GRADOVI
ZA KLIMATSKU
NEUTRALNOST
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Implementing Zero Emission Mobility Solutions

Key trends and challenges of succesful ZEMO implementation

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Mestna občina Ljubljana
City of Ljubljana

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„

...eering means engineering as it focuses on technology as a key driver to make a difference

...eering means pioneering as it employs innovation to reach its business goals

...eering means mountaineering as it aims to the summits and values those who share the same climbing attitude

...eering means steering as it steers its clients through the challenges of implementing new mobility concepts safely and within a given timeframe

"

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we take you there!

#01 TRENDS

Challenges of future mobility

By 2050 more than **70%** of World population will be living in urban areas.

As much as **2.5-3 bln** inhabitants more then in 2019!

In case of „business as usual” scenario, **140%** increase in passenger miles driven is to be expected in comparison to the present situation.

As a result, challenges such as poor air quality, decline in productivity as a result of traffic congestion and higher healthcare costs due to lower safety standards are to addressed.

If these challenges are not began to be tackled today, no technical solution will solve the pertinent problems,

...so it won't even the „smartest” Smart Mobility.

Important to understand the context

How we live is the key

The problem is not with the Exxon Mobiles of this world.

The problem is in our habits, ways of life and daily practice. To change them, we need new incentives, new technological paradigms, new ways of implementation.

Why? Cause if we continue as we've been doing so far…

…12% of China's GDP is spent on solving the negative consequences of intensive traffic such as smog

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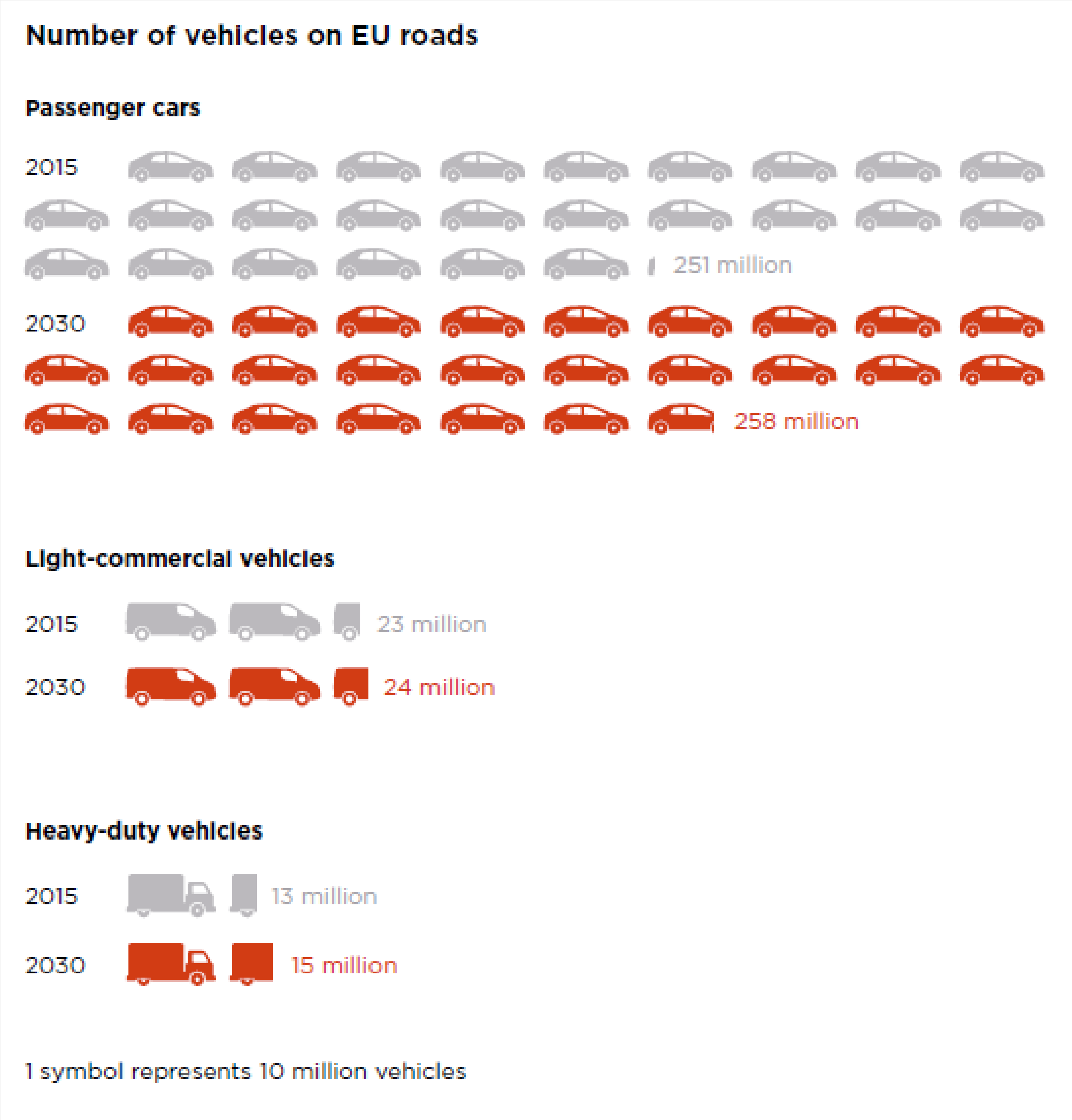
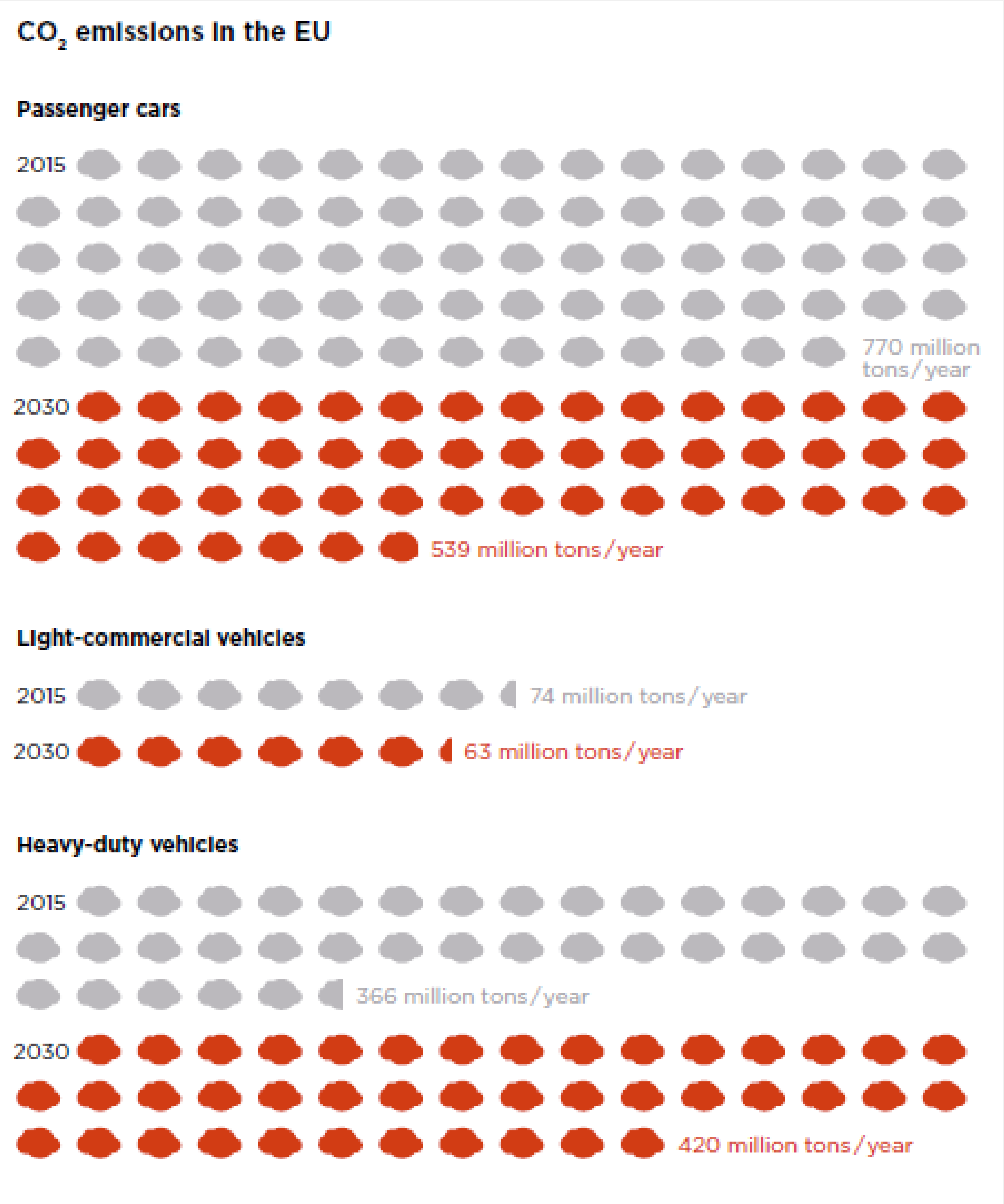
Trends

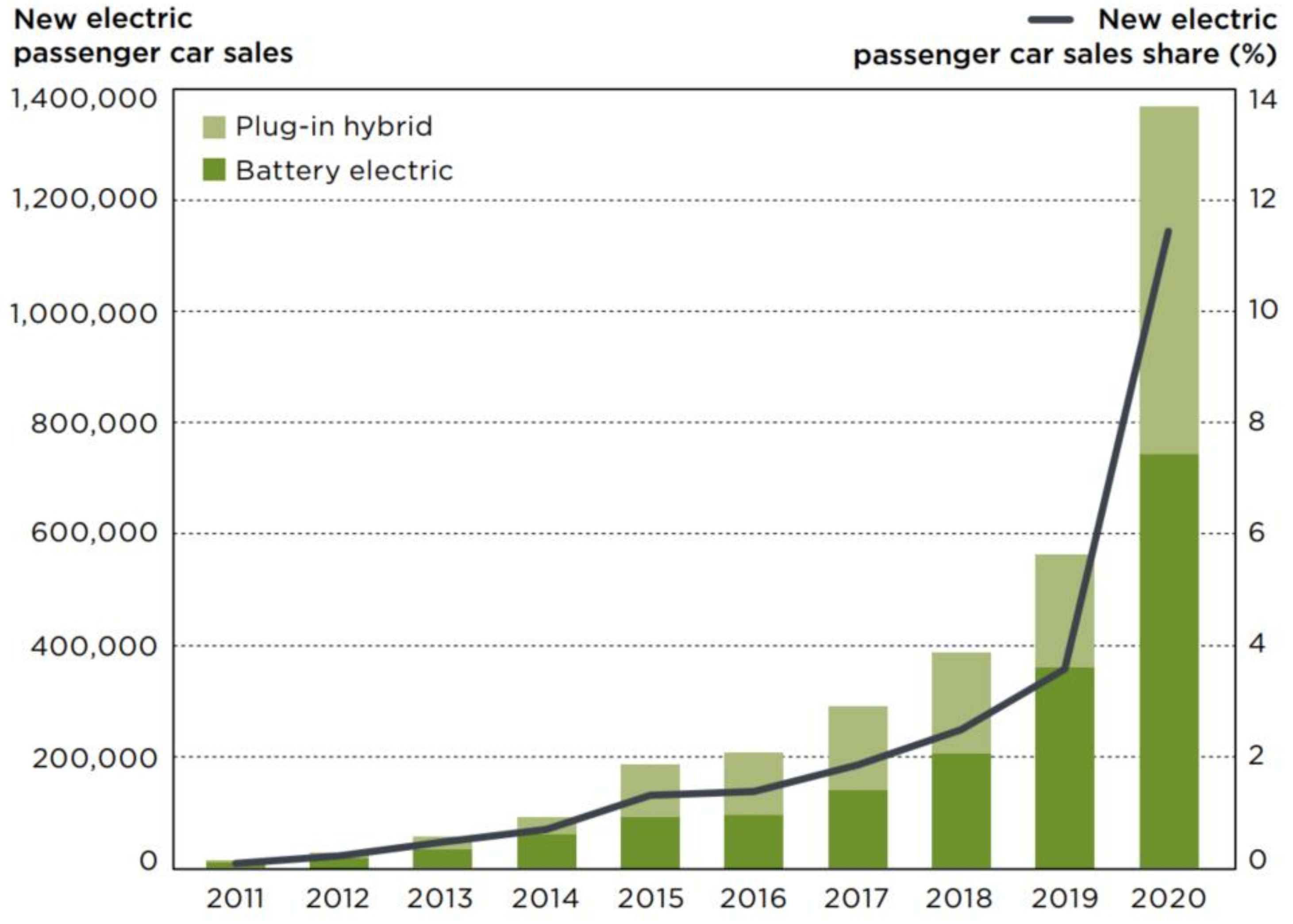




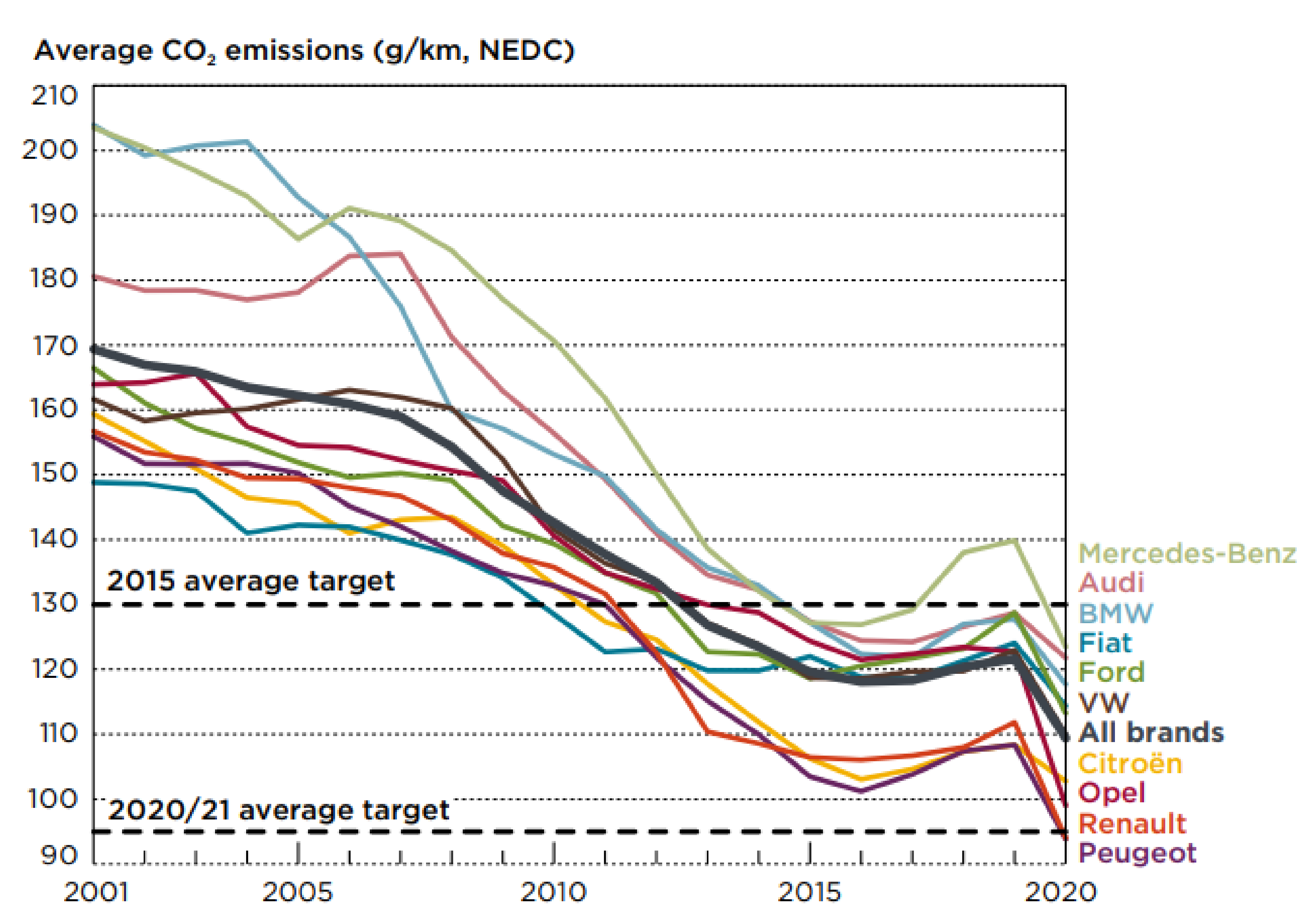
Izvor: The International Council of Clean Transportation, 2015

Realisation

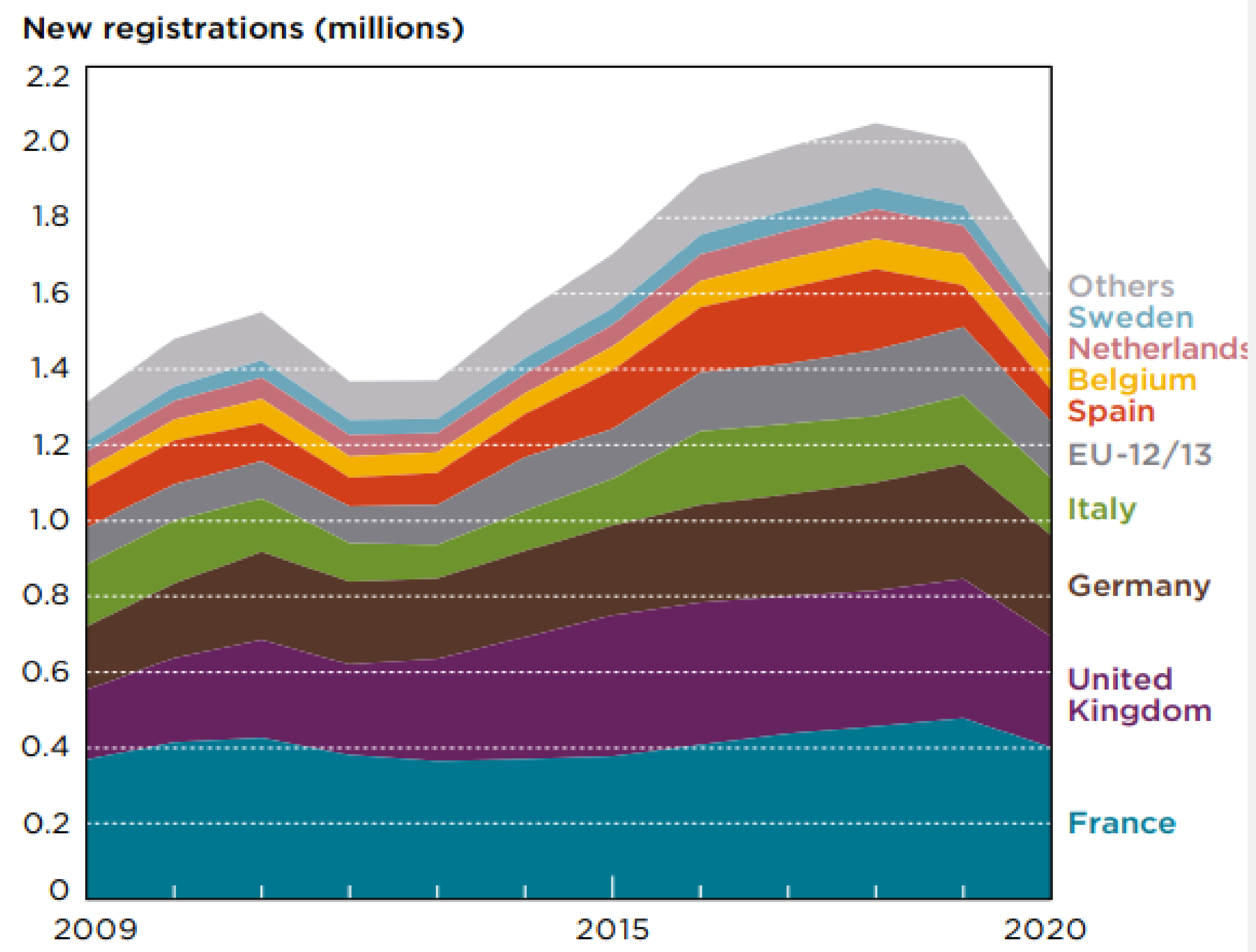
Passenger vehicles

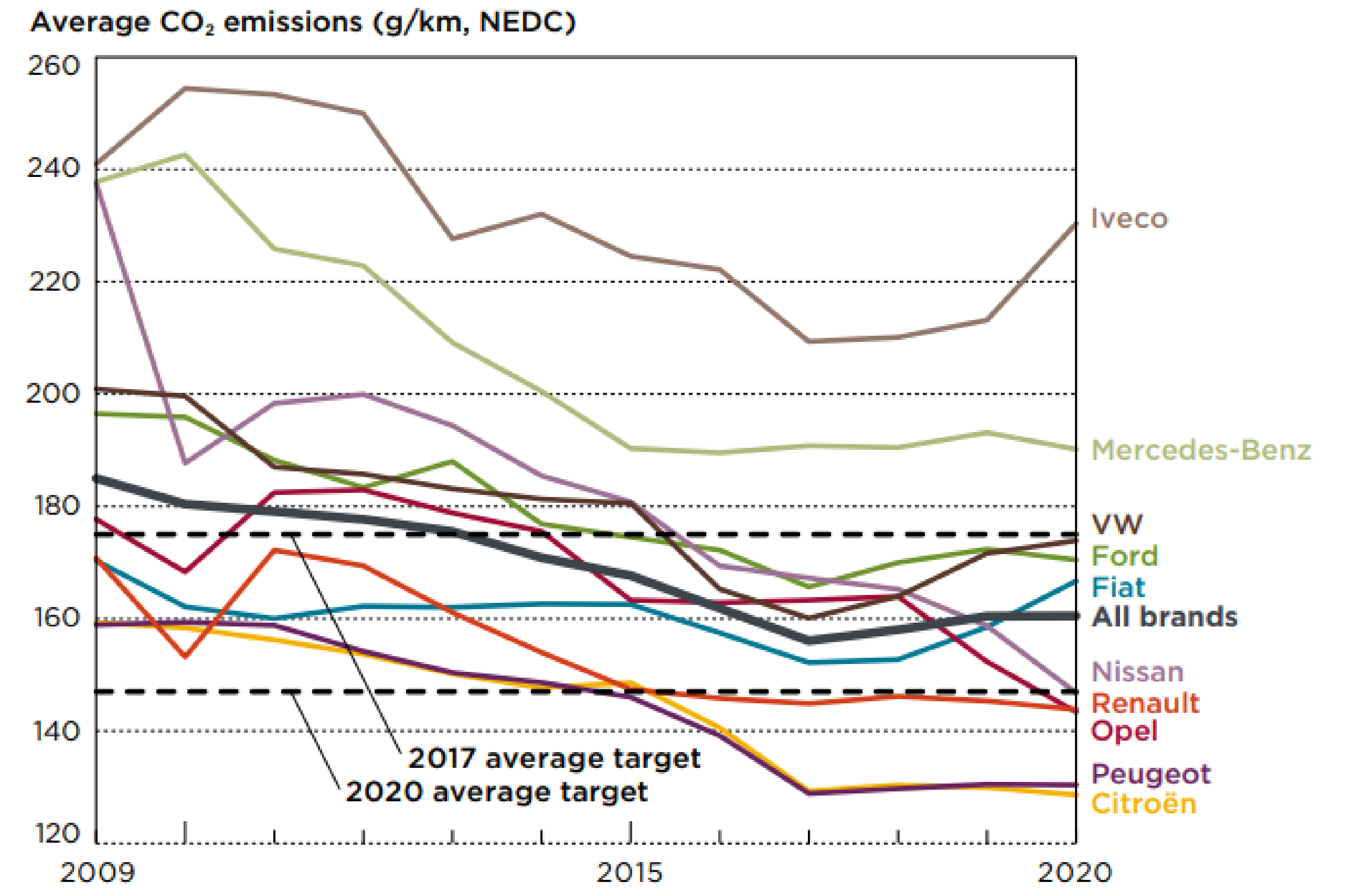


Data is for the 27 EU Member States, the UK, and the four members of the European Free Trade Association (EFTA).



Light commercial vehicles





Izvor: The International Council of Clean Transportation, 2021

…and as a result, key tech paradigms to facilitate future mobility

01 Digital Vehicle Connectivity

Enabling transport and logistics IoT and digital support for shared mobility systems.

The vehicle ceases to be just a means of transport for trips from A→B, but becomes a portable source of energy, a mobile interface for passengers, travel companion…

02 ZE Mobility

Compared to vehicles with IC engines, EVs are more powerful and easier to use and maintain. In layman's terms, EV power units "produce" motion, without direct contact between the engine and the drive shaft, while IC power units "produce" heat with large heat losses.

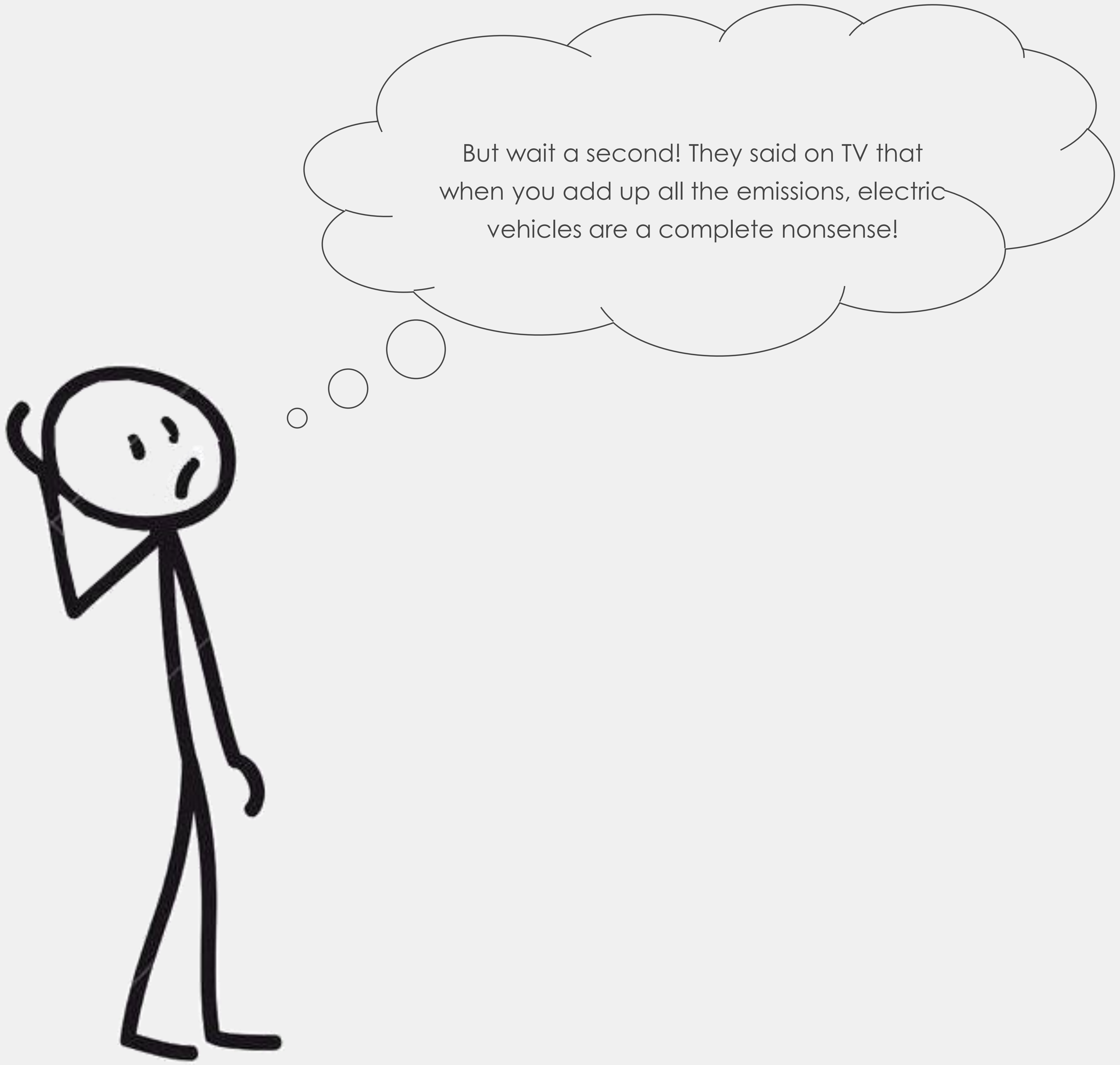
Simple operating principle of EV with low losses and advanced forms of management → greater utilisation of available power + greater energy efficiency. The property of the electric motor, which can simultaneously serve as a generator, turns every braking into recharging the batteries. This in turn means lower operating costs, and due to the stated simplicity of performance, lower maintenance costs. Finally, the electric vehicle is easier to be integrated in an IoT ecosystem!

03 Autonomous Vehicles

Autonomous vehicles are a key element/concept/technology for the transition from ownership-motivated transport of the future (Car Ownership) to service-based transport (MaaS - Mobility as a Service).

Autonomous vehicles become part of the IoT eco-system that provides physical transport, i.e. 'materializes' the digital transfer of information.

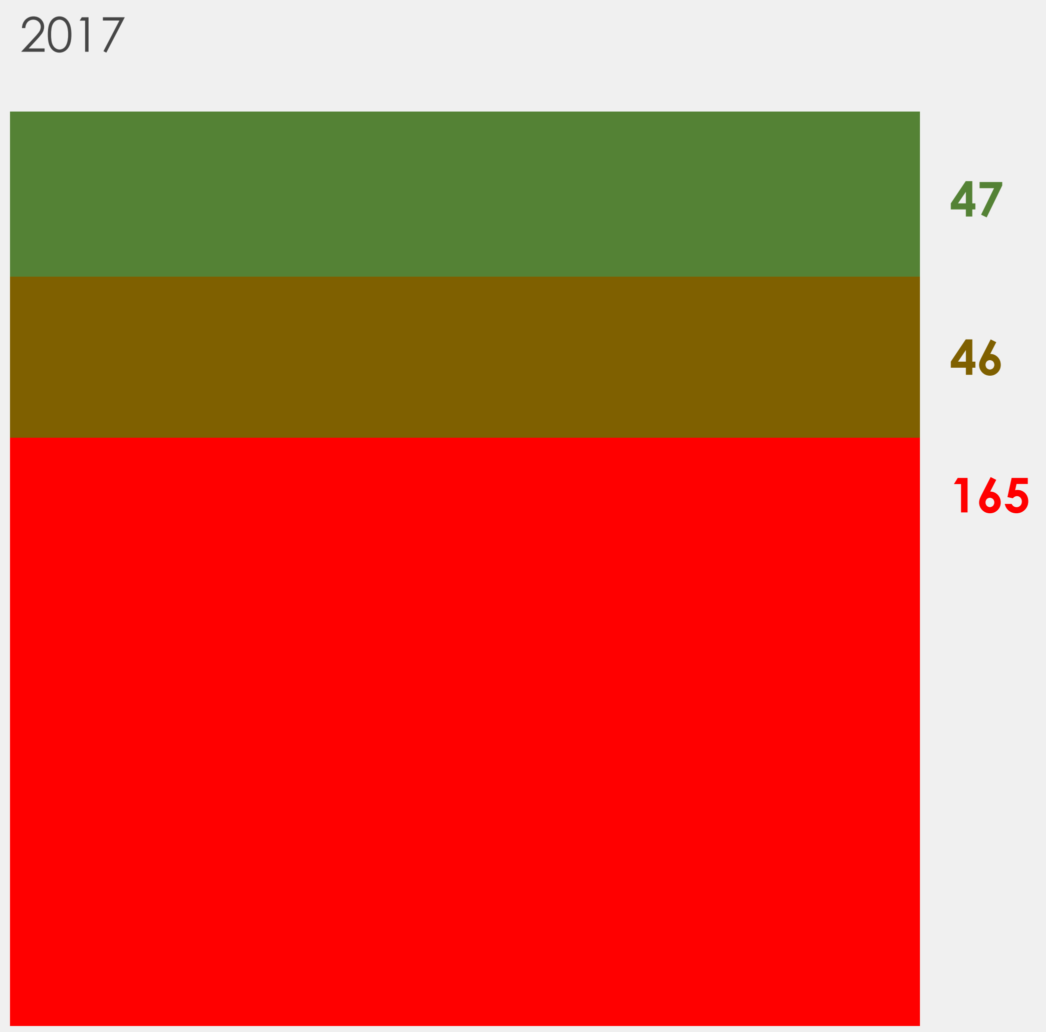
The synergy of IoT, autonomous vehicles and electric drives is revolutionizing transport demand and, in general, human action, since the vehicle ceases to be just a 'means of transportation' and becomes a mobile office.


But wait a second! They said on TV that when you add up all the emissions, electric vehicles are a complete nonsense!

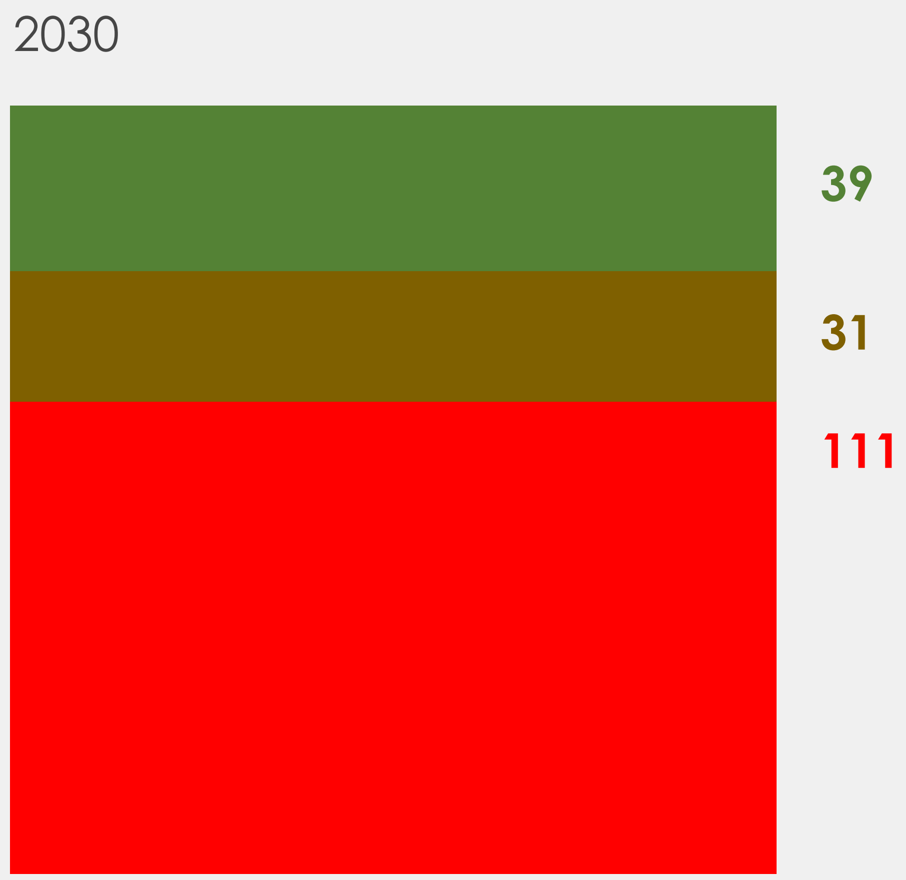
See for yourselves

W2W emissions by the segment in which the CO2 footprint has occurred during the life time of the (150.000 km or more)

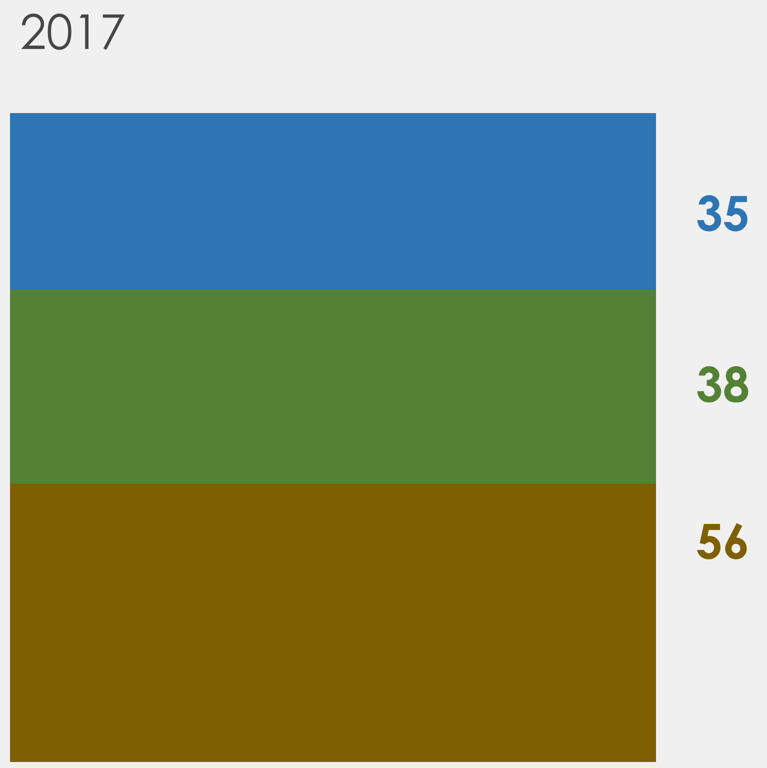
- Production of LIon batteries
- Other production
- Production of fuel/electricity
- Exhaust in the atmosphere



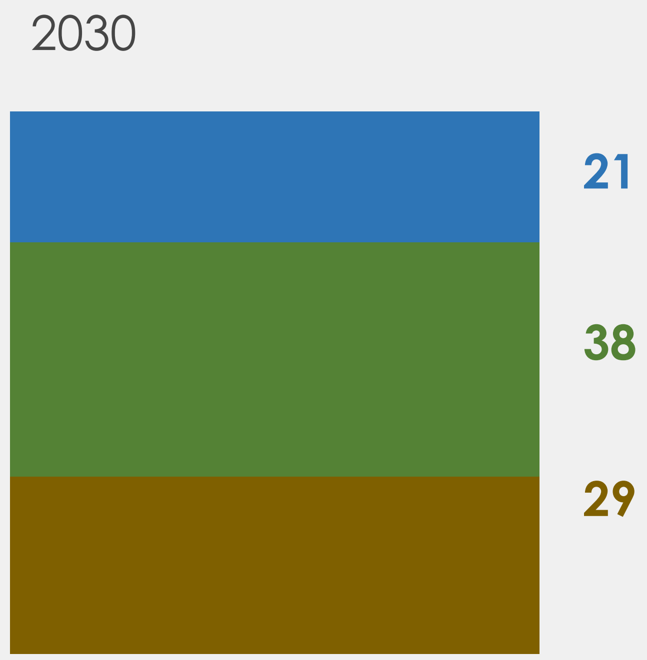
Average grade car with IC powertrain
258 g/kg



High-efficiency car with IC powertrain
281 g/kg



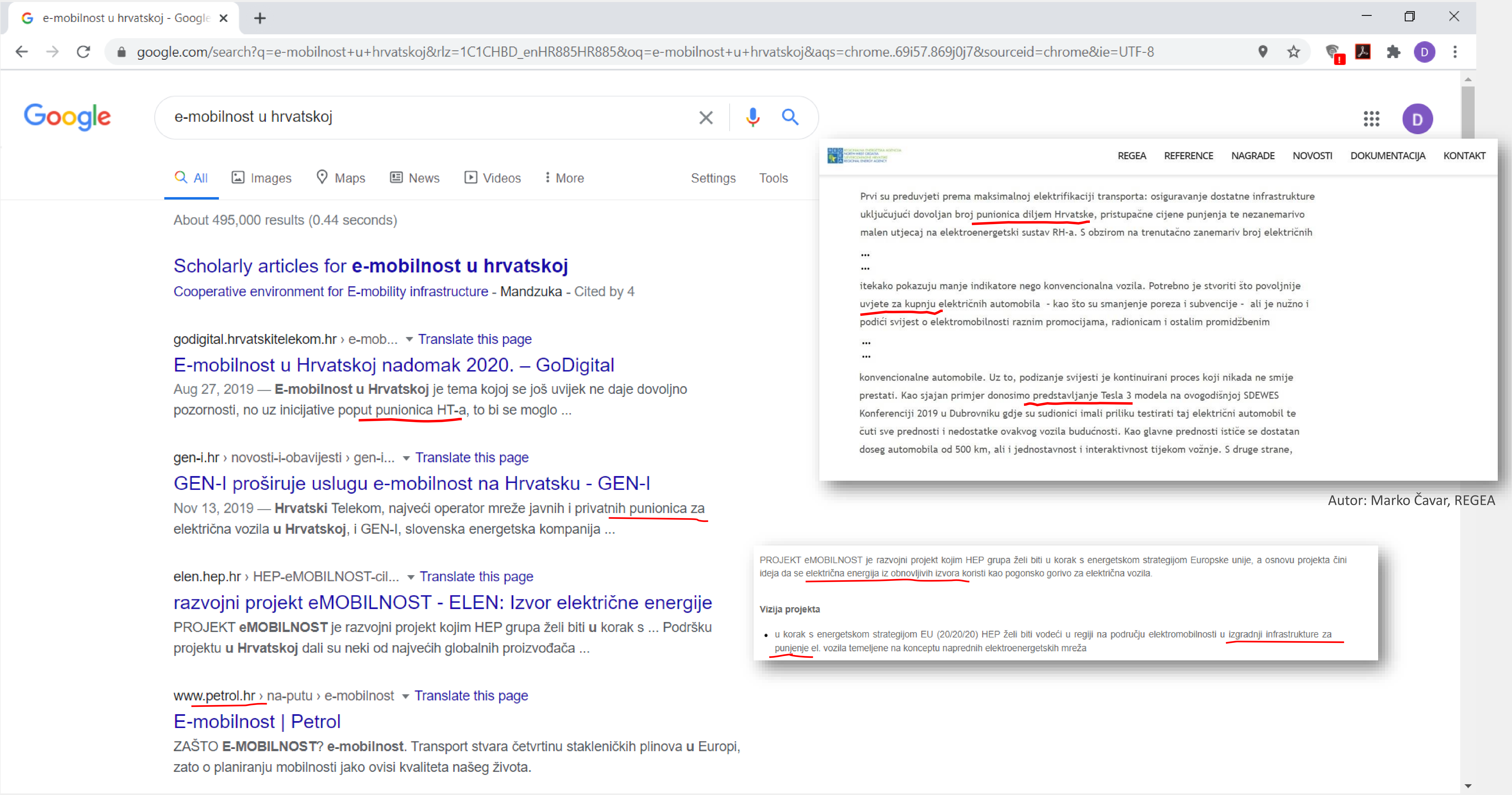
Battery electric vehicle,
EU energy mix
129 g/kg



Battery electric vehicle,
EU energy mix (forecasted)
88 g/kg

Izvor: The International Council of Clean Transportation, 2018

Future Mobility in Croatia – How the Croats get to experience eMobility



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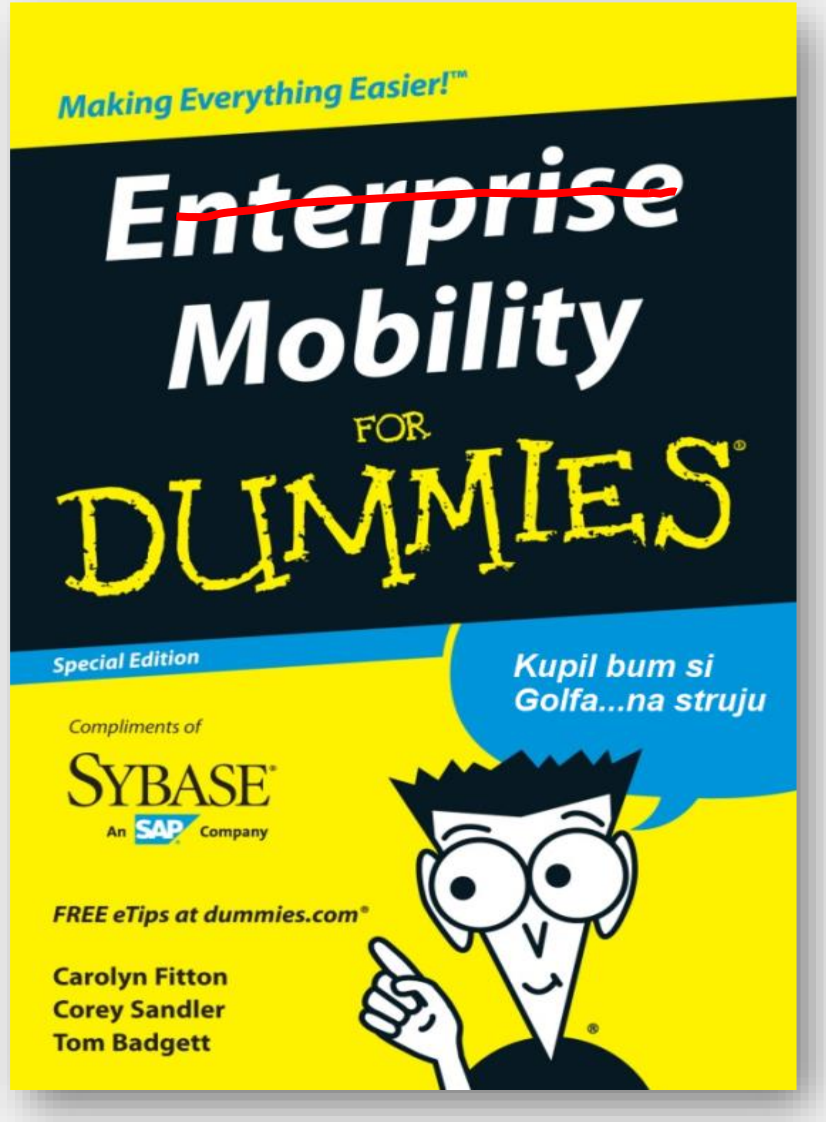
…in Croatia



Step #one – Politically motivated campaign

01 Politically motivated incentives. **02** Incentive programs without clear strategic goals. **03** Focus on private users.

Step #two – Wait for the subsidies

01 Absence of award criteria. **02** Effects of the incentives are not analysed. **03** There are no long-term incentive goals, or they are not communicated/evaluated publicly.

Step #three – Buy a fancy car

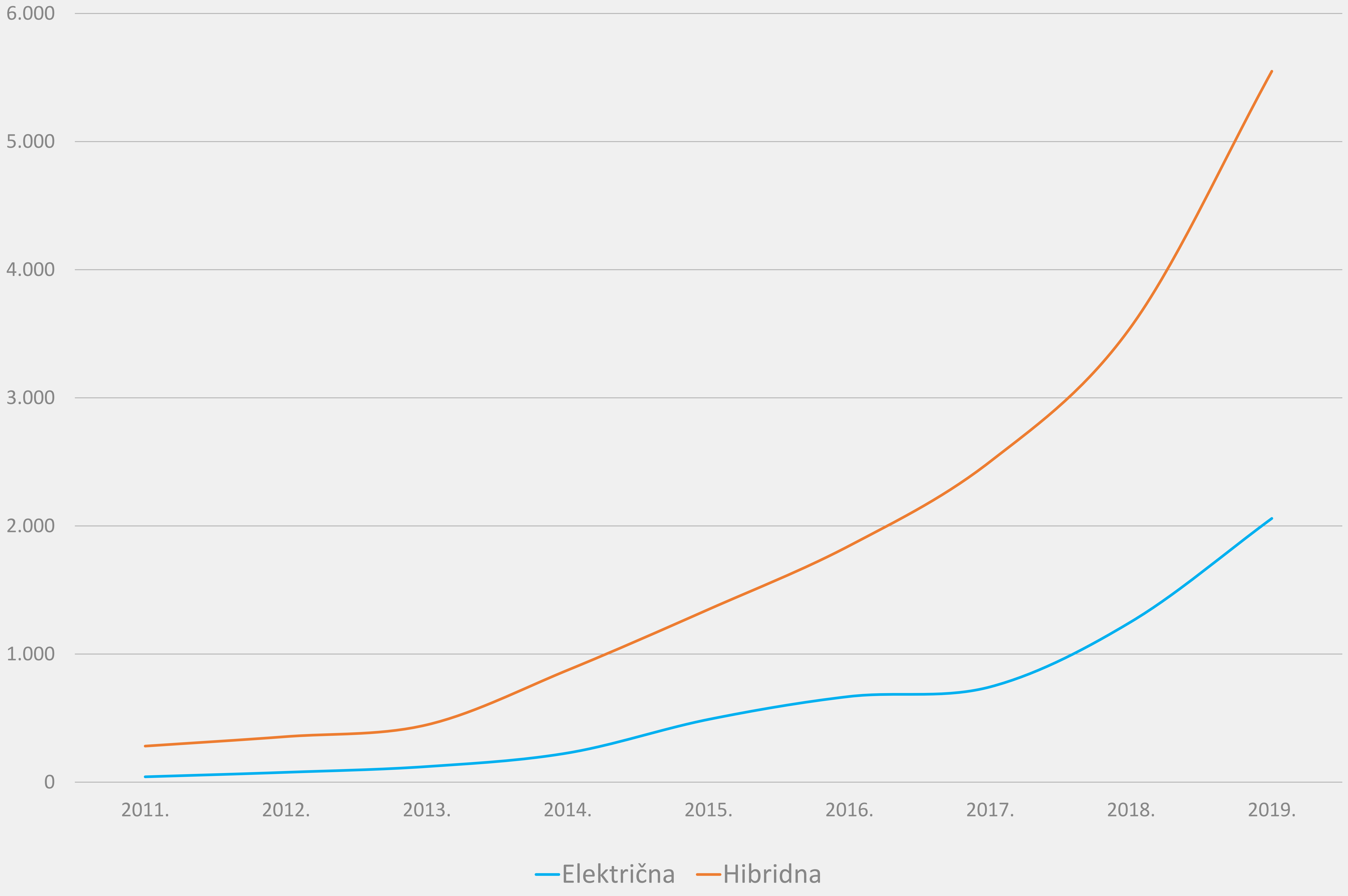
01 Most important is the range. Can I get to Split with my Tesla or not?. **02** …and how fast does it accelerate. Rimac cars are the coolest. **03** OK, Tesla is not that bad too.

Step #four – Whine about

01 Make sure you whine at any opportunity on how few charging stations there are. **02** Preach there must be a charging station at least at every 100 m so that a Duch tourist may comfortably get from Amsterdam to Bibinje. Remember we're all about tourism! **03** In case you can't be bothered any more to hassle yourself with charging, cables, and „under speeding", there's always the good old Diesel.

...and as a result

Registered BEV in CRO



Izvor: Državni zavod za statistiku RH, CVH, 2020

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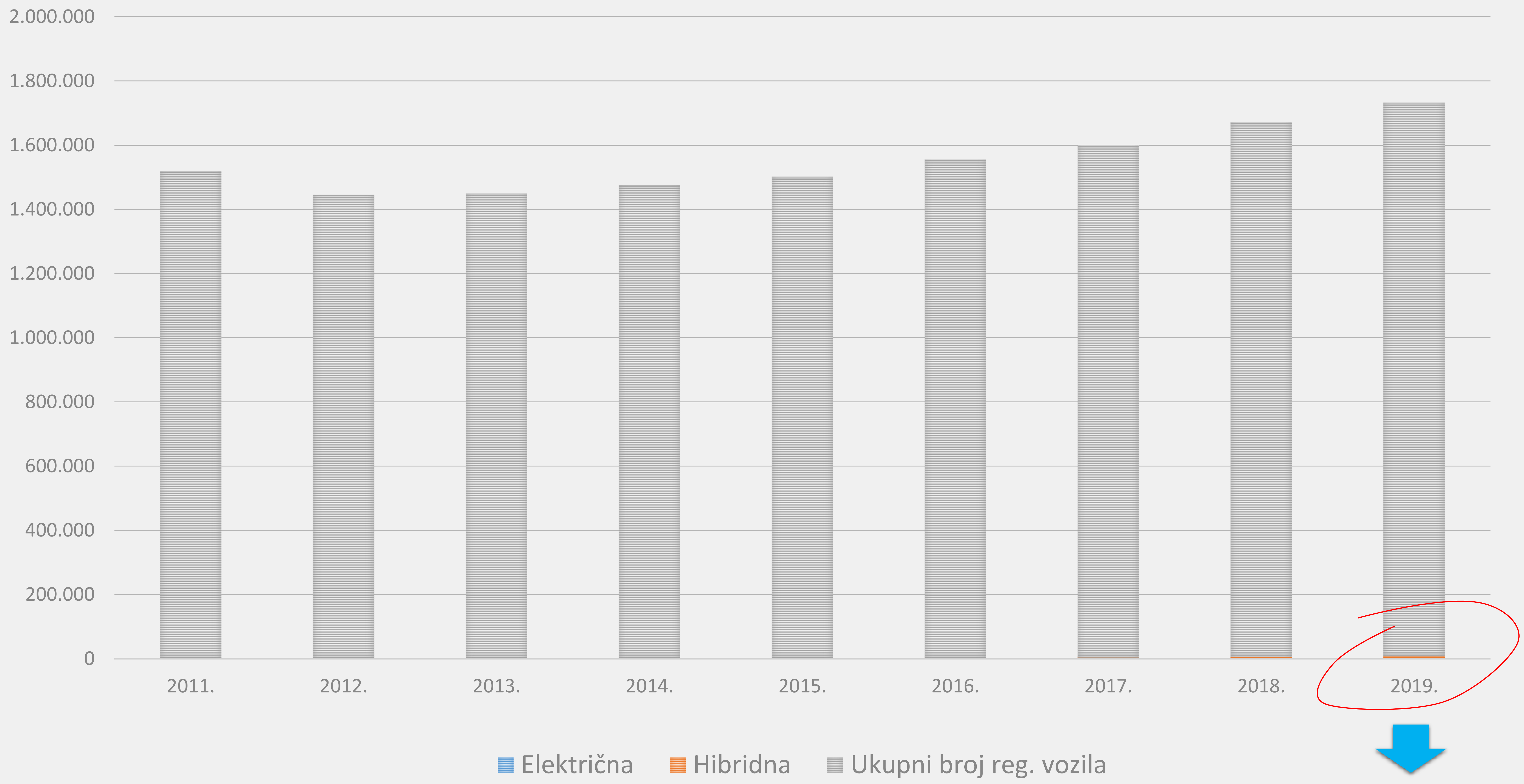
Izvor: Državni zavod za statistiku RH, CVH, 2020

Sounds good, but...



2.059 (1‰)

5.549 (3‰)

1.724.900

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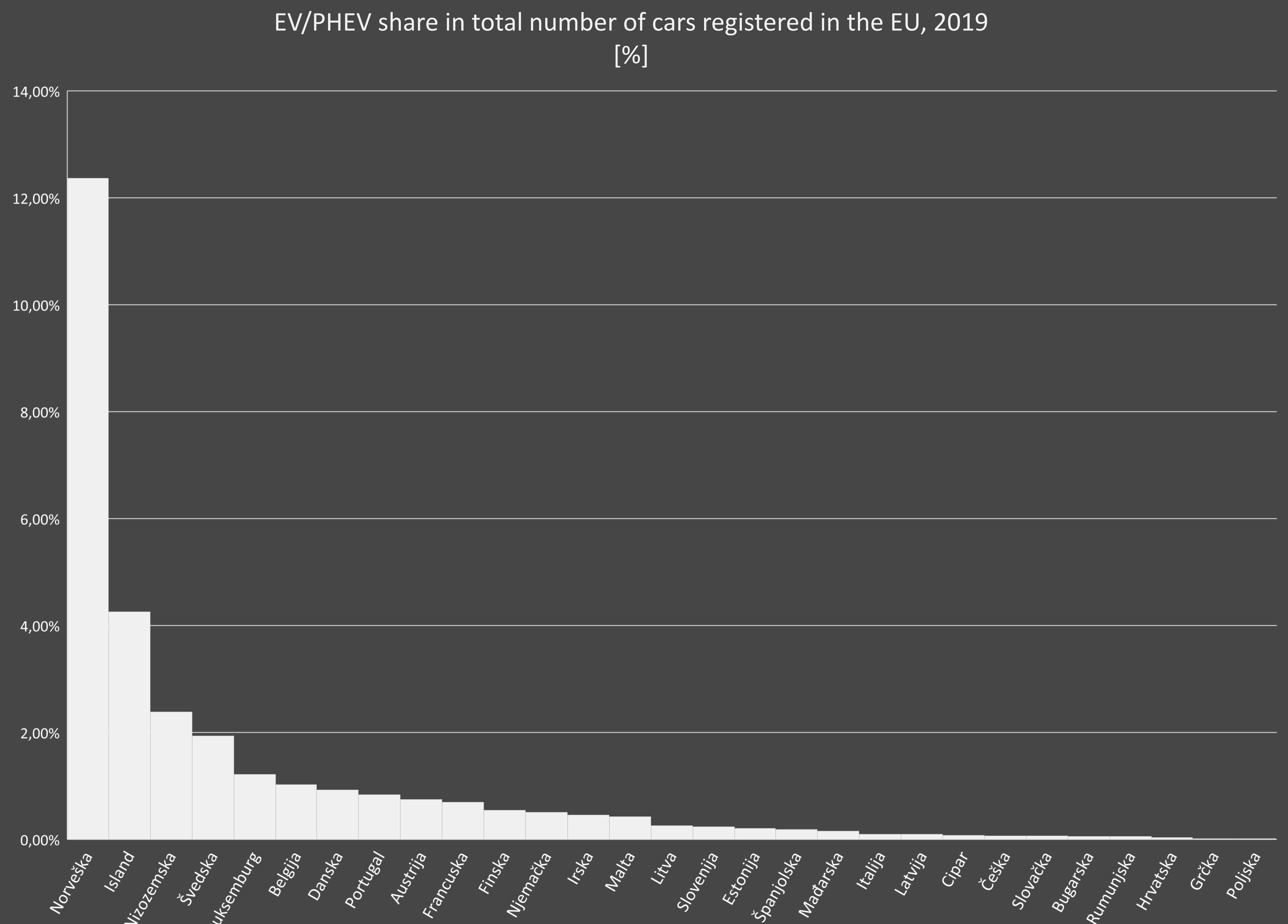

Izvor: European Alternative Fuel Observatory, 2020

…meanwhile, in EU

#02 PLANNING

Typical roadmap in planning and implementation of advanced mobility solutions

How to implement

ZE mobility solution..., and why it is so damn complicated?

Best practice analysis

Strategic Context

Step **#one**

01 Defining and communicating to the public the strategic determinants of the green economy. **02** Focus on business sector/logistics rather than private users. **03** Defining corporate strategic plans.

Process Analysis

Step **#two**

01 Analysis of business processes in which the targeted solution is intended to be applied. **02** Expected results and deliverables. **03** Teaming.

Solutioning

Step **#three**

01 Designing a technological solution in accordance with the needs of the target business process. **02** Optimal relation between technical capacity and price. **03** Focus on generating savings(CO_2 emission, energy consumption, productivity...).

Implementation

Step **#four**

01 Irreversibility of the implementation process – there is no going back to IC powered logistics. **02** Performance monitoring. **03** Expansion to other corporate processes.

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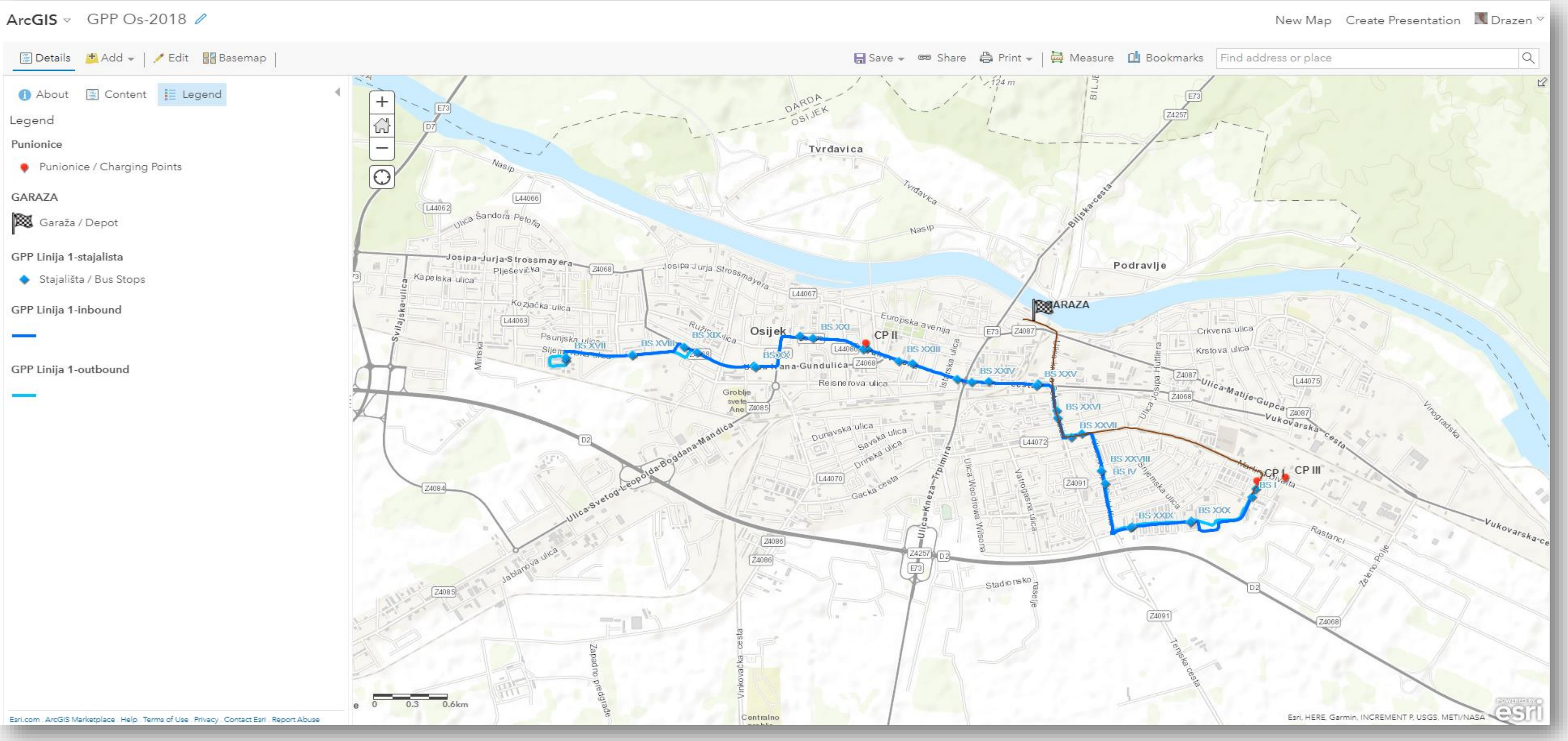
ZE mobility planning

in practice



Battery type	Nominal Energy - Beginning of Life	Usable Energy - Beginning of Life	Battery lifespan
High Power	58 kWh	52 kWh	7 years

=

Typical myths and urban legends

RANGE

If I make 200 km a day with a conventionally driven vehicle, I need a battery that will have enough stored energy for this mileage.

CHARGING

I can't expect anyone to buy EVs until the charging infrastructure is sorted out. I need super turbo fast chargers and my battery must always be 100% fully charged.

GREEN IS ALWAYS GOOD

I rely exclusively on the production of electricity from RES, I am saving the planet. This type of production is completely "clean".

IF OTHERS DO IT LIKE THAT…

…this must be right.

#03 Realisation

Case Study – Example of energy needs calculation in a typical public transport system in Croatia

Typical implementation elements

01

GENERATING **PLANS**

The goal is to provide a documentation basis for the realisation of implementation projects. The documentation includes feasibility studies, energy needs analysis for targeted mobility systems, SUMPs, etc. The implementation of ZE vehicles must be preceded by an elementary assessment of (1) number of vehicle units, (2) an assessment of the basic technical characteristics of the vehicles in terms of the required transport capacity and expected energy consumption, and (3) an assessment of the total cost of the investment.

02

PURCHASING **VEHICLES**

In addition to the procurement and contracting process itself, at this stage it is necessary to ensure that the procedures for (1) defining, validating and/or preparing the project application for financing and (2) the technical evaluation of the received offers meet all the technical and technological conditions defined by previously conducted studies and design procedures.

03

BUILDING **INFRASTRUCTURE**

This phase refers to the proposal and technical description and structuring of infrastructure elements such as charging stations for electric vehicles/buses, and own energy plants such as, for example, solar energy plants. The goal in this context would be to provide an estimate of (1) the number of infrastructure units, (2) a proposal of their basic technical features, (3) a proposal of the optimal way of management, and (4) an estimate of the total cost of the investment.

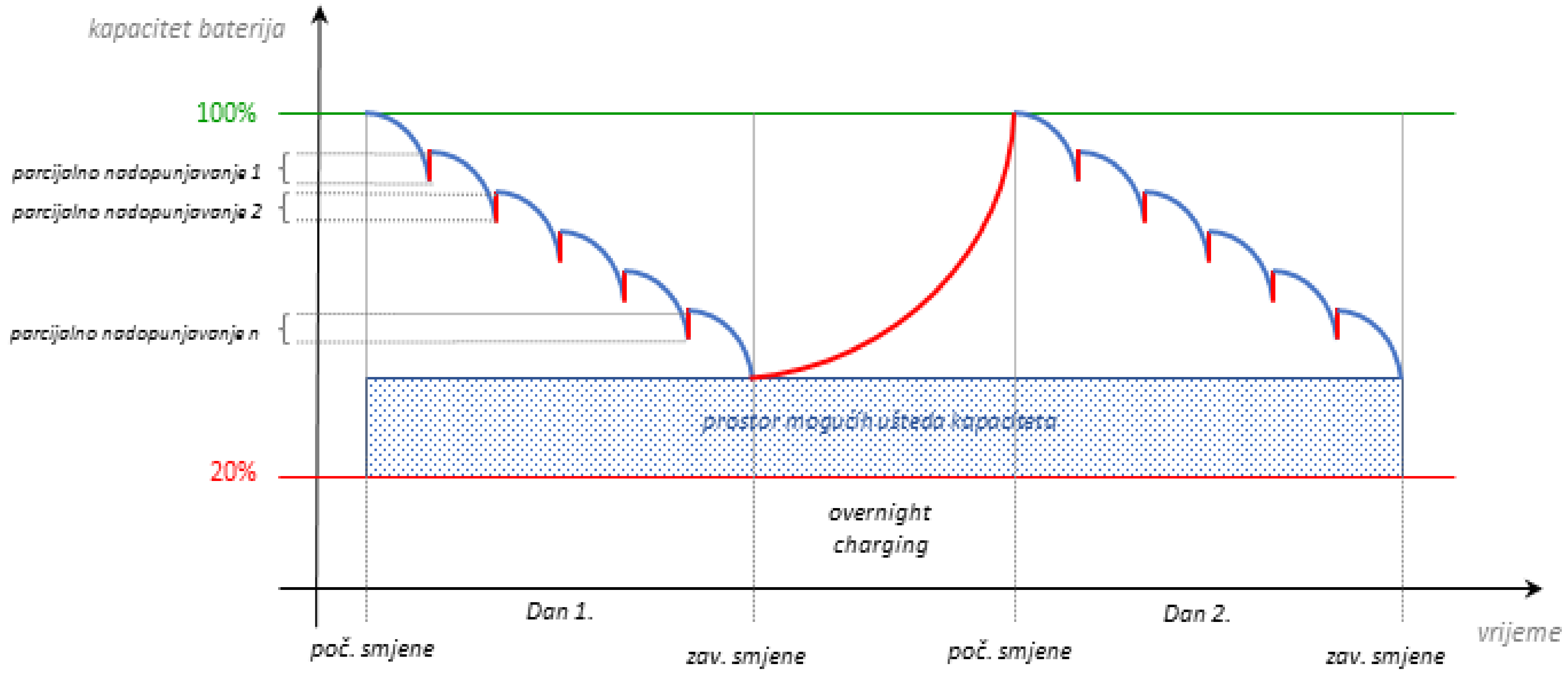
04

DIGITALISING SYSTEM

Considering the usual situation of earlier smart mobility implementation projects (e.g. e-ticketing, PIS, etc.), in this phase, in addition to suggesting and designing new digital twins, the integration of existing subsystems into the unified city mobility system is carried out. In doing so, it is crucial to define (1) the technical scope and level of integration of the future system, and (2) to estimate the total cost of the investment.

Key Challenge

Battery Capacity – Price – Veh Mass



Methodology

1

Data collection

Collection of field data on the geometries of transport lines.
Collection and/or generation of attribute data of transport lines.
Passenger counting.

2

Data **analysis**

Processing of collected data and their aggregation so that they correspond to the scope of use of the used GIS solver.

3

Network **resistance algorithms**

Calculation of network resistance using algorithms that use individual vehicle movement resistances such as rolling resistance, air resistance and others. Modelling of non-exact resistances.

4

Simulation **modelling**

Creation of models based on vectorized bus line geometries in 2D/3D environment and entry of associated attributes. Creating a network data model. Entry of network movement speed attributes, data on elevation matching, and data on the directionality of network segments. Input of nominal attributes for identification.

5

Calculating **energy needs**

Simulating data on the network of bus lines for both directions of movement on the network, i.e. in the direction of vectorization (FT) and against the direction of vectorization (TF). Simulation for different traffic scenarios such as the number of passengers in the vehicle, the use of A/C, heating, etc.

6

Define implementation **organisation**

The values of energy consumption on the network of bus lines, calculated by the conducted simulations, are brought into a meaningful organizational structure related to the processes of complete and partial replenishment of batteries.

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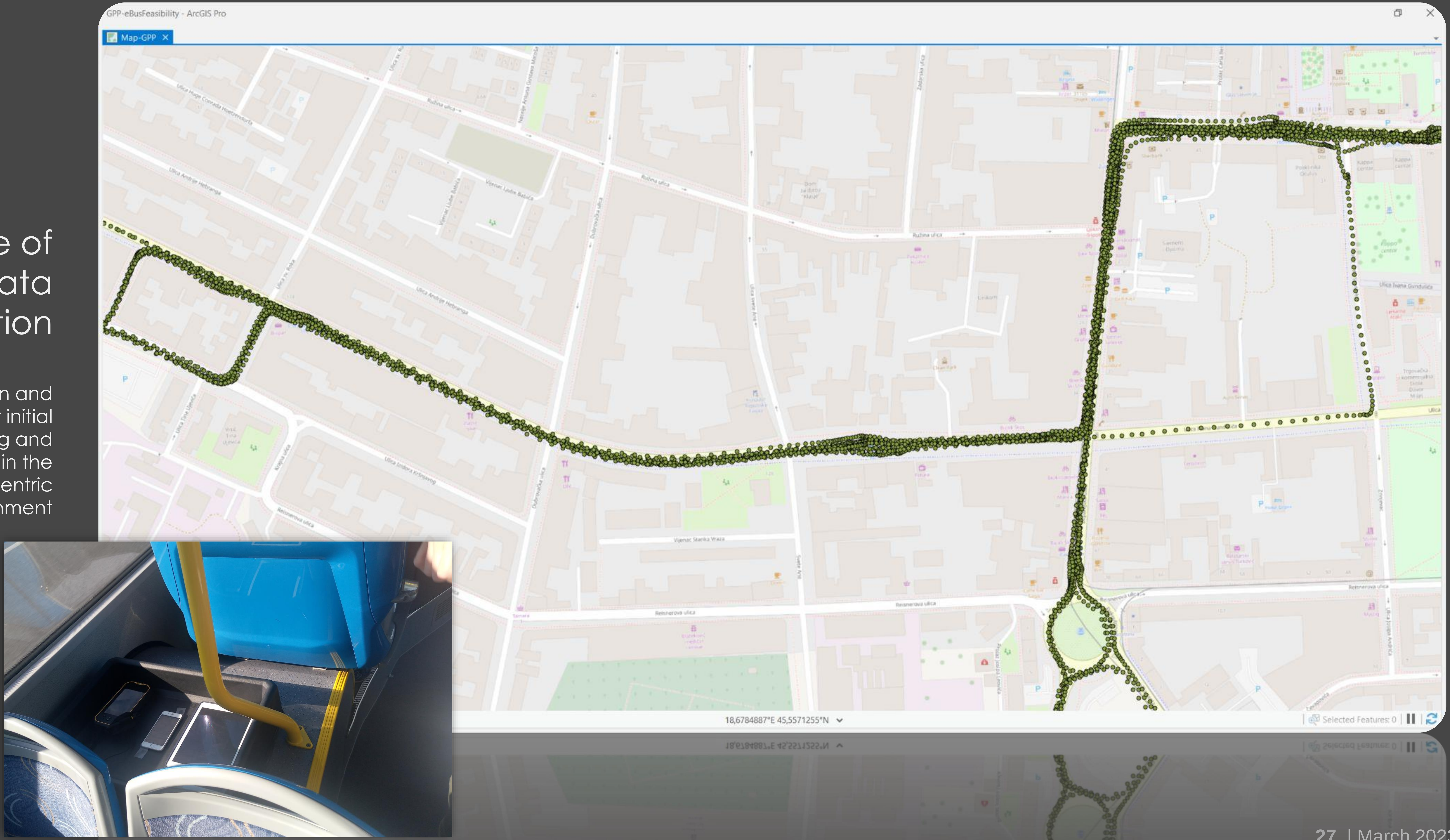
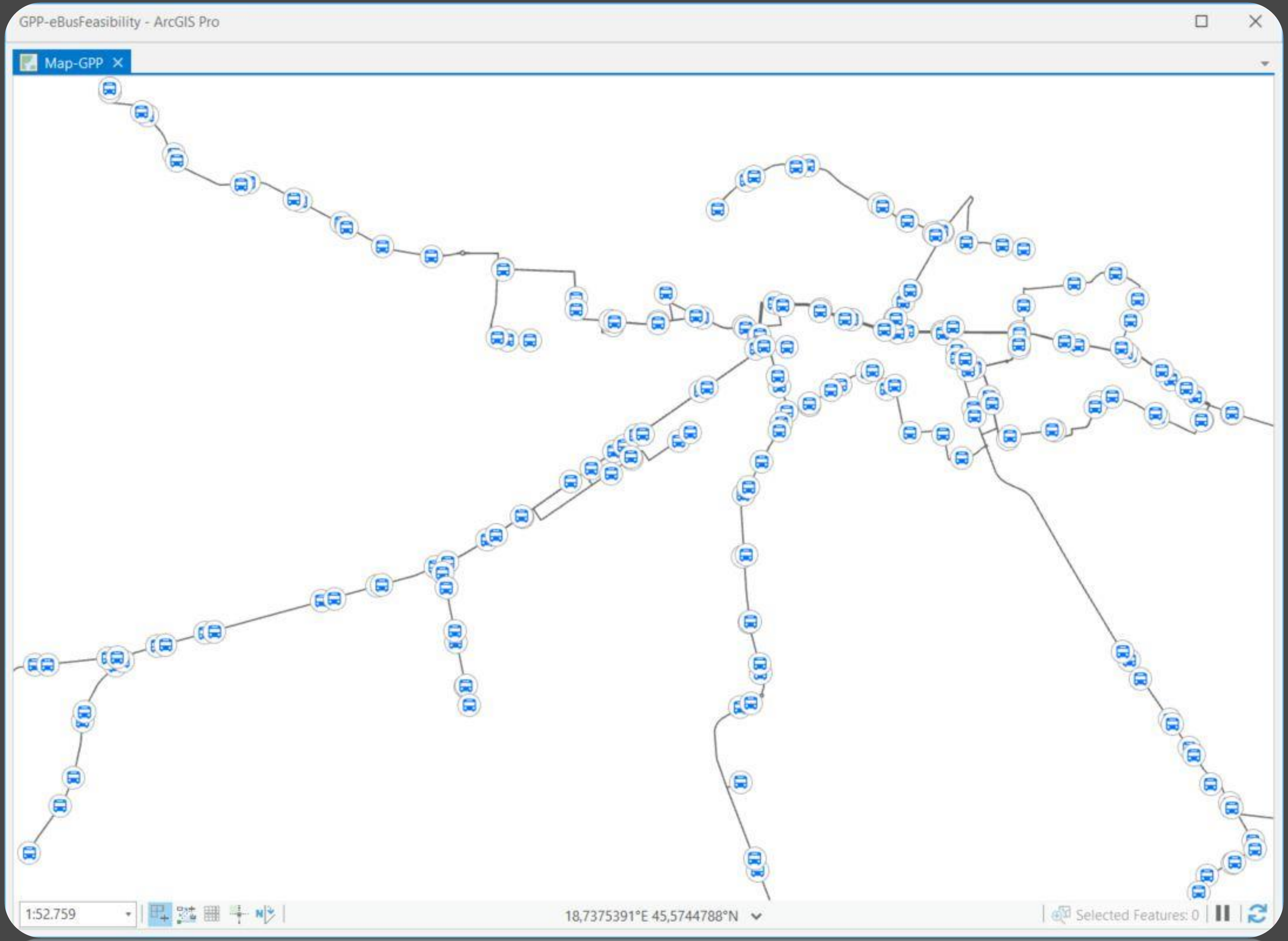
Example of data collection

Point-shape location and attribute data after initial processing and projection in the appropriate map-centric environment



Collected and edited infrastructure data

Collected spatial and attribute data on possible locations of electric charging stations and locations of bus stops



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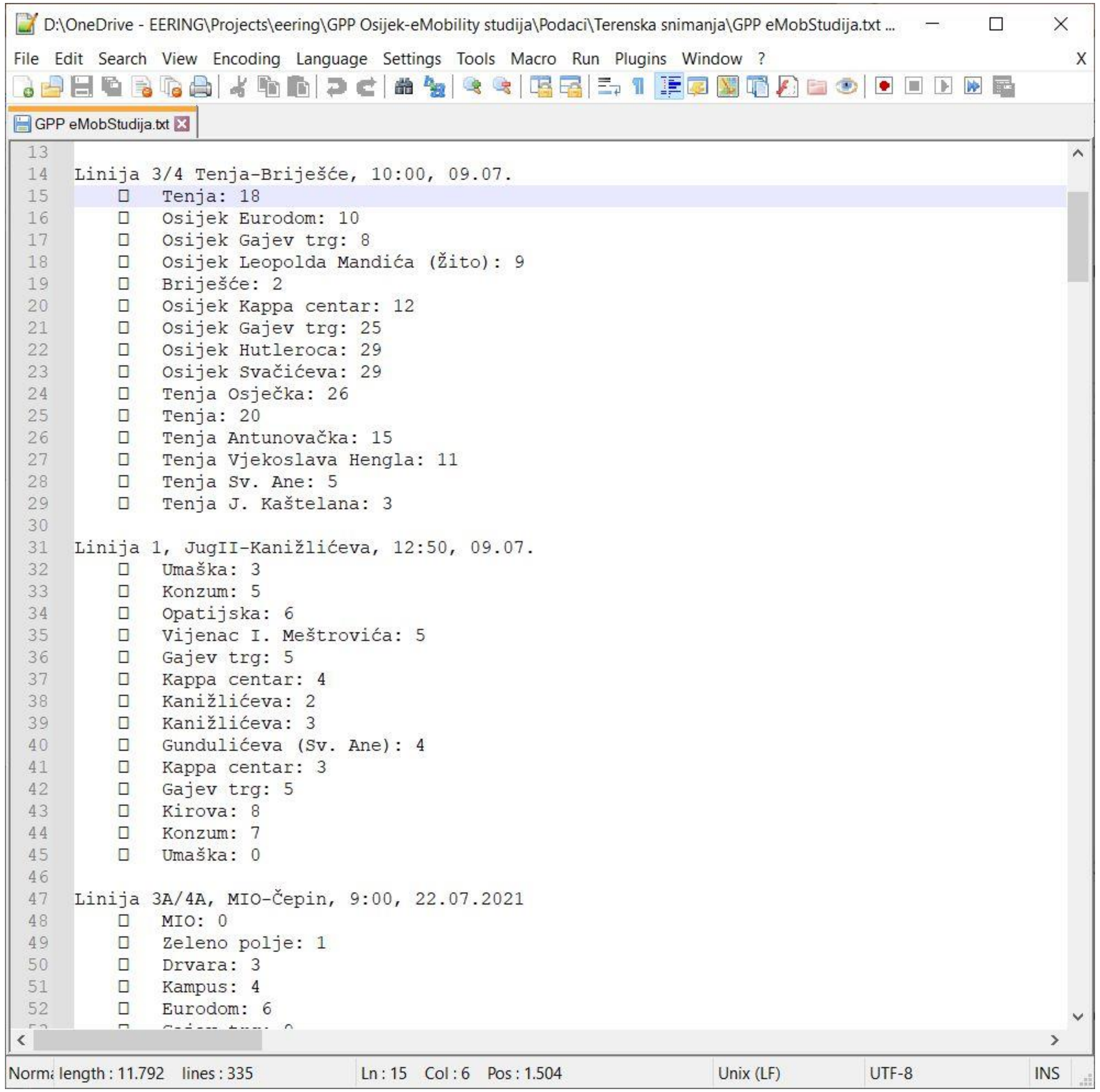
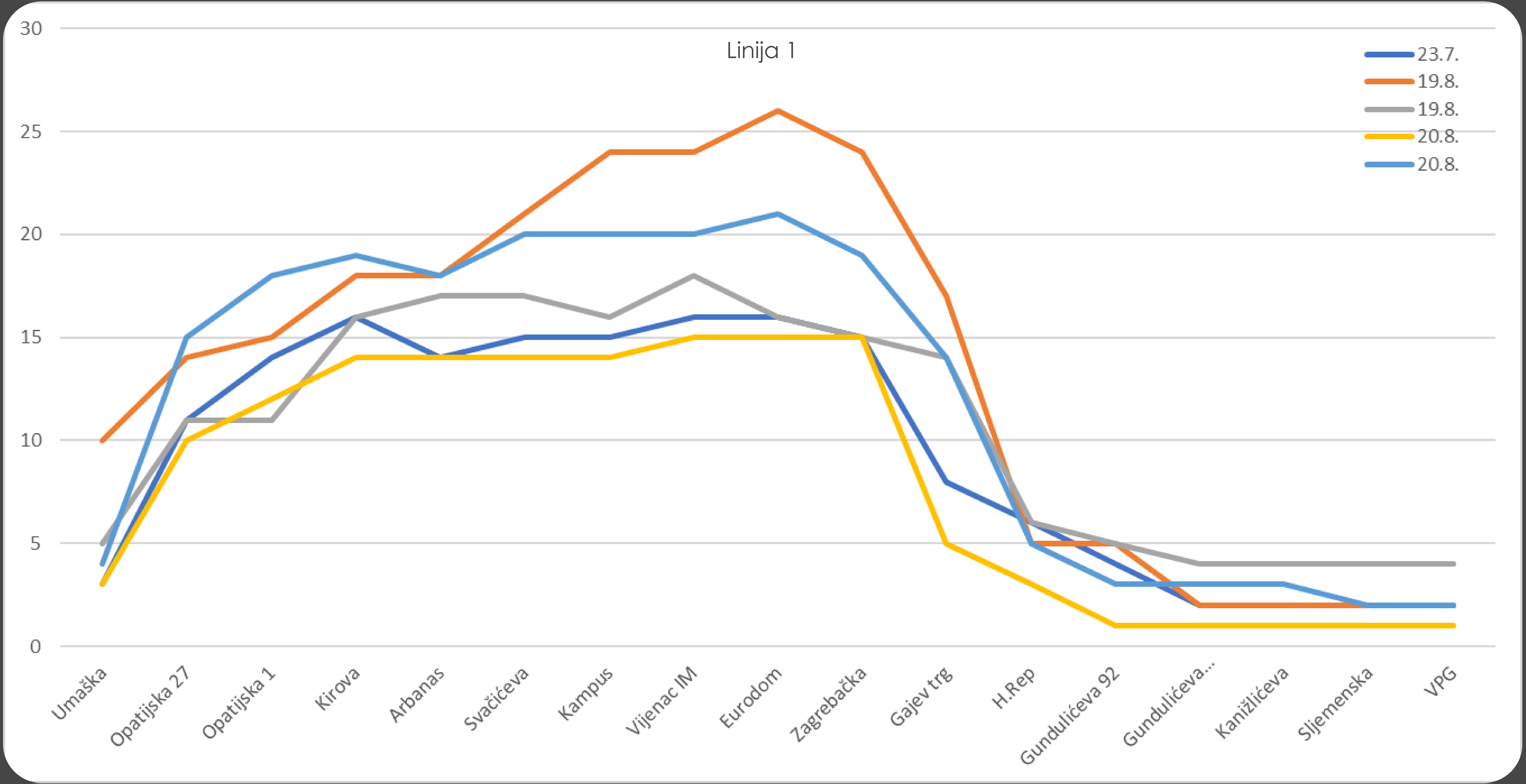
Passenger Counting

In-vehicle passenger count data

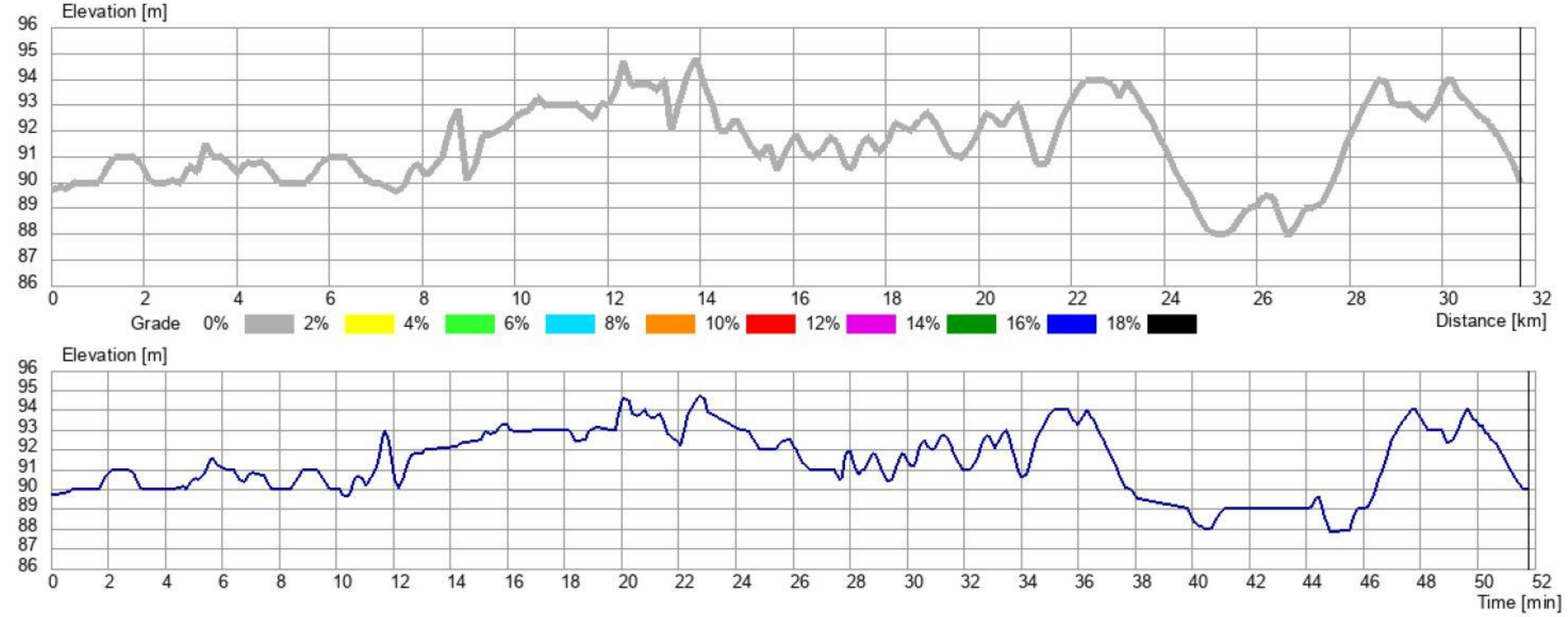


NoOfPass



Linija 1
23.7.
19.8.
19.8.
20.8.
20.8.
30
25
20
15
10
5
0
Umaška
Opatijska 27
Opatijska 1
Kirova
Arbanas
Svačićeva
Kampus
Vijenac IM
Eurodom
Zagrebačka
Gajev trg
H.Rep
Gundulićeva 92
Gundulićeva...
Kanižlićeva
Sljemenska
VPG

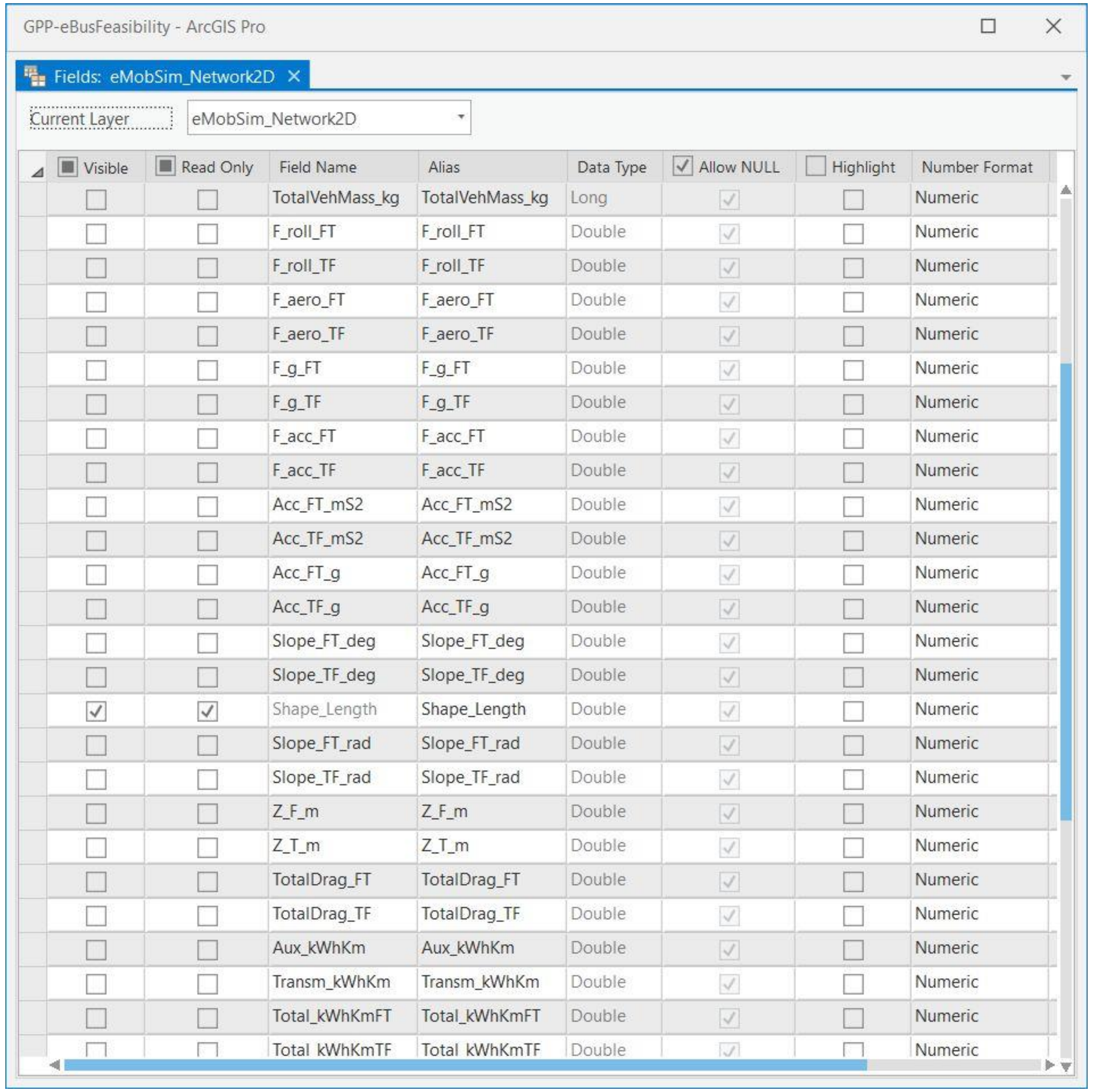
Elevation Profiling



#04 MODELLING

Development and testing of a model of the targeted PT system

Defining the attribute data model



GPP-eBusFeasibility - ArcGIS Pro

Fields: eMobSim_Network2D

Current Layer: eMobSim_Network2D

Visible	Read Only	Field Name	Alias	Data Type	Allow NULL	Highlight	Number Format
		TotalVehMass_kg	TotalVehMass_kg	Long	✓		Numeric
		F_roll_FT	F_roll_FT	Double	✓		Numeric
		F_roll_TF	F_roll_TF	Double	✓		Numeric
		F_aero_FT	F_aero_FT	Double	✓		Numeric
		F_aero_TF	F_aero_TF	Double	✓		Numeric
		F_g_FT	F_g_FT	Double	✓		Numeric
		F_g_TF	F_g_TF	Double	✓		Numeric
		F_acc_FT	F_acc_FT	Double	✓		Numeric
		F_acc_TF	F_acc_TF	Double	✓		Numeric
		Acc_FT_mS2	Acc_FT_mS2	Double	✓		Numeric
		Acc_TF_mS2	Acc_TF_mS2	Double	✓		Numeric
		Acc_FT_g	Acc_FT_g	Double	✓		Numeric
		Acc_TF_g	Acc_TF_g	Double	✓		Numeric
		Slope_FT_deg	Slope_FT_deg	Double	✓		Numeric
		Slope_TF_deg	Slope_TF_deg	Double	✓		Numeric
✓	✓	Shape_Length	Shape_Length	Double	✓		Numeric
		Slope_FT_rad	Slope_FT_rad	Double	✓		Numeric
		Slope_TF_rad	Slope_TF_rad	Double	✓		Numeric
		Z_F_m	Z_F_m	Double	✓		Numeric
		Z_T_m	Z_T_m	Double	✓		Numeric
		TotalDrag_FT	TotalDrag_FT	Double	✓		Numeric
		TotalDrag_TF	TotalDrag_TF	Double	✓		Numeric
		Aux_kWhKm	Aux_kWhKm	Double	✓		Numeric
		Transm_kWhKm	Transm_kWhKm	Double	✓		Numeric
		Total_kWhKmFT	Total_kWhKmFT	Double	✓		Numeric
		Total_kWhKmTF	Total_kWhKmTF	Double	✓		Numeric

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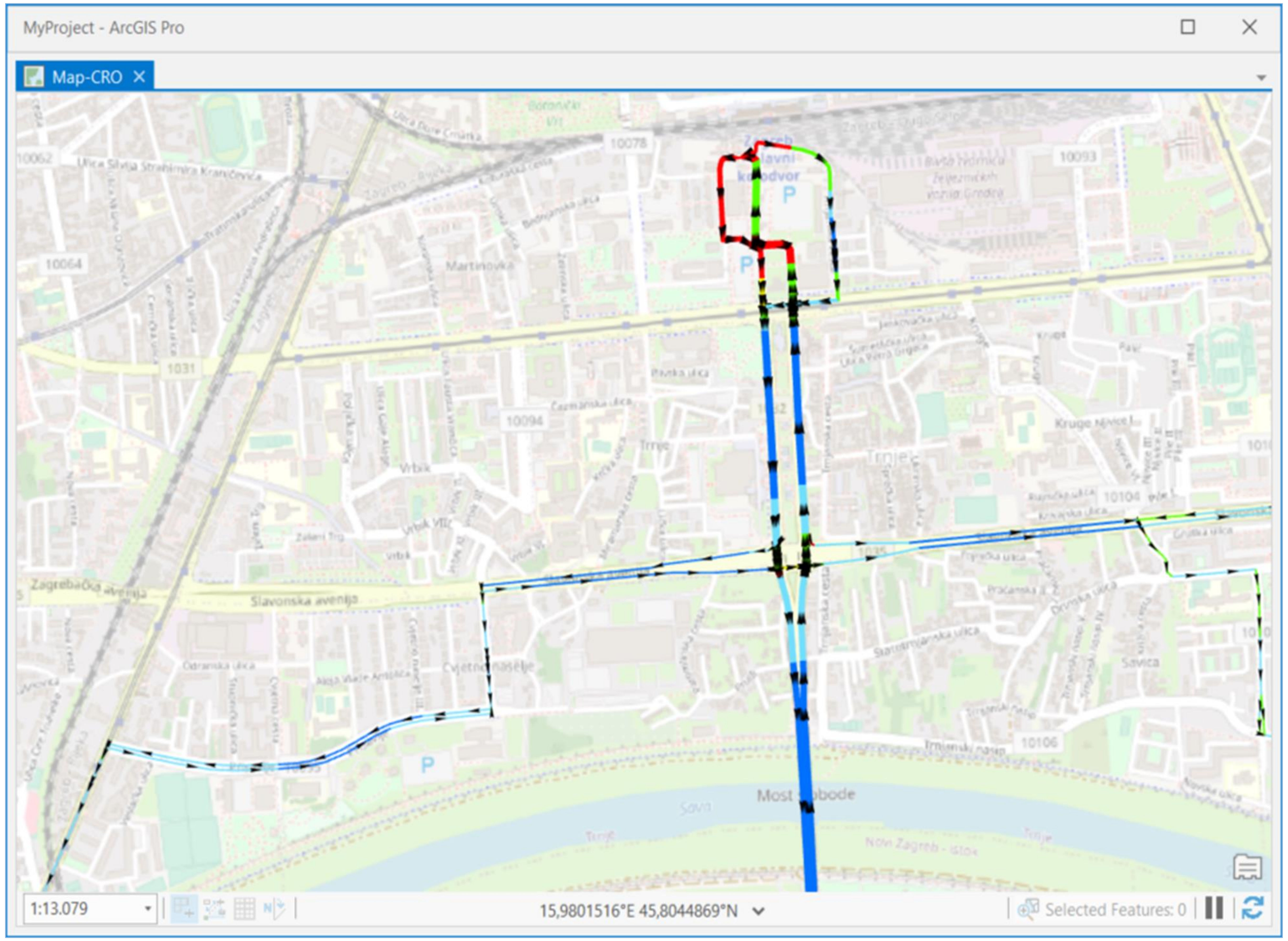
Building the network model



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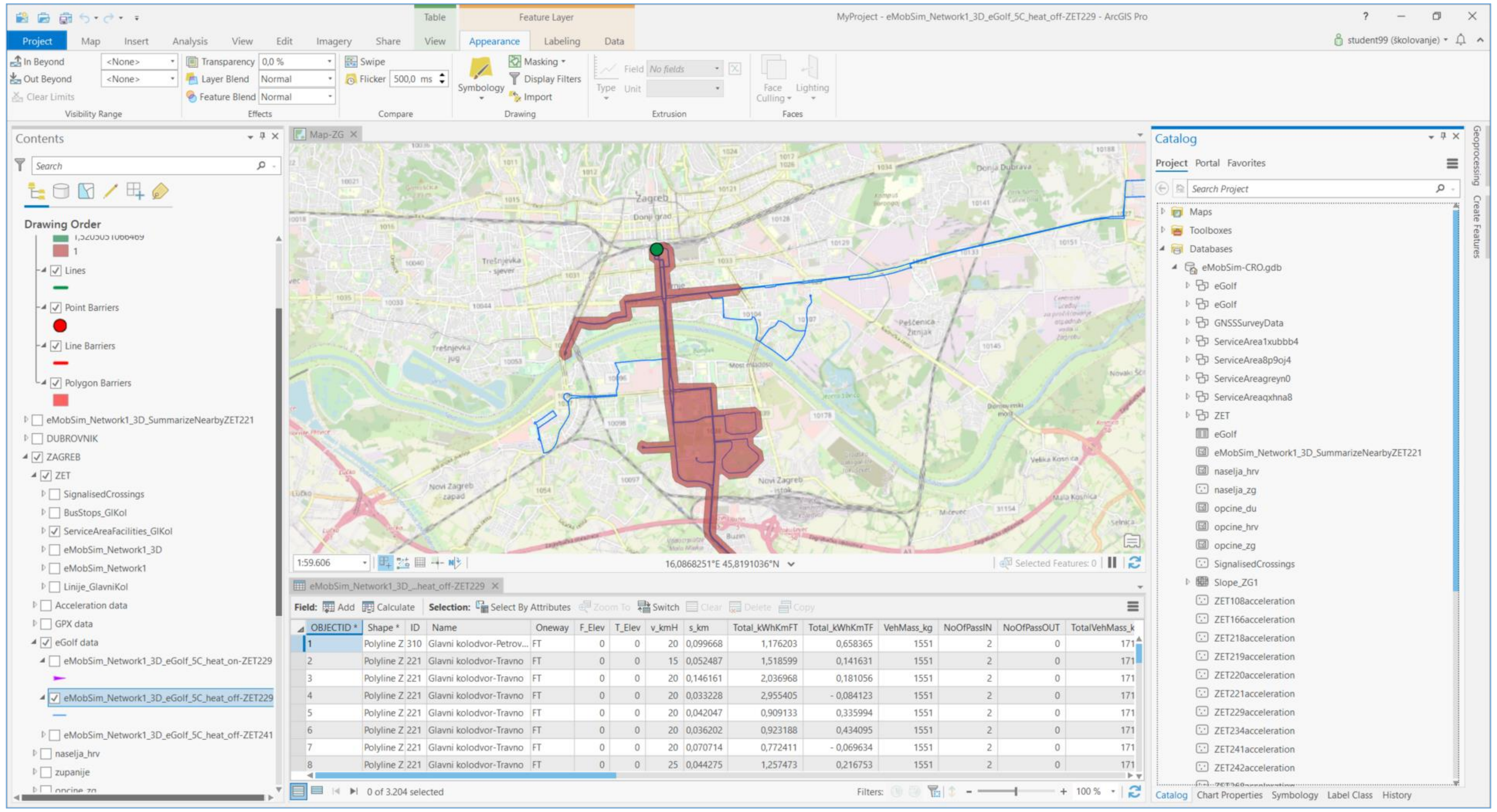
#05 RESULT

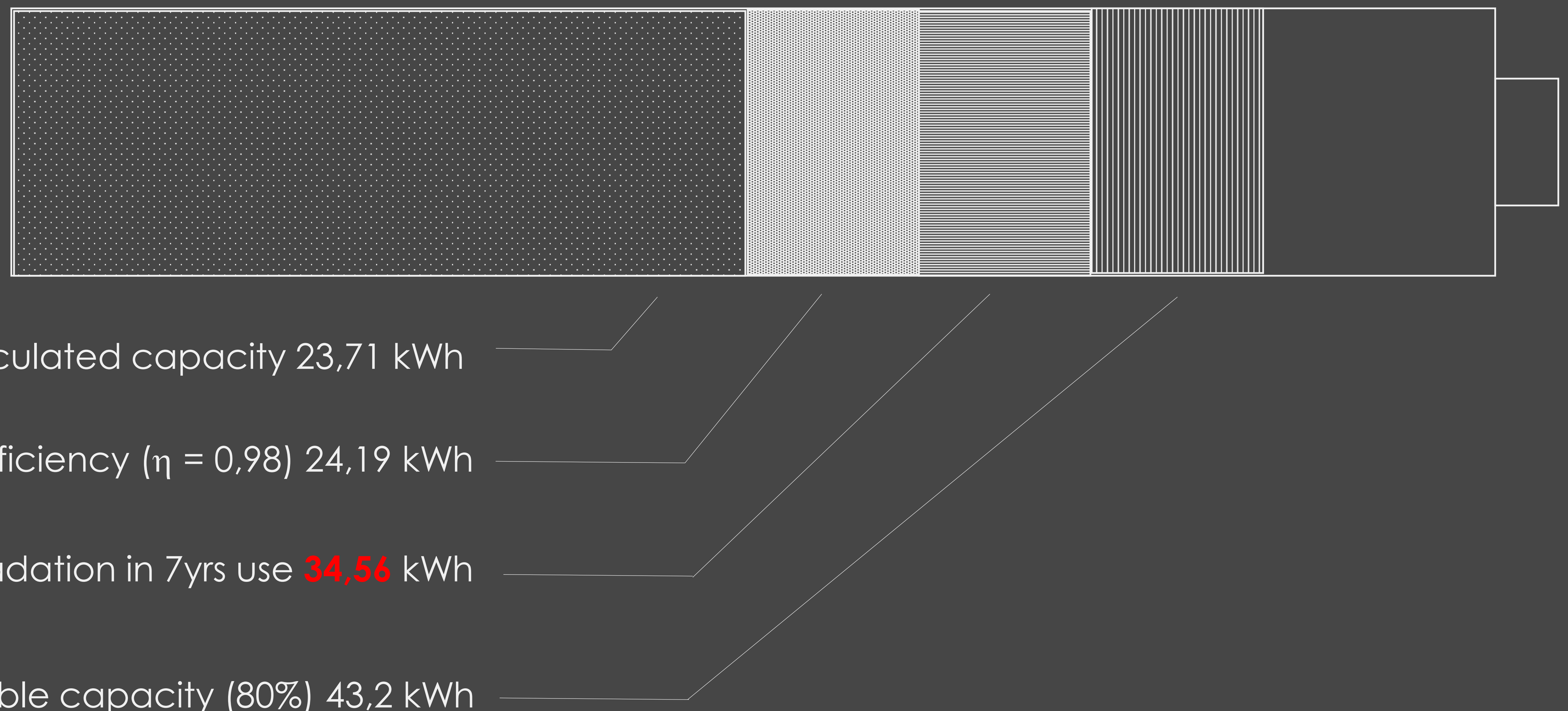
Izračunati podaci o utrošku energije na svakom pojedinačnom segmentu mreže

Simulation of the required energy



Battery Capacity

The minimum battery capacity needed to serve one drive on Line X in a period of 7 years



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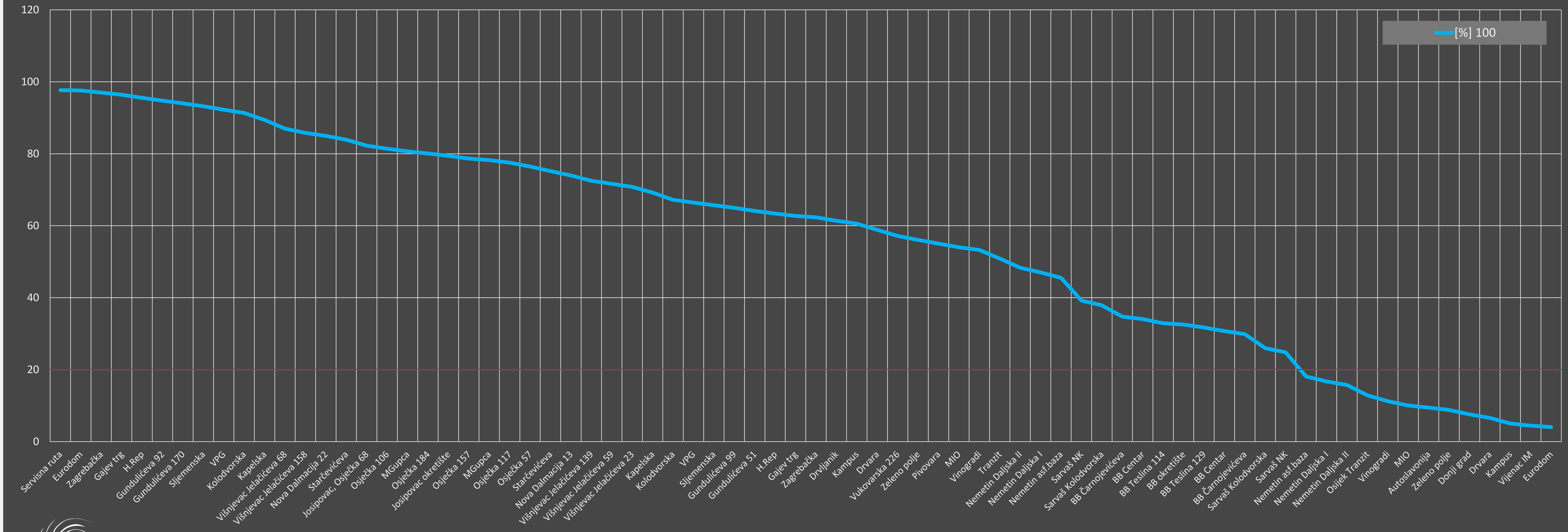
Energy consumption on route – Linija X

Average energy consumption for the 140kWh baterry installation

1,65 kWh/km



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Option 1

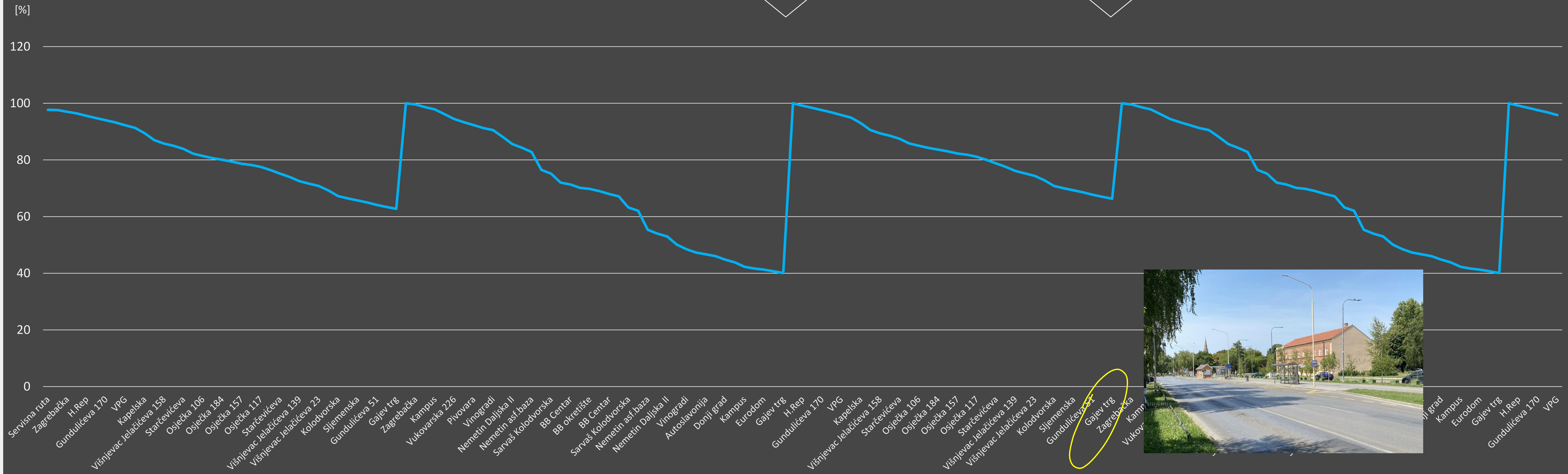
Charging designed to serve highest number of lines

Battery Opportunity Charging – Linija X

Suggested locations for partial battery charging (engl. Opportunity Charging) on the route

Required energy: **60** kWh
Pantograph nominal power: **450** kW
Charging time: **8** min

Required energy: **40** kWh
Pantograph nominal power: **450** kW
Charging time: **6** min



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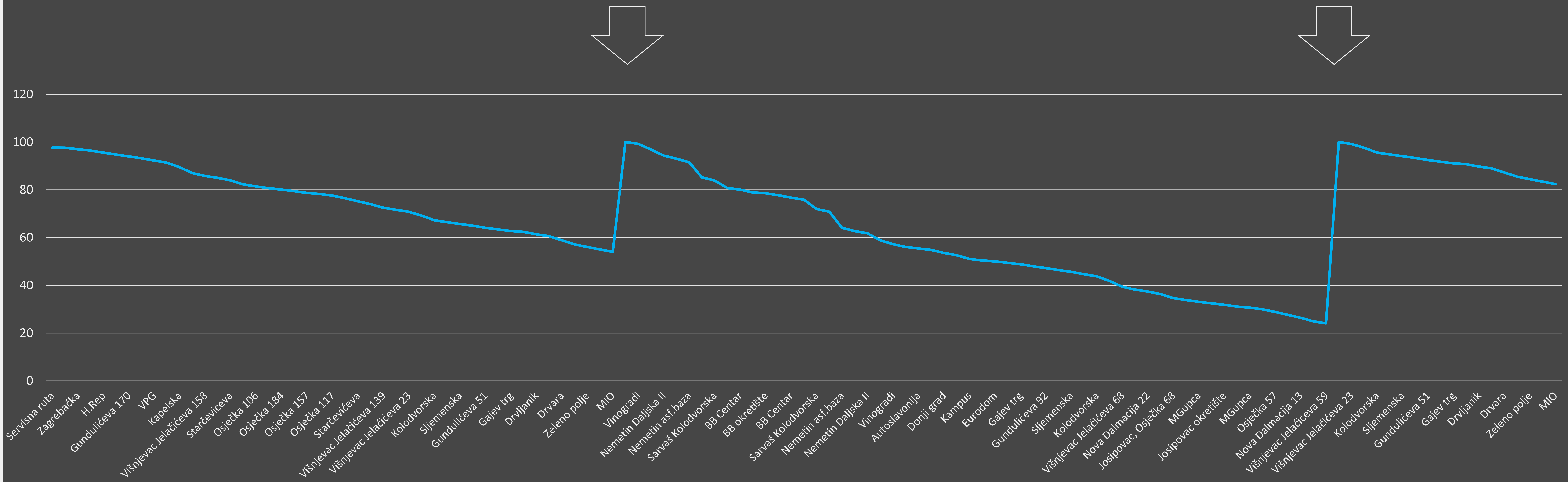
Option 2

Charging designed to use chepest infrastructure

Required energy: **50** kWh
Pantograph nominal power: **450** kW
Charging time: **7** min

Required energy: **79** kWh
Pantograph nominal power: **450** kW
Charging time : **11** min



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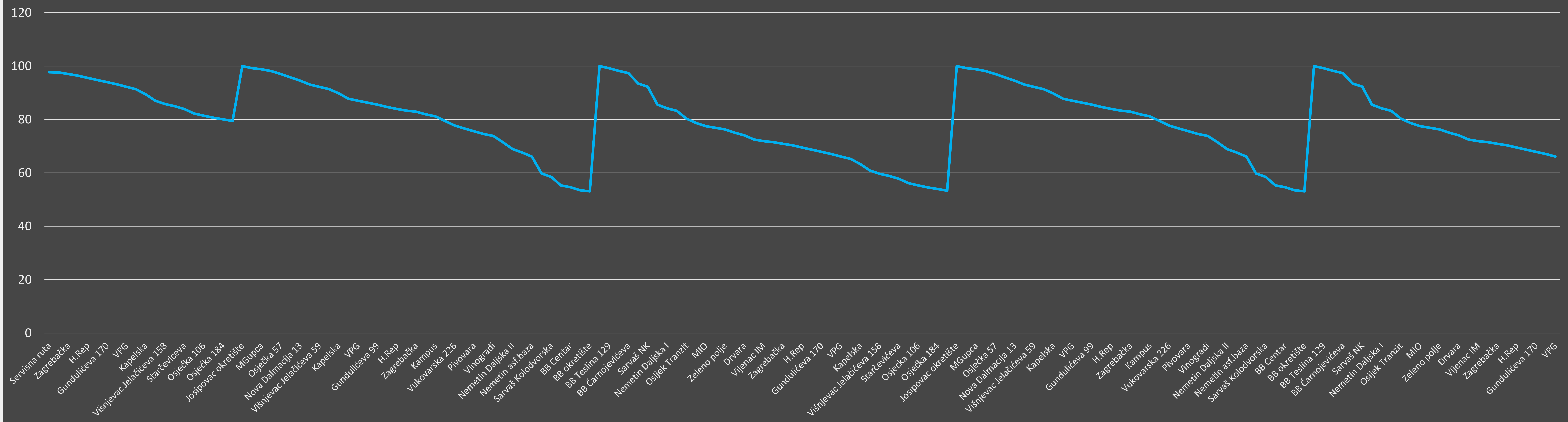
Option 3

Charging designed to run opportunity charging sessions on end stops

Required energy: **51** kWh
Pantograph nominal power: **450** kW
Charging time: **7** min

Required energy : **51** kWh
Pantograph nominal power: **450** kW
Charging time: **7** min



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#06 INVESTMENT

Technical solution proposal and estimated cost of investment

Preliminary technical solution and estimated cost of investment

Tehničko rješenje **1** za primjenu na gradskim linijama sa SORT1 specifičnostima prometovanja (Linije 1, 2, 8, 10).

$$B_{cap} = 55\ kWh$$
$$I_{OC} = 450\ kW$$

Tehničko rješenje **2** za primjenu na izvan-gradskim linijama sa SORT3 specifičnostima prometovanja (Linije 3, 4, 5, 6).

$$B_{cap} = 140\ kWh$$
$$I_{OC} = 450\ kW$$

	Specifikacija	Kol	Jed.cij.	Ukupno
Tehničko rješenje 1	Vozilo	4	€ 430.000	1.720.000,00 €
	Baterijski set	4	€ 22.000	88.000,00 €
	OP Charger (pantograph)	1	€ 450.000	450.000,00 €
	ON Charger (depot)	4	€ 30.000	120.000,00 €
			Subtotal:	**2.378.000,00 €**
Tehničko rješenje 2	Vozilo	6	€ 430.000	2.580.000,00 €
	Baterijski set	6	€ 56.000	336.000,00 €
	OP Charger (pantograph)	2	€ 450.000	900.000,00 €
	ON Charger (depot)	6	€ 30.000	180.000,00 €
			Subtotal:	**3.996.000,00 €**
Popratni trošak implementacije (15%)				956.100,00 €
			SVEUKUPNO:	**7.339.100,00 €**

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Comparison with hydrogen technology

BEV

KEY TECHNICAL CHARACTERISTICS

Compared to vehicles with IC engines, EVs are more powerful and easier to use and maintain. In layman's terms, BEV power units "produce" motion, without direct contact between the engine and the drive shaft, while SUI power units "produce" heat with large heat losses.

The simple principle of operation of BEV with low losses and advanced forms of management mean greater utilization of available power and greater energy efficiency. The property of the electric motor that it can simultaneously serve as a generator turns every braking into battery charging. This in turn means lower operating costs, and due to the stated simplicity of performance, lower maintenance costs. Finally, the electric vehicle is connectable, and in the context of the generally accepted development paradigm of the "Internet of Things" (IoT), the BEV as such represents a far more favourable infrastructure element.

Furthermore, the organization of the PT system is much simpler compared to H2 vehicles and from the aspect of battery recharging, since it can be carried out anywhere where there is a power connection and with very low transmission losses. Finally, after-sales support for BEV vehicles is significantly more developed.

H2

KEY TECHNICAL CHARACTERISTICS

Vehicles that use hydrogen technology are also electric vehicles that, instead of batteries, get electricity from hydrogen fuel cells.

Compared to the batteries of BEV vehicles, hydrogen as a fuel has almost 240x higher energy density (40,000 Wh/kg vs. 167 Wh/kg) and enables significantly faster filling of the tank in the vehicle (10 min vs. 3h). This enables vehicles with H2 drive to transport larger loads or a significantly greater range for the same vehicle mass.

But despite these advantages, key disadvantages related to the consumption of energy required for the production and storage/distribution of hydrogen limit more significant applications. Namely, hydrogen is not available in free form in nature, and it needs to be produced (most often) by electrolysis and then stored at high pressures or liquefied. All these procedures require extremely large amounts of energy, which makes the overall energy balance less favorable compared to BEV. In this context, it can be said that, just as BEV vehicles "produce" motion, and SUI vehicles heat, H2 vehicles need electricity to "produce" electricity from it again. A higher total energy consumption means a higher cost of use, so the cost per transported km for H2 vehicles is approx. 7x higher than the cost of a BEV vehicle.

Finally, the implementation of H2 vehicles is in the early stages of implementation, and in this context, there is currently no clearly defined standardization of application elements or related legislation.

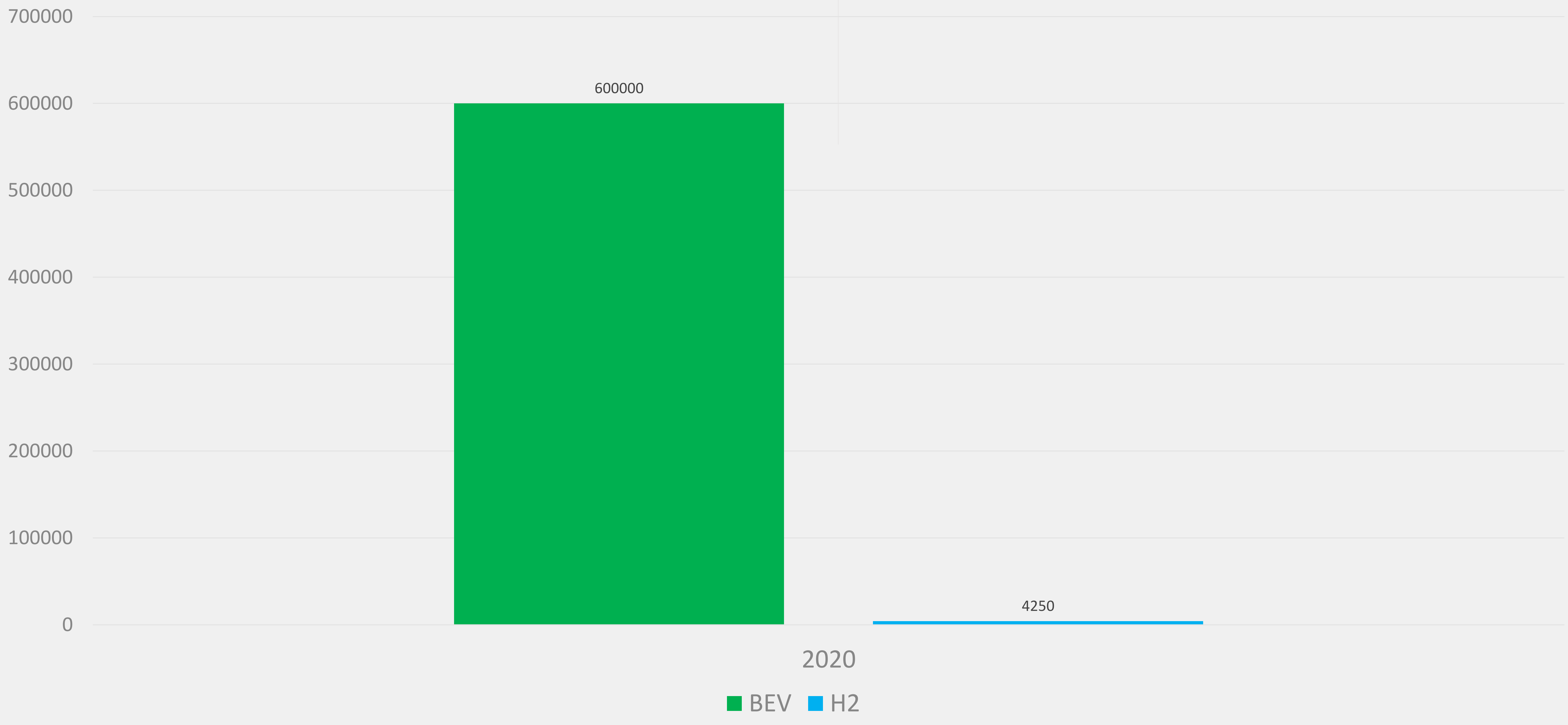
…hence, as a result

BEV

H2

Fleet size

No of veh registered WW in 2020.



Izvor: IEA, Global EV Outlook 2021, BloombergNEF, Hydrogen Economy Outlook 2020

BEV

H2

Market/Fleet Share

Current and expected market share by bus propulsion systems category

Izvor: #SolarisTalks 2021

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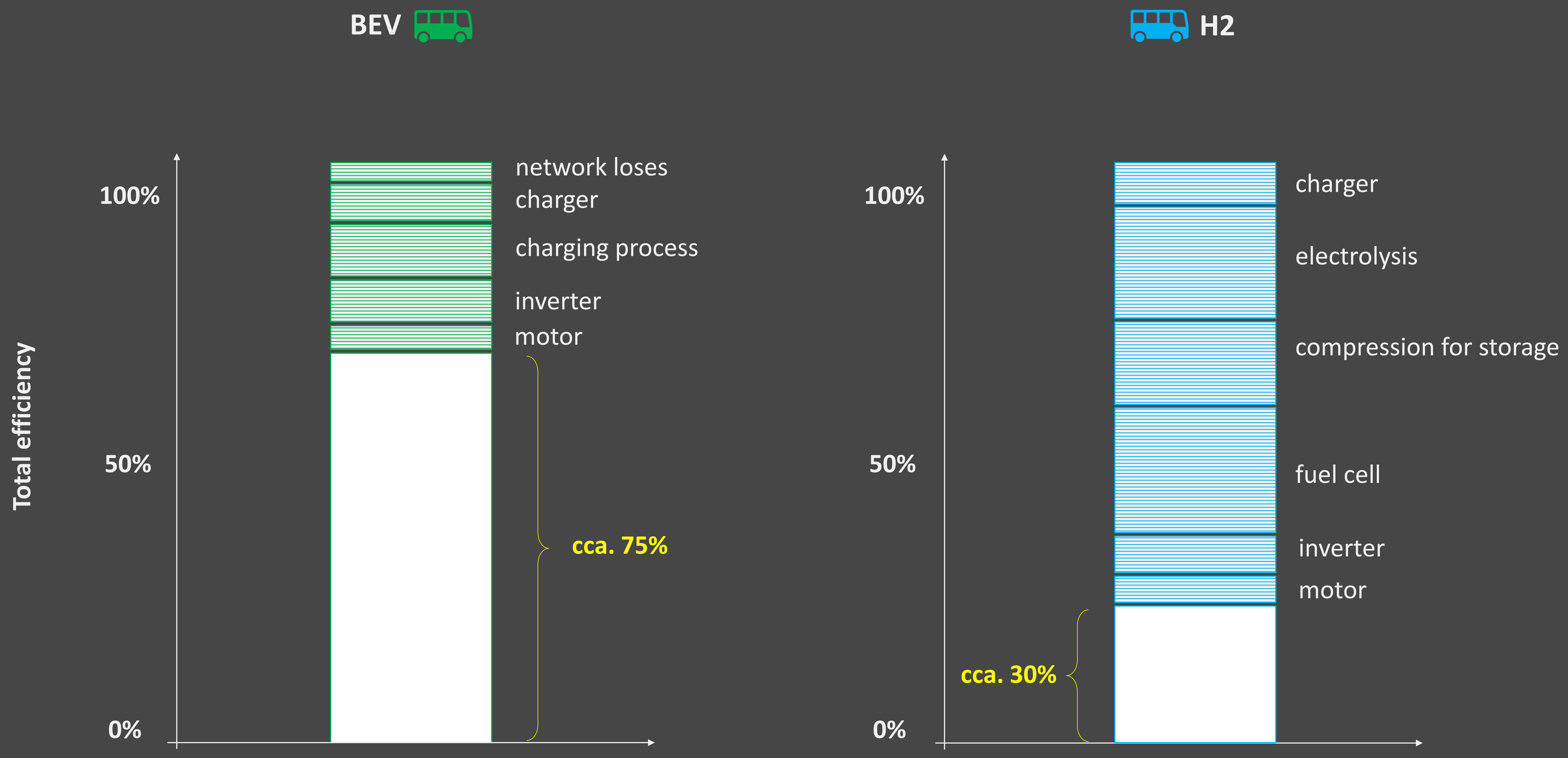
Efficiency

Comparison of the overall energy efficiency W2W for H2 and BEV vehicles



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Total cost of ownership comparison – TCO BEV vs. TCO H2

Tehničko rješenje **1** za primjenu na gradskim linijama sa SORT1 specifičnostima prometovanja (Linije 1, 2, 8, 10).

$$B_{cap} = 55\ kWh$$
$$I_{OC} = 450\ kW$$

Prosječna godišnja kilometraža po vozilu: $94.600\ km$

Tehničko rješenje **2** za primjenu na izvan-gradskim linijama sa SORT3 specifičnostima prometovanja (Linije 3, 4, 5, 6).

$$B_{cap} = 140\ kWh$$
$$I_{OC} = 450\ kW$$

BEV

	Specifikacija	Kol	Jed.cij.	Ukupno
Tehničko rješenje 1	Vozilo	4	430.000 €	1.720.000 €
	Baterijski set	4	22.000 €	88.000 €
	OP Charger (pantograph)	1	450.000 €	450.000 €
	ON Charger (depot)	4	30.000 €	120.000 €
	Operativni trošak po km		0,13 €	
	Trošak zamjene baterija	4	22.000 €	88.000 €
	Ukupni op. trošak (flota, 7g)	7	49.192 €	344.345 €
			Subtotal:	**2.810.345 €**
Tehničko rješenje 2	Vozilo	6	430.000 €	2.580.000 €
	Baterijski set	6	56.000 €	336.000 €
	OP Charger (pantograph)	2	450.000 €	900.000 €
	ON Charger (depot)	6	30.000 €	180.000 €
	Operativni trošak po km		0,13 €	
	Trošak zamjene baterija	6	56.000 €	336.000 €
	Ukupni op. trošak (flota, 7g)	7	73.788 €	516.518 €
			Subtotal:	**4.848.517 €**
	Ukupni trošak posjedovanja za cijelu flotu (10 voz):			**7.658.863 €**

H2

	Specifikacija	Kol	Jed.cij.	Ukupno
Tehničko rješenje 1 i 2	Vozilo	10	640.000 €	6.400.000 €
	Baterijski set	0	n/a	0 €
	OP Charger (pantograph)	0	n/a	0 €
	ON Charger (depot)	0	n/a	120.000 €
	Operativni trošak po kg H2		7,5 €	
	Trošak zamjene baterija	0	n/a	0 €
	Potrošnja H2 po km (Urbino12)		0,11	
	Ukupni op. trošak (flota, 7g)	7	760.181 €	5.321.267 €
	Ukupni trošak posjedovanja za cijelu flotu (10 voz):			**11.721.267 €**

Ukupan trošak posjedovanja za cijelu po trenutnim cijenama H2 (cca. 14€/kg): **16.333.032 €**

„Break Even" cijena H2: €2/kg

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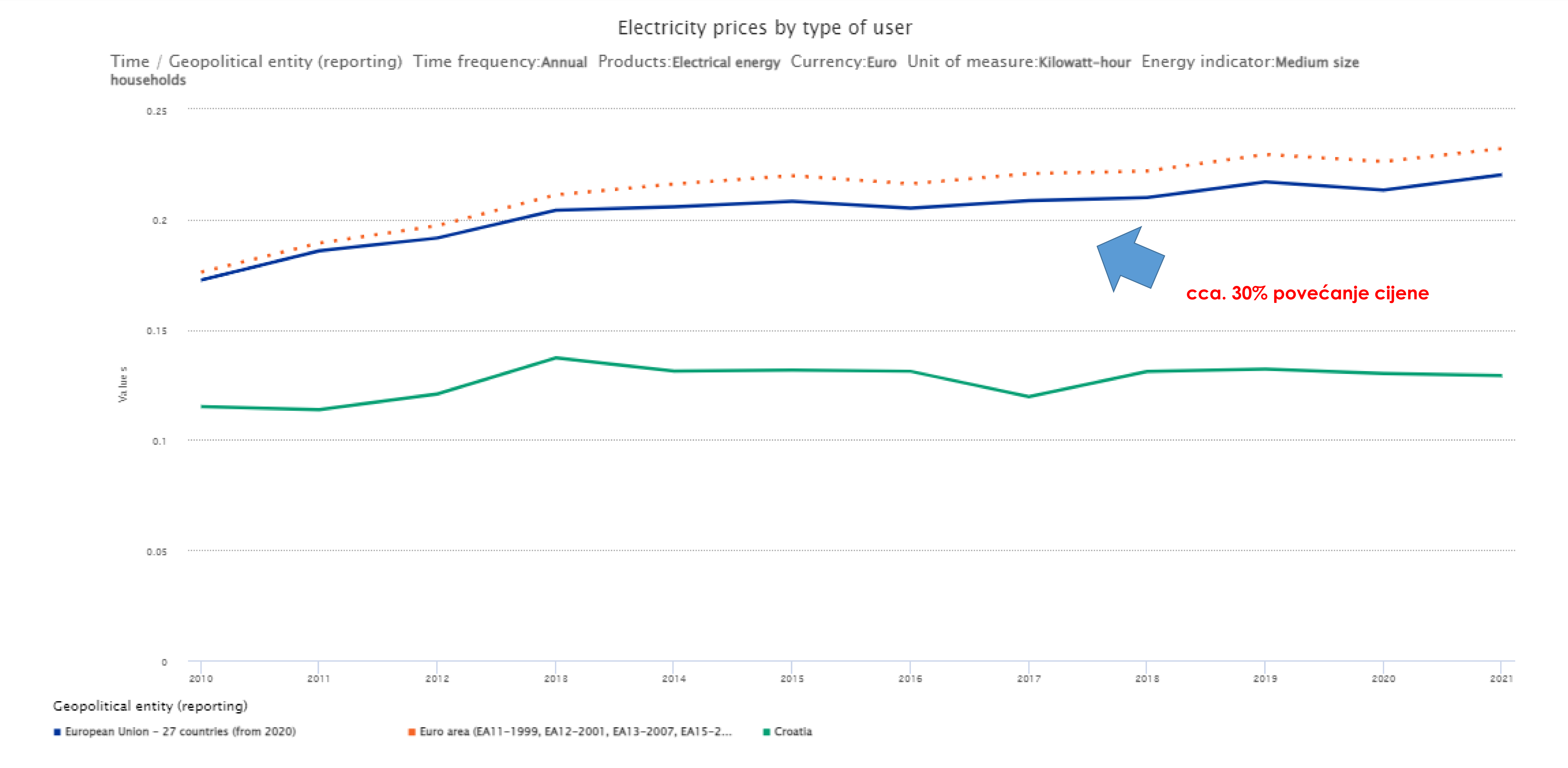
Projections of electrical energy prices

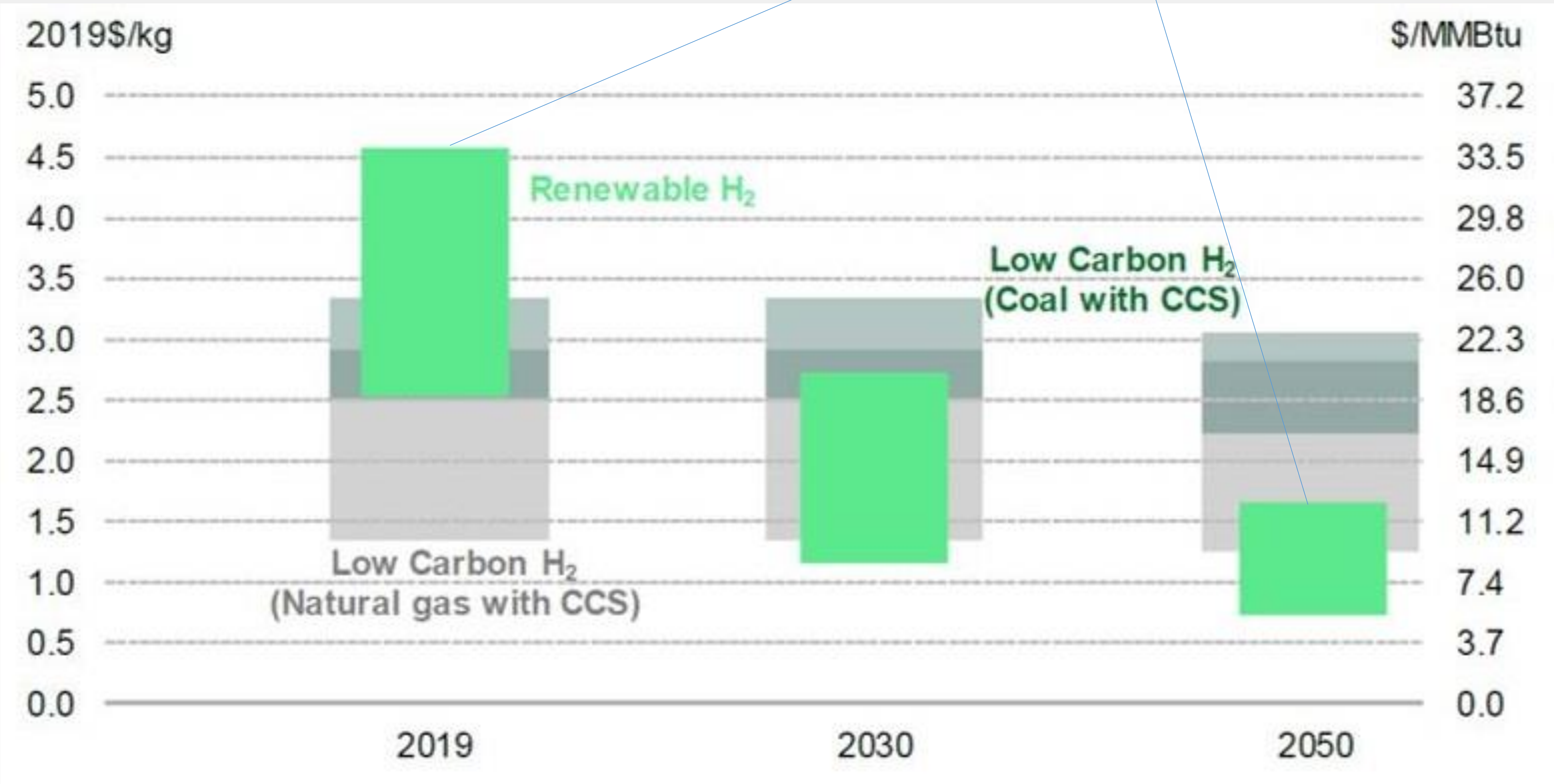


Izvor: eurostat 2022

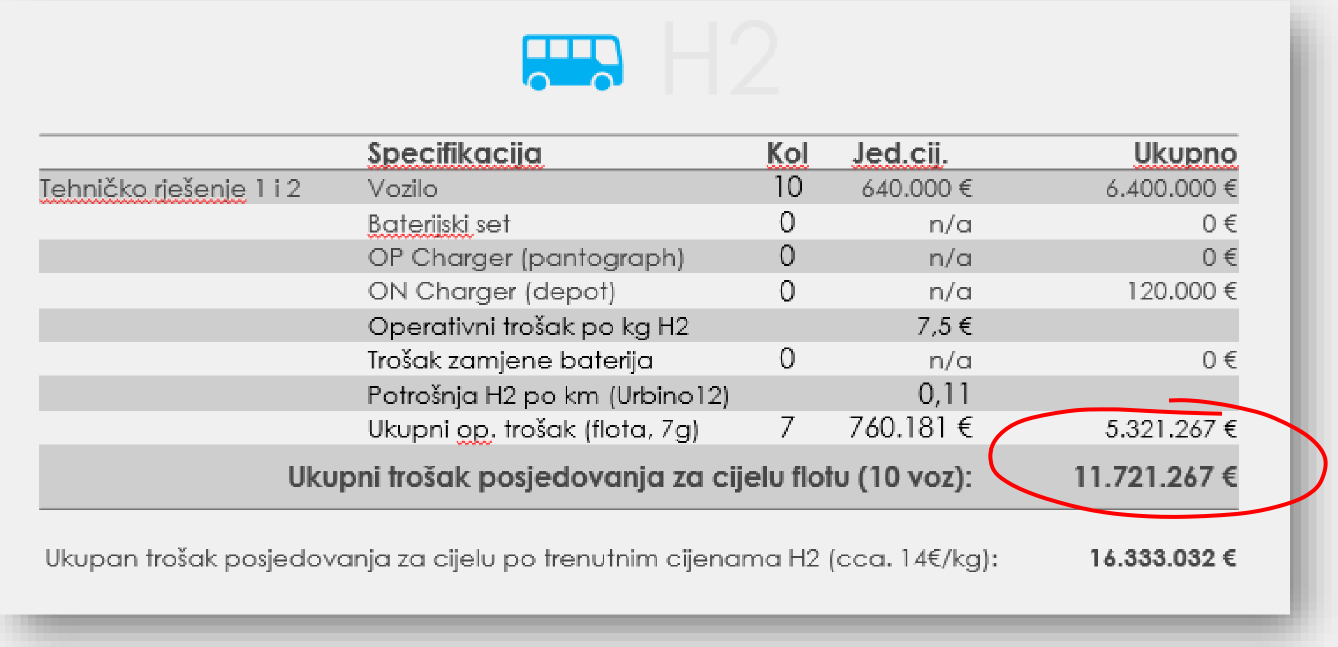
H2 – price forecasts

Cijena proizvodnje H2

⬇ cca. **66%**



Izvor: Bloomberg, 2022



H2

	Specifikacija	Kol	Jed.cij.	Ukupno
Tehničko rješenje 1 i 2	Vozilo	10	640.000 €	6.400.000 €
	Baterijski set	0	n/a	0 €
	OP Charger (pantograph)	0	n/a	0 €
	ON Charger (depot)	0	n/a	120.000 €
	Operativni trošak po kg H2		7,5 €	
	Trošak zamjene baterija	0	n/a	0 €
	Potrošnja H2 po km (Urbino12)		0,11	
	Ukupni op. trošak (flota, 7g)	7	760.181 €	5.321.267 €
	Ukupni trošak posjedovanja za cijelu flotu (10 voz):			**11.721.267 €**

Ukupan trošak posjedovanja za cijelu po trenutnim cijenama H2 (cca. 14€/kg): **16.333.032 €**

0,34 x 11.721.267 = cca. **€4 mio H2** vs. cca. **€7.8 mio BEV***

*with calculated 30% increase in el. energy price

...but it is important to remember:

→ the expected drop is in production prices, not necessarily consumer prices
→ CRO currently does not have a facility for procucing „green" H2
→ there is a Hydrogen Strategy in the CRO, but its realistic scope can be questioned
→ navedeni očekivani pad proizvođačkih cijena moguć je jedino uz snažnu potporu odgovarajućih politika
→ the expected drastic reduction in the cost of batteries is not taken into account in the BEV cost of ownership calculation

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Success strategy

01

Accepting new paradigms

Re-thinking transport!
Transport is no longer a separate activity intended for the physical transport of people and goods, but an integral part of the ecosystem of the digital economy of the future. Only synergistic solutions and approaches make sense.

02

Defining strategic development determinants

Development strategies must be based on the selection of appropriate energy and environmental policies, and not on mere desire or emotion. The focus must be on business sector logistics and on changing attitudes towards car ownership.

03

Tailor-made implementation

The design and implementation of the solution must be based according to the specifics of the process in which the solution is about to be implemented. In this way, the solution is designed to meet all the requirements of the process and guaranty long-term sustainable effects.

04

Promotion

Transition from a society in which transport is a social category to a society that perceives transport as an infrastructural element of social development.

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