
10	Optimal	Future	All BEV	34,929,952	13,807,345	6,061,748	1,138,737

3.3. Results for scenario 1

We present the simulation results by showing the geographical heat maps in FIGURE 6. It is clear to see that the emissions, noise, and energy consumption are mainly concentrated on higher-level roads, for example, highways and motorways. The connections between the two highways have the highest level of emissions and energy consumption. This happens more often in the outskirt of The Hague city since highway A4, A13 and A12 all pass by those areas. This trend also happens in the city centre area of The Hague even though no fast roads run through there. This is because city centre is a high density place of travel demand and charging activities.

Direct emissions

Indirect emissions

Noise

Energy consumption

FIGURE 6 Simulation results for scenario 1

4 Comparison of scenarios

In this section, we compare the simulation results of scenario 1 and scenario 7 by showing the heat maps regarding direct and indirect emissions, energy consumption, and noise.

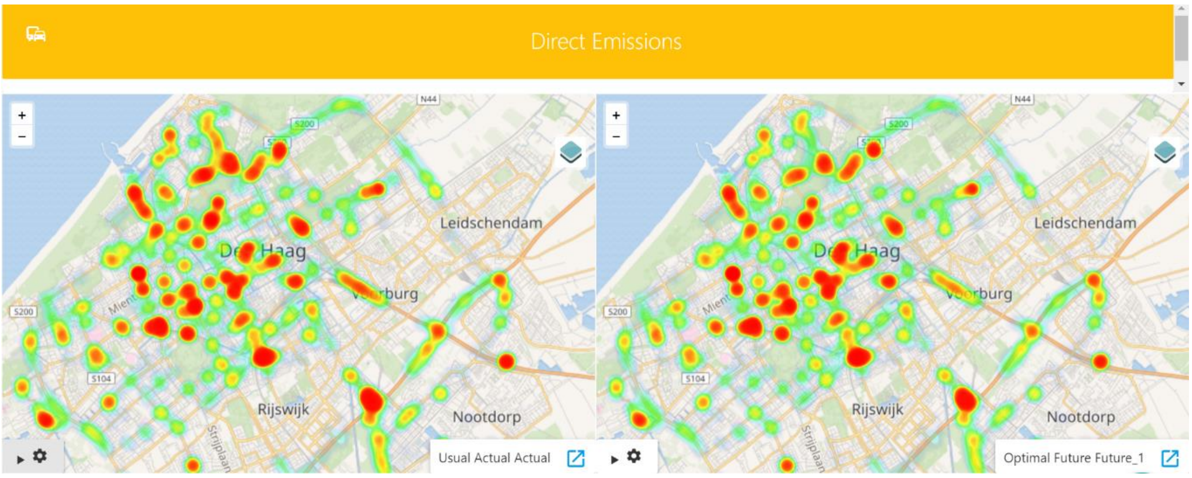

FIGURE 7 Comparison of direct emissions between scenario 1 and scenario 7

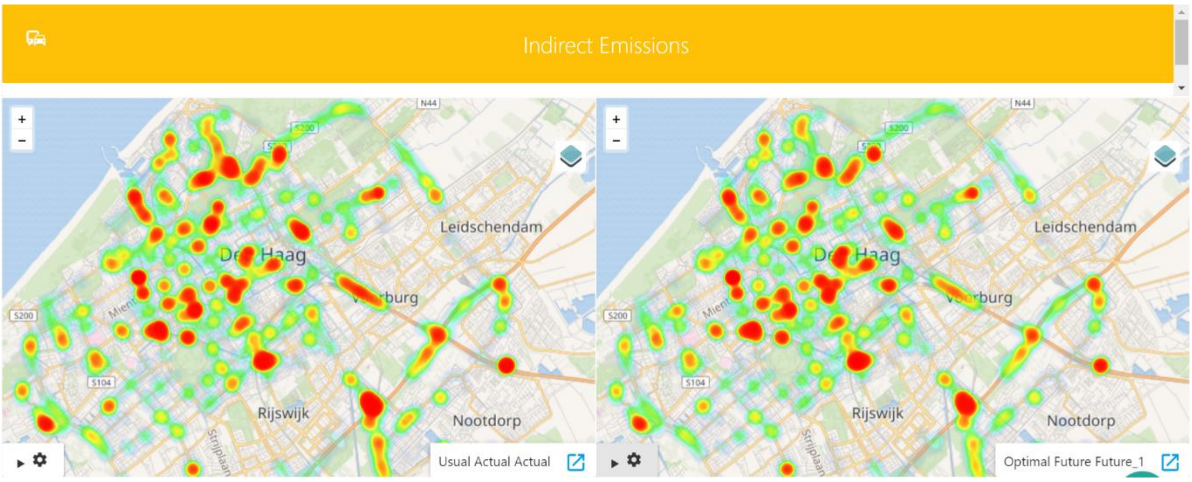

FIGURE 8 Comparison of indirect emissions between scenario 1 and scenario 7

FIGURE 7 and FIGURE 8 illustrate the total amount of direct emissions and the total amount of indirect emissions respectively. In these two figures, the left half demonstrates the current situation and the right half demonstrates the future situation. In both scenarios (current and future), the city centre is always heavier polluted. Besides, traffic on the highway also produces considerable emissions.

From the comparison, we can first identify that the emission level on the highway will drop in the future, while the emission almost remains at the same level on the city roads. It is also noticeable that the traffic on the outskirts of the city will generate fewer emissions in the future, while the same trend is not evident in the central part of the city.

FIGURE 9 indicates that the energy consumption of the vehicles will also drop, mainly on the highway and the outskirt of the city, while the EVs will not significantly reduce the energy consumption of traffic in the city centre.

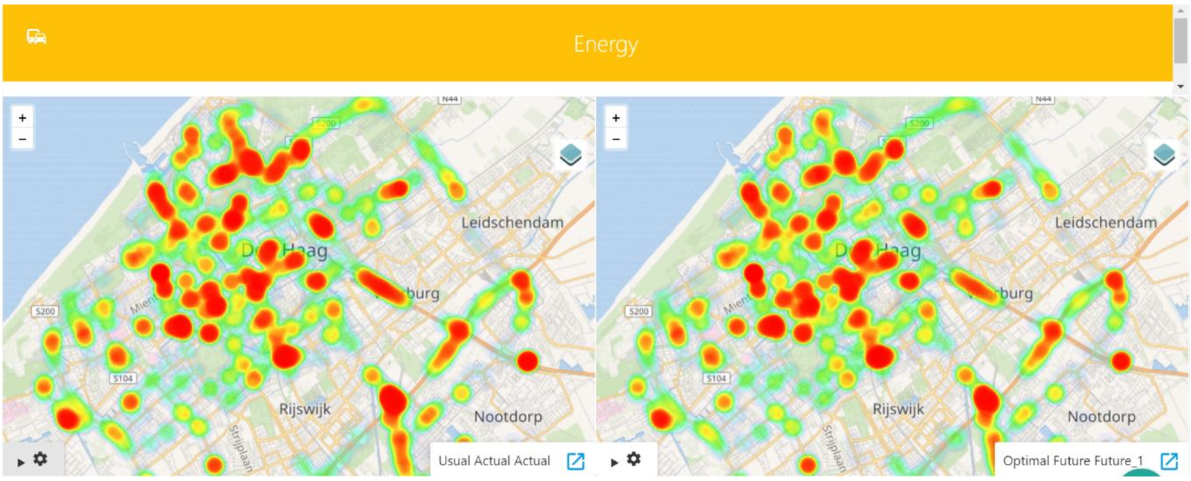

FIGURE 9 Comparison of energy between scenario 1 and scenario 7

FIGURE 10 shows the noise produced by the traffic. The left half illustrates the current situation and the right half illustrates the future situation. Similar to the emission, the central area of the city and the area along the highway suffer more from the noise produced by traffic.

From the comparison, we can find that the noise level on the highway and in the outskirt of the city will drop in the future. But the noise in the central area of the city will not decrease significantly in the future in scenario 7.

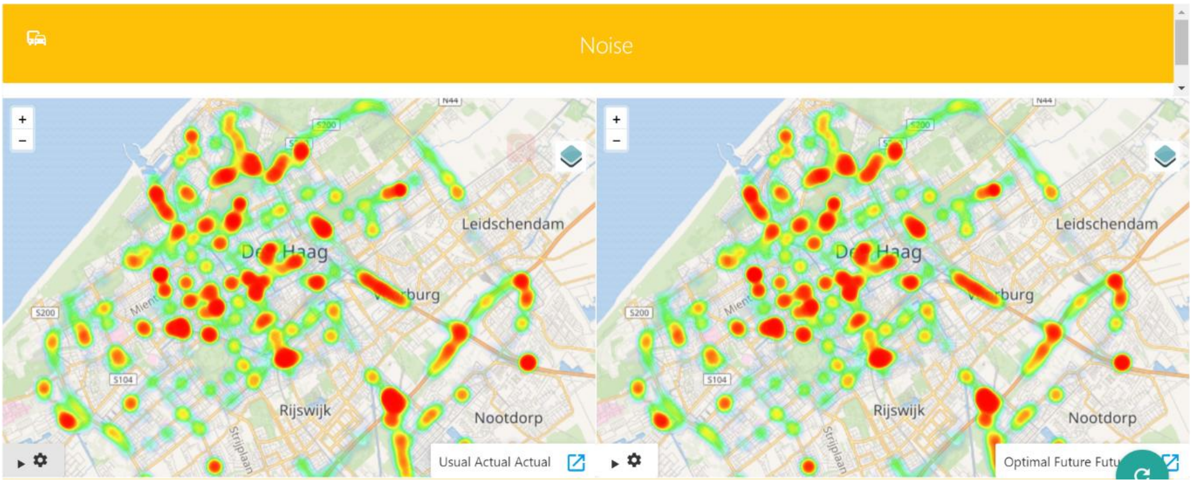

FIGURE 10 Comparison of noise between scenario 1 and scenario 7

From the comparison between scenario 1 and scenario 7, we can conclude that the future scenario of charging stations and future 1 scenario of the fleet will bring benefits regarding emissions, energy consumptions, and noise level. The benefits are more evident along the highway and on the outskirts of the city.

5 Conclusion and recommendations

This report is made with a description of proposed scenarios, optimal allocation of charging stations as well as the simulation results of the ETSys application of The Hague in the Netherlands. The ETSys tool, allows planning travellers and EVs to use mobile devices and other devices connected to the internet for EV private use and offer the choice between multiple criteria and use precise and adaptive models for energy consumption to schedule possible stops at charging stations. This system will provide support for decision-making problems related to estimating electric demand and forecasting trends in e-mobility to optimize further development of the existing EV charging infrastructure.

Based on the analysis done in this report, we have drawn the following conclusions.

- This is a handy tool to assist travellers in choosing the travel mode and route. It can also provide support to local authorities of appropriate directions for the development of e-mobility by testing scenarios with the current state, new charging station and proposed new incentives.
- This tool is sensitive to the size of the city regarding the simulation speed. The Hague is a relatively small city which can be handled in short running time. However, when increasing applying this tool to a larger city e.g. Amsterdam and Rotterdam where there are more vehicles, more complicated road networks and more charging stations, the running time of such simulation might be an inevitable problem.
- We also notice that when the proportion of the EVs increases while the demand and charging stations remain the same, the emission and energy consumption level will drop. This means that the charging station is not the limiting factor for the EV fleet. The simulation results also indicate that if the proportion of the EVs remains the same, the higher travel demand in the future will result in higher emission and energy consumption.

Delft University of Technology and Over Morgen will conduct a demonstration event of this project by presenting the case study results on the conference Forum ISTS2020, which will be held in Delft, the Netherlands, 3-5 November 2020.