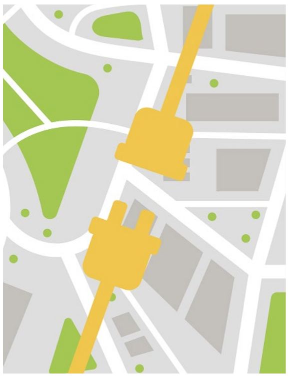

ELECTRIC TRAVELLING

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

CASE STUDY FOR HUNGARY

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1 Executive summary

Electric Travelling aimed to support the implementation of electric mobility in smart cities based on ICT applications. To have a proper outcome of the project, pilots were set up in Poland, the Netherlands and Hungary to test the applications in a real-life environment and to collect feedback from local representatives. Use case related activities covered input data collection, supporting the development from the customer perspective, setting up scenarios for modules in ETSys, presenting to associated partners and collecting feedback from them. This deliverable is presenting the results of the pilot in Budapest and its functional urban area, and provides a short description of the feedback collected in the workshop with associated partners.

Prognosis and projections vary a lot in the spreading of electric mobility, whereas the effects of Covid-19 pandemic were not yet included in the estimations. The scenario development in the Budapest use case tried to cover this uncertainty in a way to use upper and lower values of the prognosis of each parameter. In this way we created an optimistic and a pessimistic scenario, and most probable the actual future will be in the range between these two scenarios. Based on the simulations, CO_2 emission could be decreased by 19% in the pessimistic case, and by 32% in the optimistic case.

2 Scenario descriptions

The input data of Budapest pilot was mostly based on the strategic macrosimulation model of Budapest, the Budapest Unified Model. This is a complex transport macromodelling tool, containing public and private transport as well and the four-step demand modelling. This multimodal macromodelling tool provides a credible description of the expected impacts of possible interventions. This model has milestones in 2030 and 2050 for predicted traffic and mobility demand. The break-through of electric vehicles is expected to happen until 2030, so it was rational to choose 2030 as a forecast year of the scenarios. Matrices of future travel demands and the zone division in ETSys was realized according to the Budapest Unified Model. Following the ceteris paribus (other things being equal) principle, every input data was the same (e.g. road network, travel demand) except for the composition fleets.

In order to examine the possibilities of electric travelling, scenarios were developed. Each scenario had different input data. Electric travelling, especially amongst private cars, grows faster than it was previously expected. To see the possibilities of the future, two scenarios were developed: one is optimistic, and one is pessimistic. Input requirements of the Electric Travelling platform was not a one-on-one matching with the Budapest Unified Model, with Hungarian prognoses of electric mobility or other statistical resources (e.g. vehicle categories). So, transformation of datasets was necessary. In some cases, data were not available, in this case expert estimations were used.

The following datasheets were generated for the different scenarios in terms of vehicle categories by driving system (1. Table – 7. Table).

1. Table Emission category shares for personal cars

	Actual	Optimistic 2030	Pessimistic 2030
Personal Cars (PC)	**100,00%**	**100,00%**	**100,00%**
PETROL: “PC/PC petrol Euro-5”	57,75%	7,00%	14,00%
PETROL: “PC/PC petrol Euro-6ab”	9,01%	17,00%	22,00%
DIESEL: “PC/PC diesel Euro-5”	27,37%	3,00%	8,00%
DIESEL: “PC/PC diesel Euro-6a”	4,79%	12,00%	19,00%
BEV: “PC/PC BEV”	0,18%	31,00%	19,00%
CNG: “PC/PC CNG/petrol Euro-6_(CNG)”	0,36%	2,00%	1,00%
LGP: “PC/PC LPG/petrol Euro-6_(LPG)”	0,36%	2,00%	1,00%
PH: “PC/PC PHEV diesel Euro-6ab_(El)”	0,18%	21,00%	15,00%
FC: “PC/PC FuelCell”	0,00%	5,00%	1,00%

2. Table Emission category shares for motorcyle

	Actual	Optimistic 2030	Pessimistic 2030
Motorcycle (MC)	**100,00%**	**100,00%**	**100,00%**
PETROL: “MC/Moped <=50cc Euro-5”	31,00%	26,00%	29,00%
PETROL: “MC/MC 4S <=250cc Euro-6”	26,00%	24,00%	28,00%
PETROL: “MC/MC 4S >250cc Euro-6”	27,00%	25,00%	23,00%
PETROL: “MC/MC 2S <=250cc Euro-6”	15,00%	5,00%	8,00%
BEV: “MC/MC BEV”	1,00%	20,00%	12,00%

3. Table Emission category shares for heavy goods vehicle

	Actual	Optimistic 2030	Pessimistic 2030
Heavy Good Vehicle (HGV)	**100,00%**	**100,00%**	**100,00%**
CNG: HGV CNG <=7,5t Euro-VI	0,14%	3,00%	2,00%
LNG: HGV LNG <=7,5t Euro-VI	0,14%	3,00%	2,00%
FC: RigidTruck FCEV <=7,5t Euro-VI	0,00%	1,00%	0,50%
PH: RigidTruck PHEV <=7,5t Euro-VI-(El)	0,01%	1,00%	0,50%
DIESEL: RT <=7.5t Euro-VI	75,70%	55,00%	65,00%
CNG: HGV CNG >7,5-12t Euro-VI	0,01%	3,00%	1,00%
LNG: HGV LNG >7,5-12t Euro-VI	0,01%	3,00%	1,00%
FC: RigidTruck FCEV >7,5-12t Euro-VI	0,00%	1,00%	0,50%
PH: RigidTruck PHEV >7,5-12t Euro-VI-(El)	0,00%	3,00%	0,50%
DIESEL: RT >7,5-12t Euro-VI	6,80%	5,00%	6,00%
CNG: HGV CNG >12t Euro-VI	0,03%	4,00%	2,00%
LNG: HGV LNG >12t Euro-VI	0,03%	4,00%	2,00%
FC: RigidTruck FCEV >12t Euro-VI	0,00%	1,00%	0,50%
PH: RigidTruck PHEV >12t Euro-VI-(El)	0,00%	1,00%	0,50%
DIESEL: RT >12-14t Euro-VI	17,12%	12,00%	16,00%

4. Table Emission category shares for light commercial vehicle

	Actual	Optimistic 2030	Pessimistic 2030
Light Commercial Vehicle (LCV)	**100,00%**	**100,00%**	**100,00%**
BEV: LCV BEV N1-II	0,28%	33,00%	27,00%
CNG: LCV CNGpetrol N1-II Euro-6_(CNG)	0,36%	4,00%	6,00%
DIESEL: LCV diesel N1-II Euro-6c	93,89%	41,00%	48,00%

	Actual	Optimistic 2030	Pessimistic 2030
PETROL: LCV petrol N1-II Euro-6c	5,47%	0,00%	3,00%
PH: LCV PHEV petrol N1-II Euro-6_(El)	0,01%	22,00%	16,00%

5. Table Emission category shares for personal transporters

	Actual	Optimistic 2030	Pessimistic 2030
Personal transporter	**100,00%**	**100,00%**	**100,00%**
BEV: “MC/eBike”	2,00%	5,00%	10,00%
BEV: “MC/eScooter”	2,00%	5,00%	10,00%
BEV: "Other"	2,00%	10,00%	10,00%
0: Walk	80,00%	50,00%	60,00%
0: Bike	14,00%	30,00%	10,00%

6. Table Emission category shares for urban buses

	Actual	Optimistic 2030	Pessimistic 2030
Urban Buses (UBUS)	**100,00%**	**100,00%**	**100,00%**
DIESEL: “UBUS/UBus Std >15-18t Euro-VI“	97,26%	5,00%	15,00%
CNG: “UBUS/UBus Std >15-18t CNG Euro-VI”	0,34%	9,00%	14,00%
ETHANOL: “UBUS/UBus Std >15-18t Ethanol Euro-VI”	0,34%	6,00%	9,00%
BEV: “UBUS/UBus Electric Std >15-18t”	0,34%	58,00%	37,00%
FC: “UBUS/UBus FuelCell Std >15-18t”	0,00%	9,00%	7,00%
LNG: “UBUS/UBus Std >15-18t LNG Euro-VI”	0,34%	7,00%	13,00%
PHEV: “UBUS/UBus Std >15-18t PHEV Euro-VI”	1,36%	6,00%	5,00%

7. Table Emission category shares for coaches

	Actual	Optimistic 2030	Pessimistic 2030
Coach (COACH)	**100,00%**	**100,00%**	**100,00%**
DIESEL: “COACH/Coach Std <=18t Euro-VI”	100,00%	53,00%	71,00%
CNG: “COACH/Coach Std <=18t CNG Euro-VI”	0,00%	40,00%	27,00%
BEV: “COACH/Coach BEV Std <=18t”	0,00%	5,00%	1,00%
FC: “COACH/Coach FuelCell Std <=18t”	0,00%	2,00%	1,00%

This Electric Travelling input is generated based on official statistics and public transport operator fleet descriptions and were transferred to this specific categorization. Fleet descriptions are based on number of vehicles, since this was the available data, but with current technologies, traditional combustion engines driven buses can run a lot more a day than electric driven ones. It means that these assumptions are underestimating for example the emissions.

Regarding the charging infrastructure, the calculations were done for Budapest (NUTS region: HU110) and its functional urban area Pest county (NUTS region: HU210). The hexagons were only changed, where the automatic assumptions incorrectly set the type of the area. The motorization rate was set with the following assumption: for Budapest a slightly lower motorization rate was set, while for Pest County a slightly higher. These generated the following vehicle stocks (8. Table).

8. Table Vehicle stocks

	Budapest	Pest County
2016	611 941	486 467
2017	633 554	512 819
2018	659 513	537 952
2019	684 197	568 012
2030	**650 000**	**650 000**

These values were set the same in the two scenarios, only the driving system of vehicles has differences between scenarios. The shares of the different electric vehicle types were defined accordingly to the emission categories. The following settings were applied (9. Table).

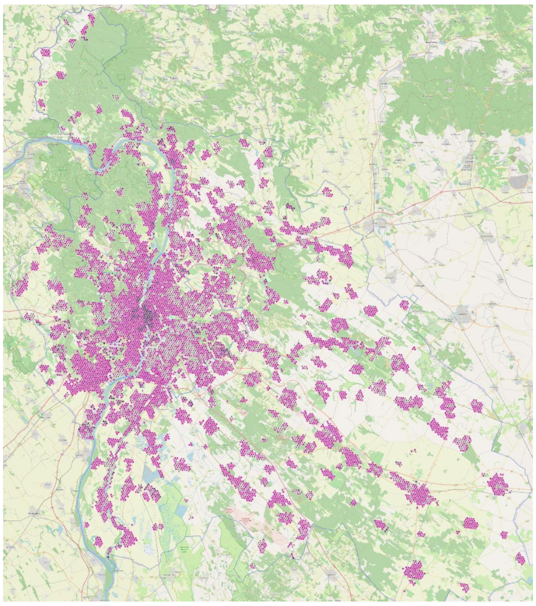
9. Table Electric vehicle types

	Optimistic	Pessimistic
Battery EV	31%	19%
Plug-in EV	21%	15%
Range-extended EV	1%	1%

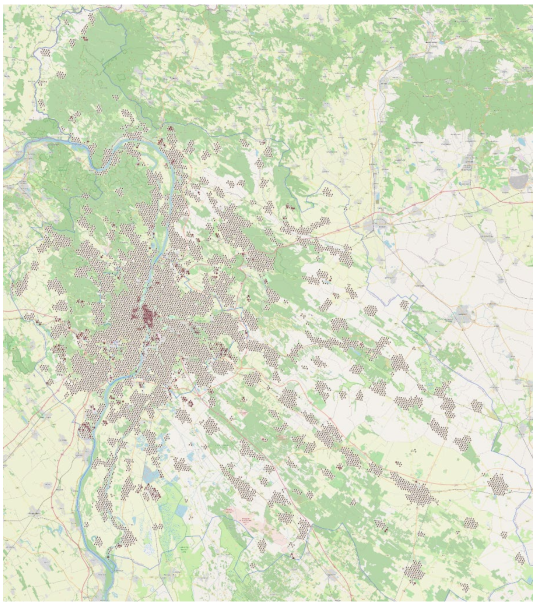
3 Simulation results

3.1 Charging locations

With the above-mentioned settings, the optimistic scenario provided the following charging station allocations in the region.



1. Figure Regular charging station allocation (optimistic scenario)

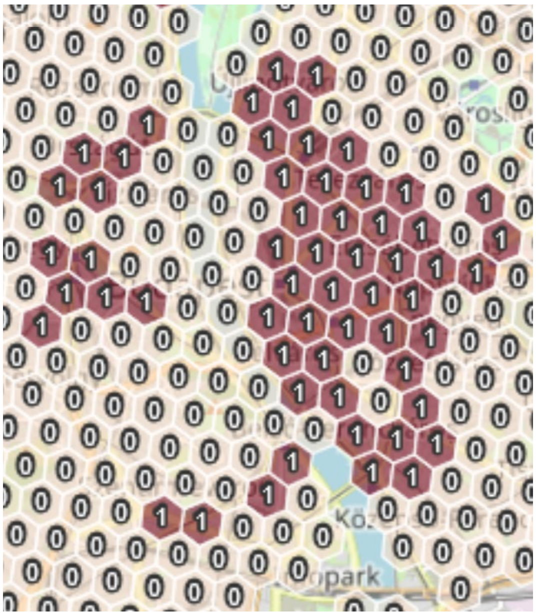


2. Figure Fast charging station allocation (optimistic scenario)

1. Figure shows the regular charging station allocation. Transparent purple marks hexagons without charging station, light purple marks with one suggested charging station, and deep purple shows hexagons with two suggested charging stations. With this settings, three charging regular charging station was no allocated in any hexagons.

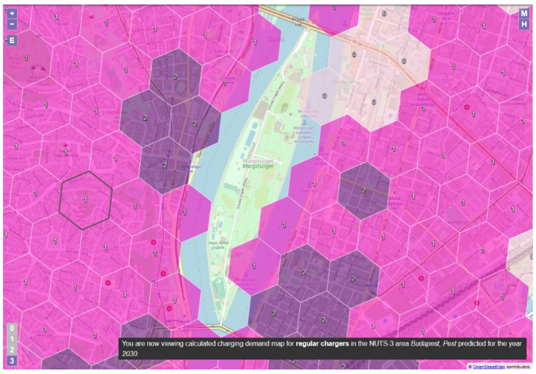
2. Figure shows the fast charging station allocations. Transparent brown marks hexagons without charging station and light brown marks with one suggested charging station. In this scenario, two or more fast charging stations were not allocated in any of the hexagons.

In the figures suburban centers are also shown. While the normal charging infrastructure is equally connected to residential and industrial, office and commercial areas, fast charging infrastructures are only demanded in industrial, office and commercial areas.

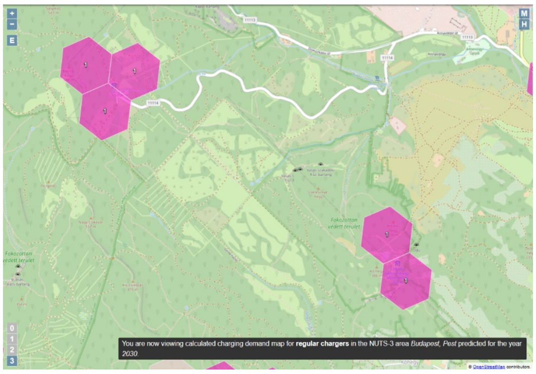


3. Figure Fast chargers in downtown area

3. Figure shows a cut-out from the downtown area of Budapest, where hexagons of the charging station allocation algorithm are visible. It can be seen that the downtown of Pest side of Budapest is full of proposed fast chargers, and this is correct, since this part of the city is the commercial and economic center. Meanwhile, the Buda side of Budapest, which is more historical part with the castle, is calculated with less fast chargers, also accurately.

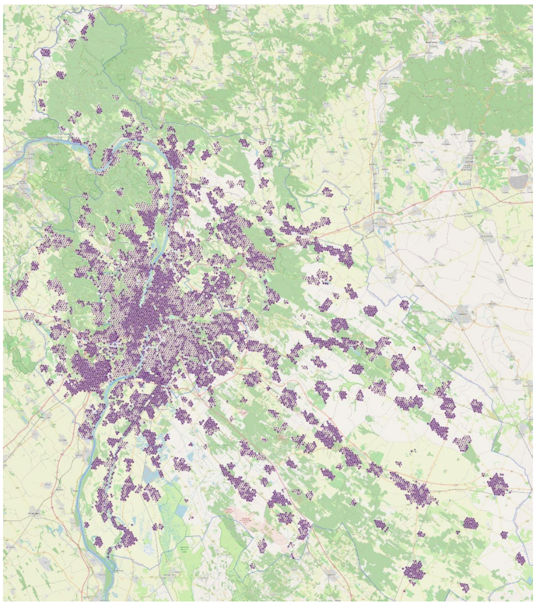


4. Figure Regular chargers in downtown area

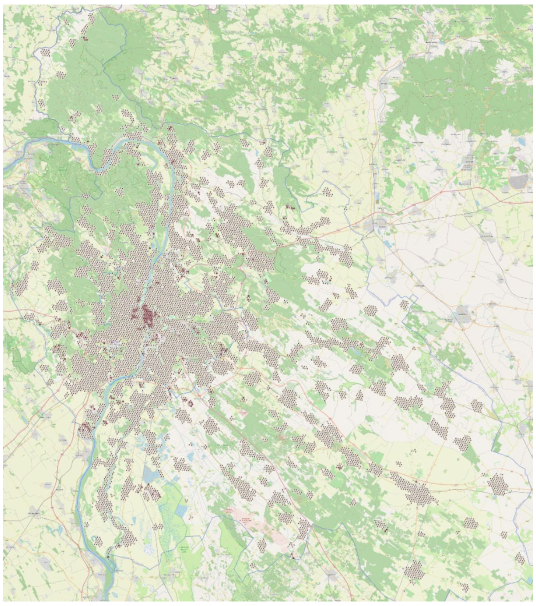


5. Figure Regular chargers in rural area

Detailed views of the regular charging station allocation are shown in *4. Figure* and *5. Figure*. The model is well calibrated in the urban environment but performs less accuracy in rural area. In 4. Figure shows the area around Margit-island, which is a traffic calmed area in the downtown of Budapest, and the algorithm correctly avoided this area. However, in the country area presented in 5. Figure, the algorithm suggests charging stations in the right bottom part, where only hikers could go. Since the system was designed for city areas, this is within the margin of error, but a possible future development area.



6. *Figure Regular charging station allocation (pessimistic scenario)*



7. *Figure Fast charging station allocation (pessimistic scenario)*

Charging station allocation in the pessimistic scenario has quite the same pattern, but of course with lower numbers. *6. Figure* and *7. Figure* represent the results of these scenarios. The lower number of required fast chargers means that the algorithm calculated less for the sub-centers of the functional urban area. This is visible when comparing *2. Figure* and *7. Figure*.

3.2 Impact model

For presentation purposes, the downtown area of Budapest modelled separately with filtered inner traffic of zones in the 1st and 5th districts. The impact model calculates direct CO2 emission and noise for this area, which is represented in the next figures

8. Figure
Direct CO2 emission heatmap (actual)

9. Figure
Direct CO2 emission heatmap (pessimistic scenario)

10. Figure
Direct CO2 emission heatmap (optimistic scenario)

The figures show the noise emission with the same limitations: this was examined on a sample travel demand matrix only in the downtown of Budapest.

11. Figure
Direct noise emission heatmap (actual)

12. Figure
Direct noise emission heatmap (pessimistic scenario)

13. Figure
Direct noise emission heatmap (optimistic scenario)

This visualization shows, that with the same amount of private car traffic, significant amount of direct emission can be eliminated (8. Figure – 10. Figure). However, changes in noise are visible, but not as significant as with emissions (11. Figure – 13. Figure). It is probably because fossil fueled cars are getting more quiet year by year.

4 Comparison of scenarios

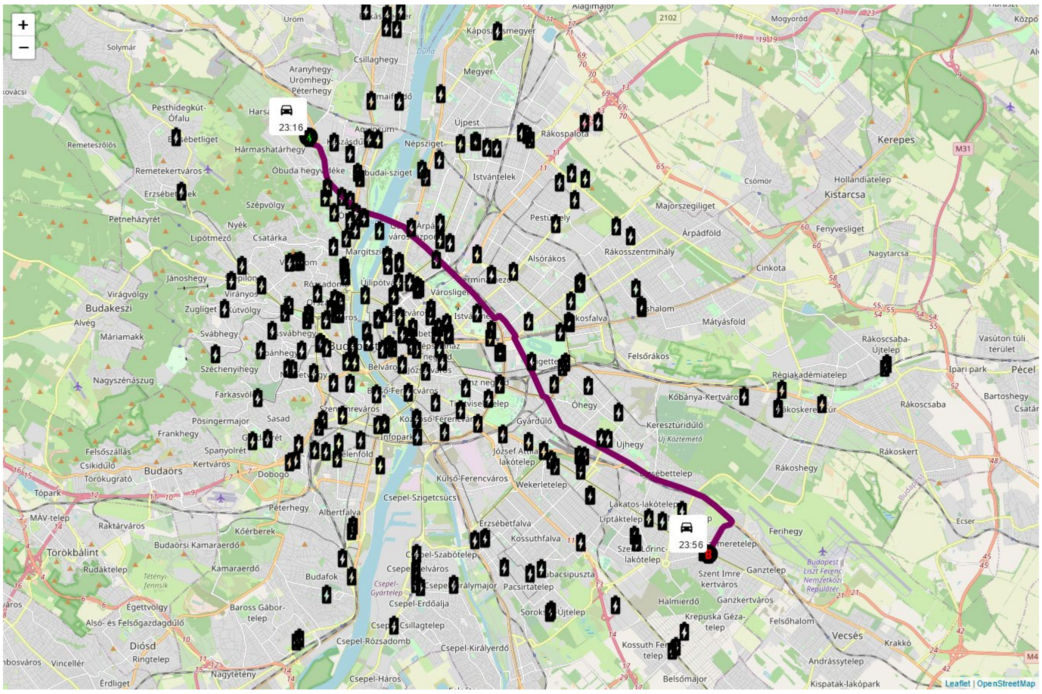
The platform allows the users to create infinite number of comparisons:

- changes in routing between conventional vehicles and electric vehicles;
- changes in different future scenarios of electric charging stations;
- changes in CO2 emissions and energy consumptions for current and future scenarios of electric travelling, or comparable heatmaps of noise emissions.

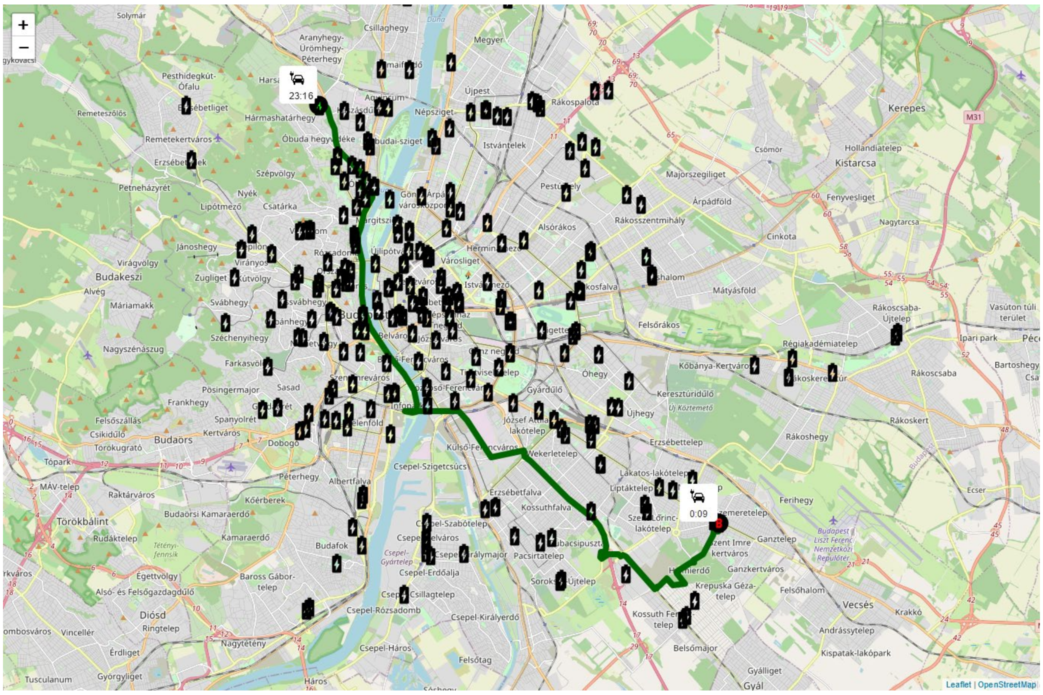
In the following, one comparison is presented from each of the above-mentioned possibilities as a use case.

4.1 Comparison of routings

14. Figure and 15. Figure show the ETPlanner with two sample routing. The first one is a quick planning mode with conventional car. The second one is a green routing mode with electric car. The figures also show the current chargers in Budapest.



14. Figure ETPlanner route in quick mode with conventional car



15. Figure ETPlanner route in green mode with electric car

The webtool provides the details of the two different routes between the same origin and destination. The quick route is 40 minutes and 22 kilometers, whereas the green route is 53 minutes and 29 kilometers. However, the comparison between the CO_2 emissions are 4535 gCO_2 vs 2404 gCO_2, which means that the green route with electric car has half of the CO_2 emission, then the quick route with conventional car. These values are including direct and indirect emissions as well.

4.2 Comparison of future charging locations

The comparison of scenarios presented in Chapter 3.1 has the following results.

10. Table Comparison of ETCharger scenarios

<table>
<tr><th colspan="2"></th><th>Optimistic</th><th>Pessimistic</th></tr>
<tr><td colspan="2">Conventional</td><td>587 500</td><td>812 500</td></tr>
<tr><td colspan="2">Battery</td><td>387 500</td><td>237 500</td></tr>
<tr><td colspan="2">Plug-in</td><td>262 500</td><td>187 500</td></tr>
<tr><td colspan="2">Range-extended</td><td>12 500</td><td>12 500</td></tr>
<tr><td colspan="2">Sum of electric</td><td>662 500</td><td>437 500</td></tr>
<tr><td rowspan="2">Required chargers</td><td>Regular</td><td>8 057</td><td>6 640</td></tr>
<tr><td>Fast</td><td>242</td><td>200</td></tr>
<tr><td colspan="3">Difference in nr. of electric cars</td><td>151%</td></tr>
<tr><td colspan="3">Difference in nr. of required charging locations</td><td>121%</td></tr>
</table>

As 10. Table shows, although the optimistic version is 51% higher in number of electric cars than the pessimistic version, only 21% more charging locations is needed. With another words, a lower number of electric cars demands relatively higher number of charging locations in order to provide minimal spatial accessibility. Also, the optimistic version brings a better efficiency with 79 electric cars per charging location, compared to the pessimistic version with 63 cars per charging location.

4.3 Comparison of scenarios

Numerical comparisons of KPIs of the two scenarios are shown in 11. Table. This dataset is generated from a sample traffic described in Chapter 3. It means, that not the concrete values are important, but the relative differences between the scenarios. For a better overview, actual data sets were added to the comparison, whole a theoretical one is also represented, where all private cars are electric. Direct emissions are local emissions, where the vehicle travels. Indirect emissions are everything else calculated by the ETSys Life Cycle Assessment tool.

11. Table KPIs of current status and different future scenarios

				Direct Emissions	Indirect Emissions	Energy Consumption
	Fossil	BEV	PHEV	gCO2	gCO2	W/h
Actual	99,6%	0,2%	0,2%	25 898 624	4 513 616	290 827
Pessimistic future	66,0%	19,0%	15,0%	21 457 017	3 042 368	226 850
Optimistic future	48,0%	31,0%	21,0%	18 540 290	2 255 157	191 197
Theoretical	0,0%	100,0%	0,0%	405 756	155 925	68 713

In 12. Table results are shown as percentages of the current state.

12. Table Comparison of future scenarios to current status

	Direct Emissions	Indirect Emissions	Energy Consumption
	gCO2	gCO2	W/h
Actual	100%	100%	100%
Pessimistic future	83%	67%	78%
Optimistic future	72%	50%	66%
Theoretical	2%	3%	24%

Indirect and direct CO2 emission together could be decreased by 19% in the pessimistic case and by 32% in the optimistic case.

5 Conclusion and recommendations

In order to collect conclusions and formulate recommendations, BME organized an online workshop, where participants represented relevant areas of electric mobility.

In the Budapest use case, E-Mobi was one associated partner. E-Mobi was a governmental background institute, and was responsible for the promotion of electric mobility, and the accessibility of charging stations in whole Hungary. The stakeholder's main activity was to deploy electric chargers. From 2020 E-Mobi and its expert pool was integrated to e-charging infrastructure operator Mobiliti plc. and to electric grid operator MVM Hungarian Electricity plc. Mobiliti has over 150 charging stations nation-wide.

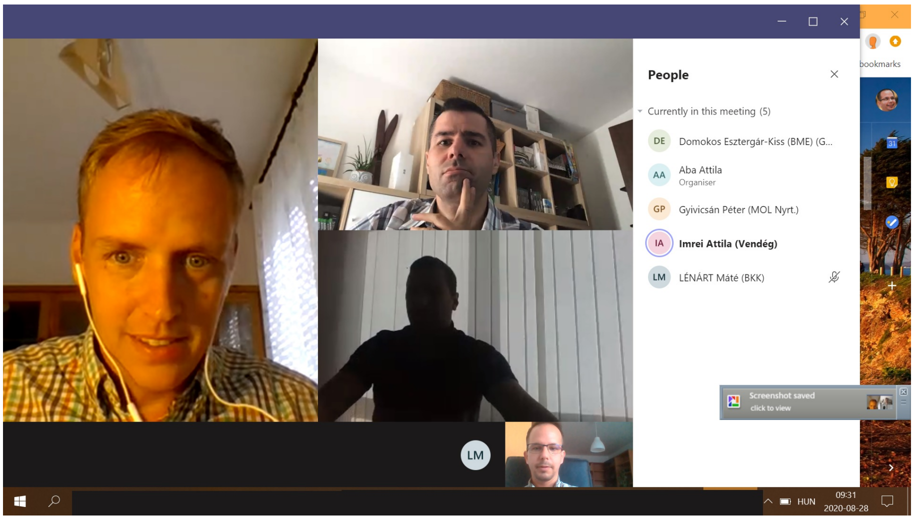
Another associated partner was MOL. MOL was originated from petrochemistry industry, but currently is getting more involved to electric mobility with car-sharing company (MOL-Limo), which operates battery electric vehicles as well and with operating e-charging infrastructure (MOL Plugee). MOL Plugee has e-charging stations not just in Hungary, but in Slovenia, Croatia and Romania as well, and the numbers of locations are over 50, and is based on MOL's petrol station network.

BKK Centre for Budapest Transport is the transport authority for Budapest, involved in each level of transport development from strategic to operative. BKK is also involved in the preparation of mobility related local regulations and legislations.

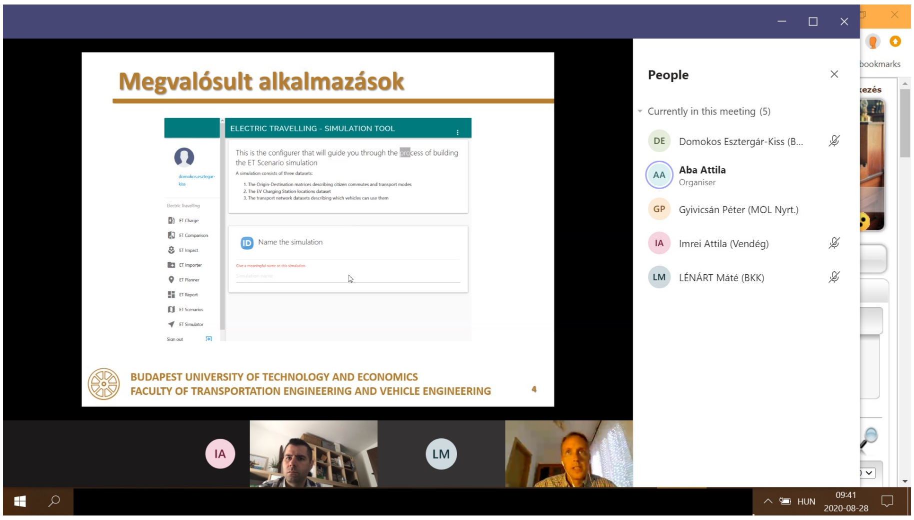
The participating three companies have a wide coverage of possible stakeholders. The workshop was organized as an online meeting. The first part covered a presentation of the project and the results of the Budapest use case, then every tool was demonstrated, and their functions were presented, and finally an open discussion closed the meeting. Figure 16 – Figure 18 show the screenshots of the event.

The list of participants is provided here:

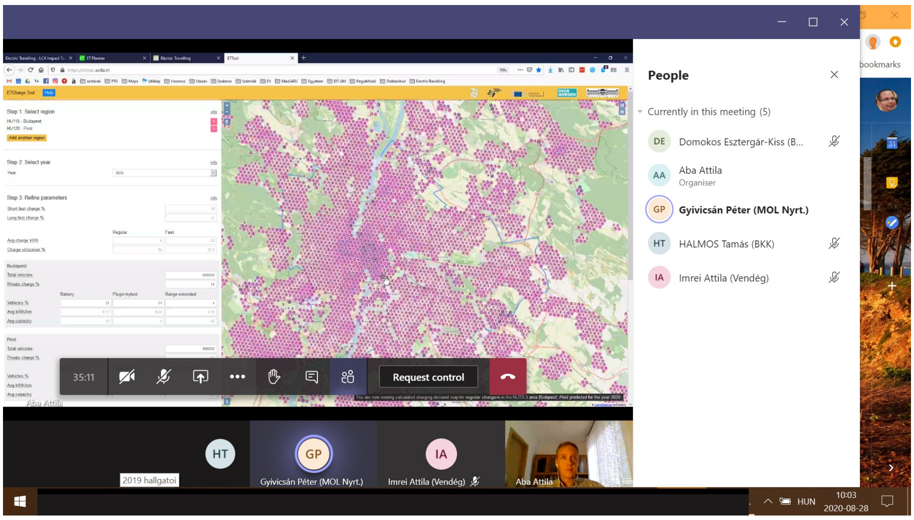
- Attila Imrei, MVM TITAN Ltd., General Project Manager
- Máté Lénárt, BKK Centre for Budapest Transport, Innovation Officer
- Tamás Halmos, BKK Centre for Budapest Transport, Innovation Officer
- Péter Gyivicsán, MOL, Alternative Fuel Expert (E-mobility)
- Domokos Esztergár-Kiss, BME KUKG, International Project Coordinator
- Attila Aba, BME KUKG, Assistant Researcher



16. Figure Screenshot with the participants



17. Figure Screenshot during the presentation



18. Figure Screenshot during live demonstration of the tools

The following conclusions and recommendations were collected from the associated partners during the discussion session.

- This is the first tool to comprehensively handle electric mobility with all aspects, personal and social. The outcome should be integrated into traditional strategic urban traffic models. This can be a module of it, with standardized data exchange between the two applications or it can be fully integrated.
- Faster running times of ETSys would be welcomed. Slower running times means less iteration of the same time. Since the system is very sensible for input data, finetuning would be required to see the effects of each input parameters. Also, for parameters that are difficult to determine or predict, it is rational to examine its potential ranges, which means again more scenarios to examine.
- The assignments of ETCharger are performing better in urban and suburban area, while rural areas provide less realistic suggestions. Differentiation of the algorithm in different types of area could improve the performance.
- ETCharger needs integration with the electric grid systems, and a built-in cost analysis of electric charging station deployment would be also welcomed. Charging station allocations in real environments are currently driven more by electric grid network capacities than by users' demands. Generally, further parameters and functions could help more the charger infrastructure development.
- ETCharger could work in smaller regions or zones than NUTS regions. It could provide also more useful suggestions due to the more precise parameterization of smaller zones.
- ETSys should be always updated by monitoring the changes of user behaviour on how they use electric cars. Also, the market solutions should be monitored, which can affect the user behaviour, for example discounting off-peak charging.
- The associated partners expressed their interest in ETSys in two major ways. First is the above mentioned more detailed charging infrastructure development supporting tool. The other is an advanced route planner based on ETPlanner, which copes with vehicle charging requirements and can be a basis of a MaaS scheme.