



**POLITECHNIKA
GDAŃSKA**

WYDZIAŁ ELEKTROTECHNIKI
I AUTOMATYKI



University
of Gdańsk



RAILWAY INNOVATIONS

Interreg
CENTRAL EUROPE



Co-funded by
the European Union

CE4CE

Decreasing the risk in public transport electrification investments: Simulating decisions with a digital twin



eBus:conference

23 October 2024 | Prague | Czech Republic

Jan Röhl, Kruch Railway Innovations, Vienna

Mikołaj Bartłomiejczyk, Gdansk University of Technology

Marcin Wótek, University of Gdansk



JAN RÖHL
KRUCH RAILWAY
INNOVATIONS,
WIEN



PROF. MARCIN WOLEK
UNIVERSITY OF GDANSK



PROF. MIKOLAJ BARTLOMIEJCZYK
GDANSK UNIVERSITY
OF TECHNOLOGY

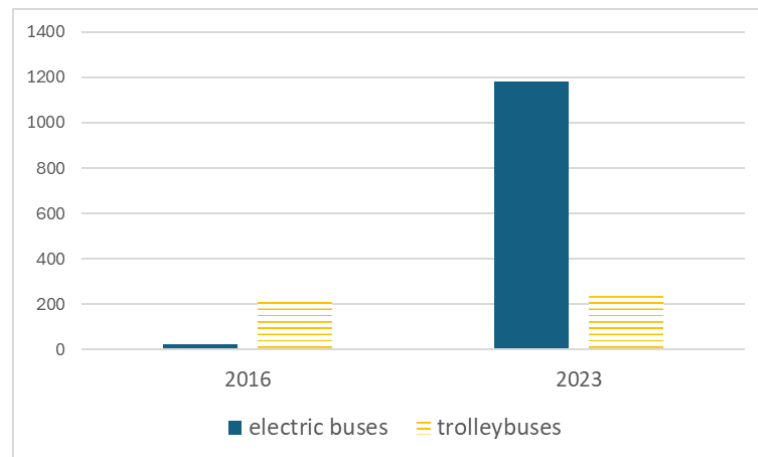
Agenda

- Main risks in public transport development;
- Energy Flow Simulation in the CE4CE Project;
- The EFS concept;
- The EFS development process for the electrification of the Western Corridor in Gdynia;
- Economic and operational analysis;
- Conclusions.

Main risks in the e-public transport development

- high pace of implementing new technologies,
- high upfront expenditures,
- increase in current maintenance and operational costs of the system,
- Many promising messages from the industry,
- institutional and legal changes,
- a need for new HR...

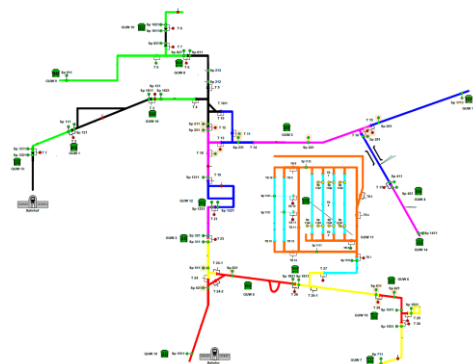
Number of electric vehicles
in the public transport fleet
in Poland in 2016 and 2023



DEVELOPING A DIGITAL TWIN: ENERGY FLOW SIMULATION

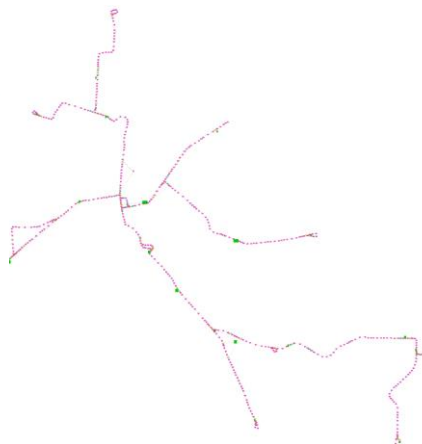
1

Railway network



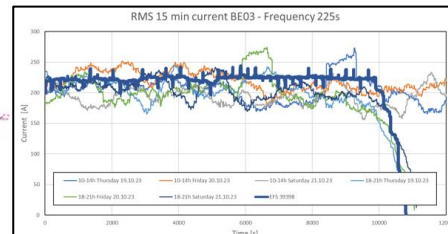
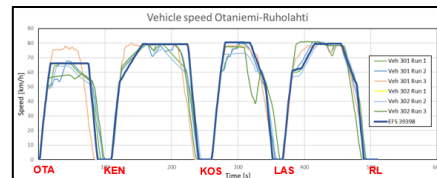
2

Digital model



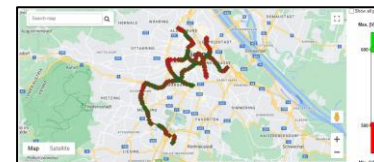
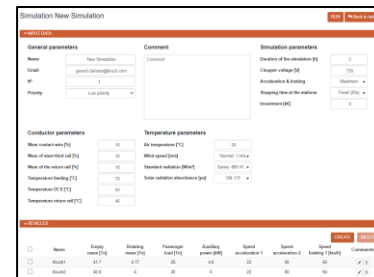
3

Validation



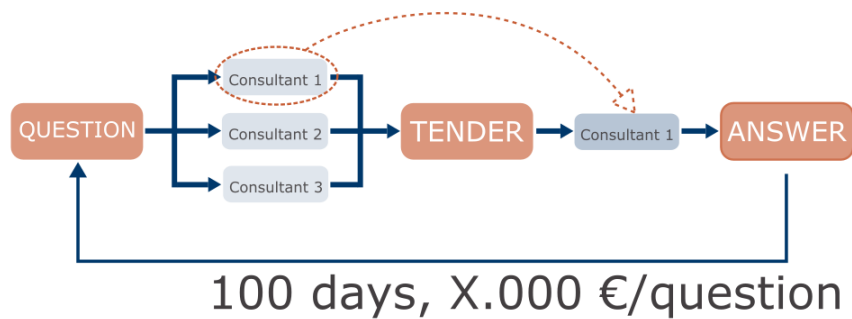
4

Cloud results

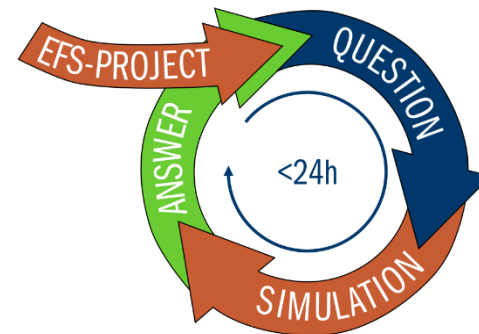


FEATURES OF EFS

Traditional



Energy Flow Simulation



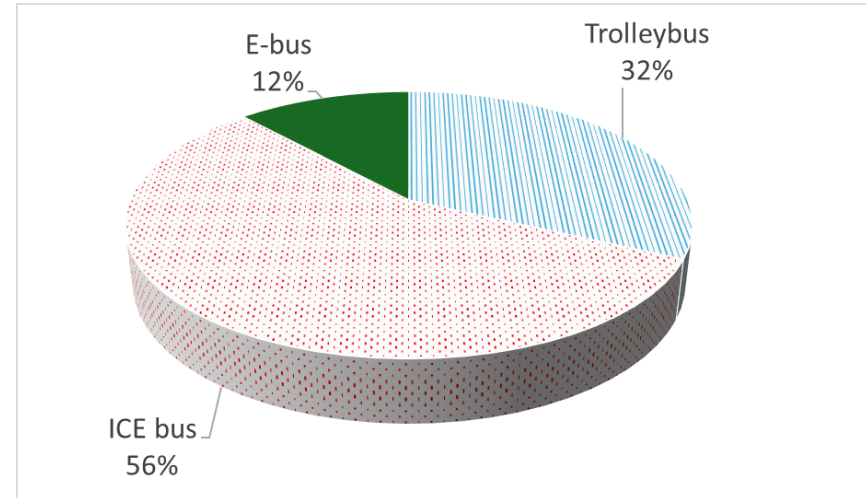
REFERENCES



Public transport in Gdynia: an overview

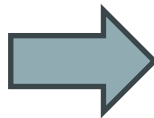
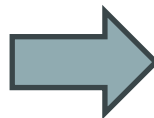
- Gradually electrification process of the road public transport supply;
- The trolleybus transport represents a solid base for electrification of public transport;
- Trolleybuses in operation since 1943 - a platform for the development of a modern system integrating infrastructure, vehicles and energy;
- Electrification supplemented by the introduction of battery bus vehicles in 2022;
- On the other hand, public transport in Gdynia accounts for less than 2% of the total CO₂e emissions (2020).

The structure of public transport
in Gdynia in 2023
[%, calculation based on veh-kms]



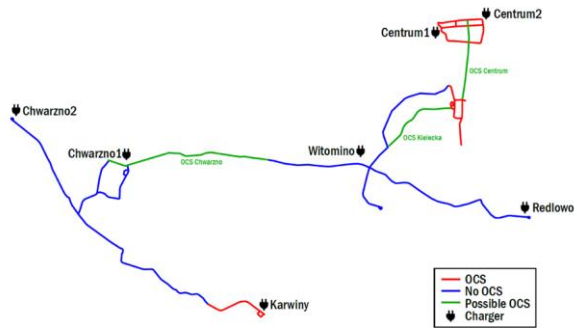
Energy Flow Simulation for Gdynia in the CE4CE Project

- Electrification of the Western Corridor in Gdynia - a connection between the city centre and a distant district with a rapidly growing population;
- Current service run by diesel buses and, to a lesser extent - e-buses (since 2022);
- A potential for further electrification of public transport supply;
- Possible options - opportunity charging e-buses, IMC trolleybuses.





Bus line	N departures	Electrified
147	69	N
190	57	Y
140	30	N
160	28	N



eBus:conference
23 October 2024 | Prague | Czech Republic

Defining
collaborative
framework

Determining
the spatial
scope
of the model

Selection
of lines

Digital twin for
the selected
corridor

Options for the
electrification
of public
transport

Socio-
economic
analysis

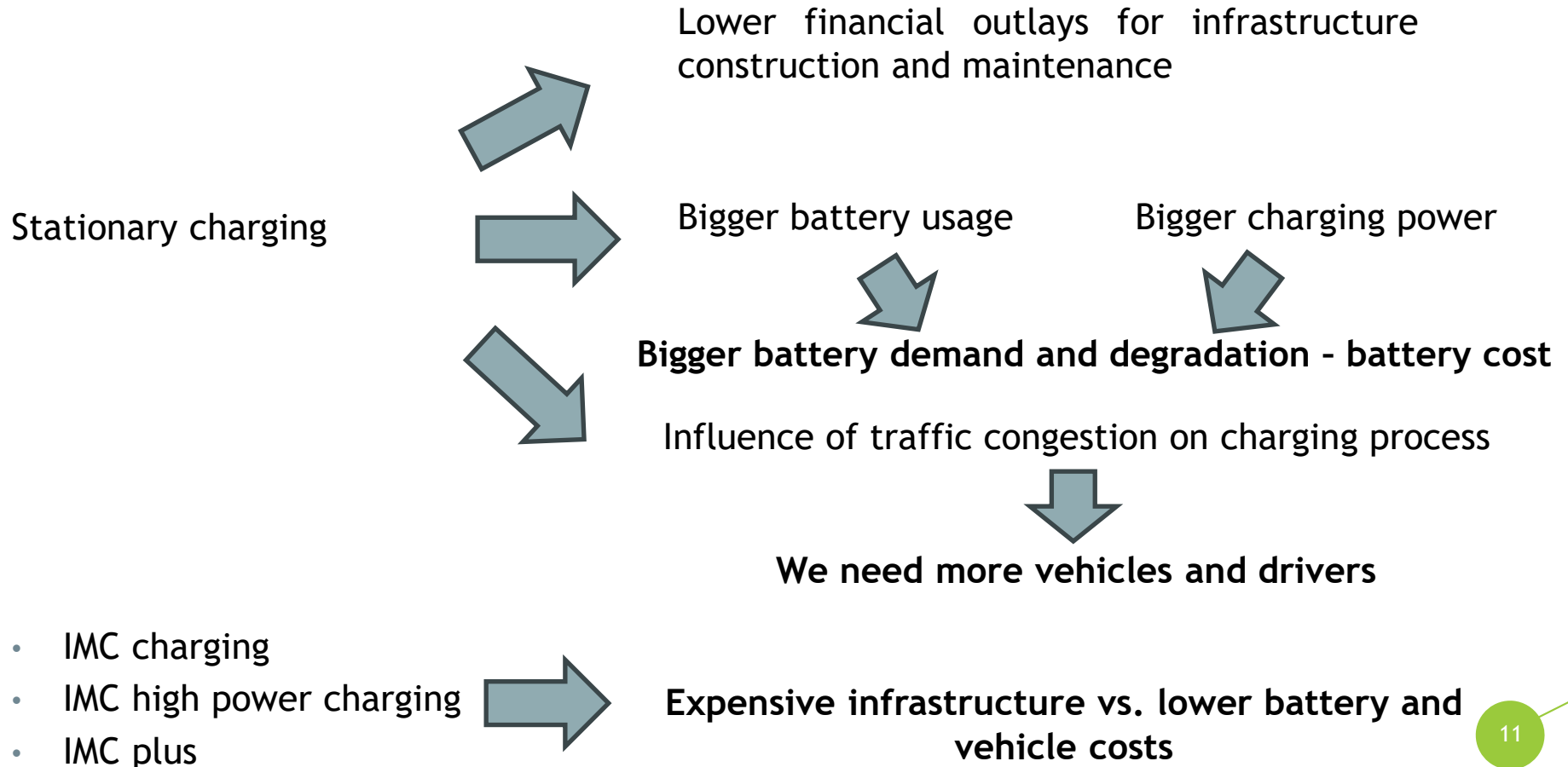
Sep. 2023

Dec. 2023-Oct. 2024

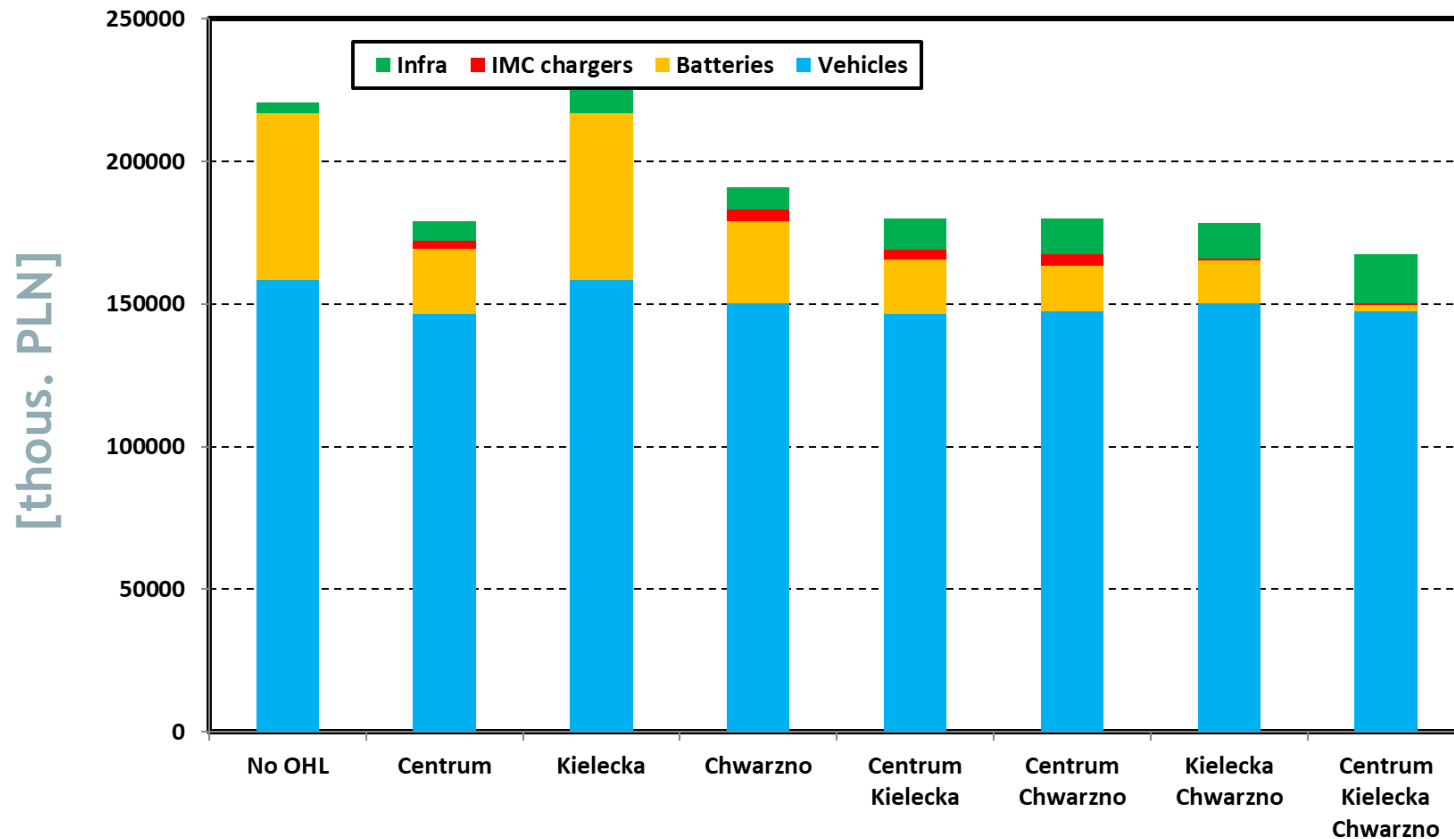


Line	IMC No extra OCS	IMC OCS Centrum	IMC OCS Kielecka	IMC OCS Chwarzno	IMC OCS Centrum + Kielecka	IMC OCS Centrum + Chwarzno	IMC OCS Kielecka + Chwarzno	IMC OCS Centrum + Kielecka + Chwarzno
121	✗	✗	✗	✗	✗	✗	✗	✗
140	✗	✗	✗	✗	✗	✗	✓	✓
147	✗	✗	✗	✗	✗	✗	✓	✓
160	✗	✓	✗	✓	✓	✓	✓	✓
190	✗	✓	✗	✓	✓	✓	✗	✓

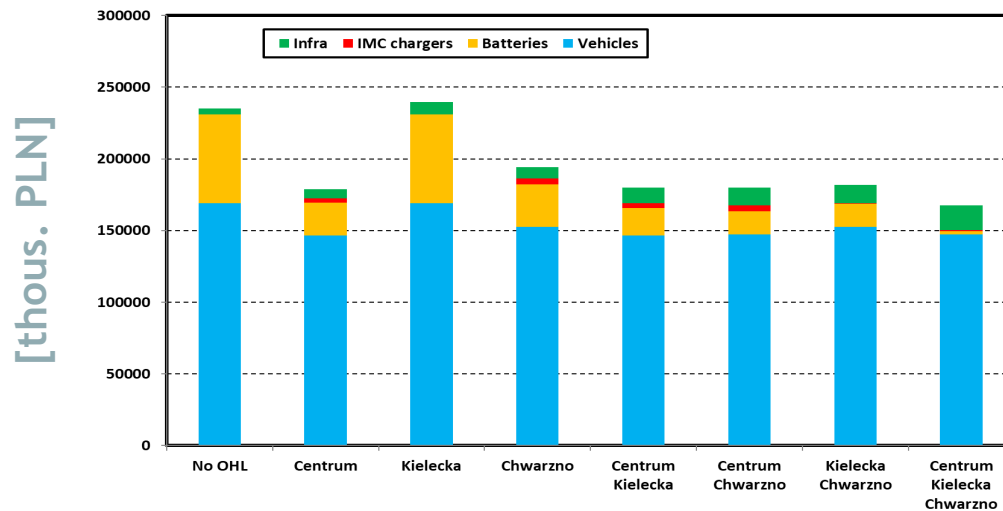
Choosing the optimal scenario - optimization task



Scenario: 7 minutes frequency, no congestion

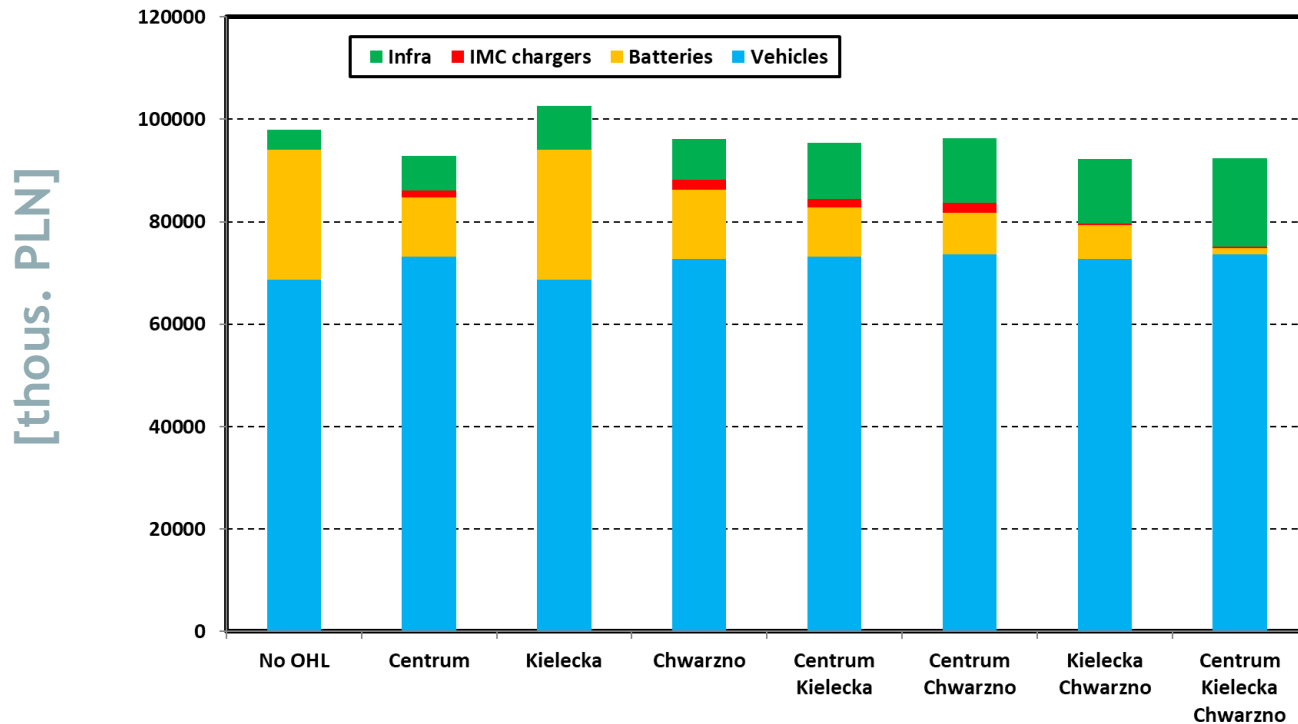


Scenario: 7 minutes frequency, congestion

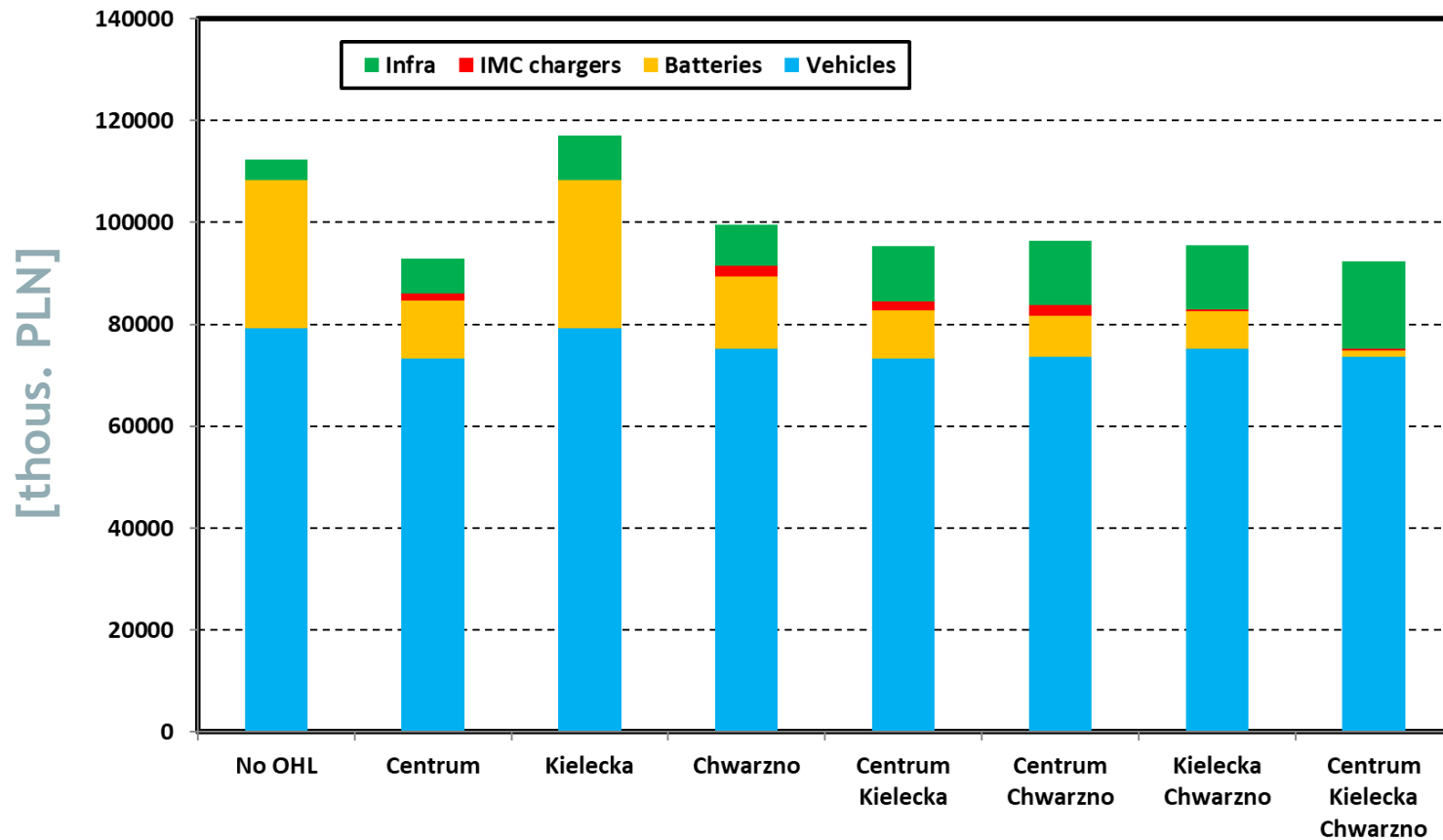


OHL	Price of OHL kPLN	121	140	147	160	190
No OHL		OPP	OPP	OPP	OPP	OPP
Centrum	4673	OPP	IMC +	IMC +	IMC std	IMC std
Kielecka	4642	OPP	OPP	OPP	OPP	OPP
Chwarzno	7956	IMC pwr	IMC pwr	IMC pwr	IMC std	OPP
Cent. Kielecka	9315	OPP	IMC pwr	IMC pwr	IMC std	IMC std
Cent. Chwarzno	12629	IMC pwr	IMC pwr	IMC pwr	IMC std	IMC std
Kielecka Chwarzno	12598	IMC pwr	IMC std	IMC std	IMC std	OPP
Cent. Kielecka Chwarzno	17271	IMC pwr	IMC std	IMC std	IMC std	IMC std

Scenario: 15 minutes frequency, no congestion

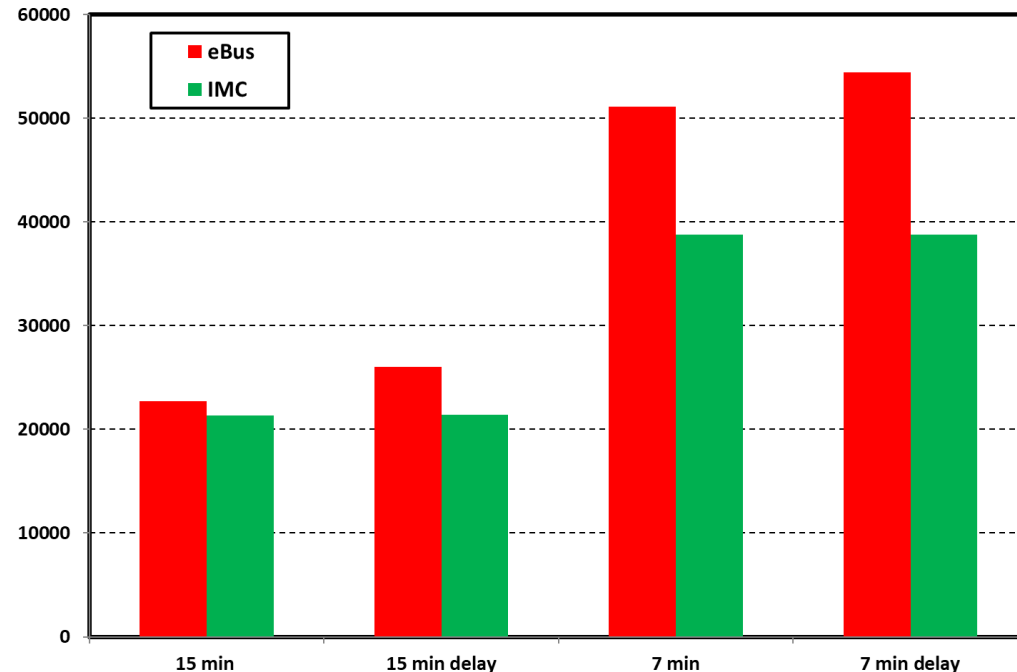


Scenario: 15 minutes frequency, congestion



- Minimal costs of particular variants regarding frequency and traffic conditions in the Western Corridor [thous. EUR];
- 2 batteries exchange in the e-bus lifetime, one battery exchange in the IMC trolleybus lifetime;
- The model allows us to put different (preferably real!) values reflecting specific conditions of a particular public transport system.

Density of traffic and congestion - the final comparison [thous. EUR]



- EFS allowed for generating numerous scenarios based on real data from buses and trolleybuses.
- EFS makes an economic and operational analysis of potential investment undertakings easier and more precise;
- Four main scenarios based on frequency and traffic conditions (congestion) were finally tested for the Western Corridor in Gdynia (Poland).
- The model is susceptible to congestion—the larger the number of battery buses needed to execute the timetable, the higher the final cost of the scenario.
- Rolling stock costs of acquisition highly influence the results.
- Also, higher frequency makes overhead infrastructure more efficient.
- A general conclusion is that prioritising electric vehicles in traffic can reduce the need for larger, more expensive batteries, thus lowering the total cost of ownership (TCO) for e-buses.



<https://www.interreg-central.eu/projects/ce4ce/>

<https://www.pg.edu.pl>

<https://www.ug.edu.pl>

<https://kruch.com/>

<https://www.facebook.com/Interreg.CE4CE>

https://twitter.com/Interreg_CE4CE

Contact:

jan.roehl@kruch.at

mikolaj.bartlomiejczyk@pg.gda.pl

marcin.wolek@ug.edu.pl