ELIPTIC Use Case Eberswalde

Extension of trolleybus operation

Methodology and Results

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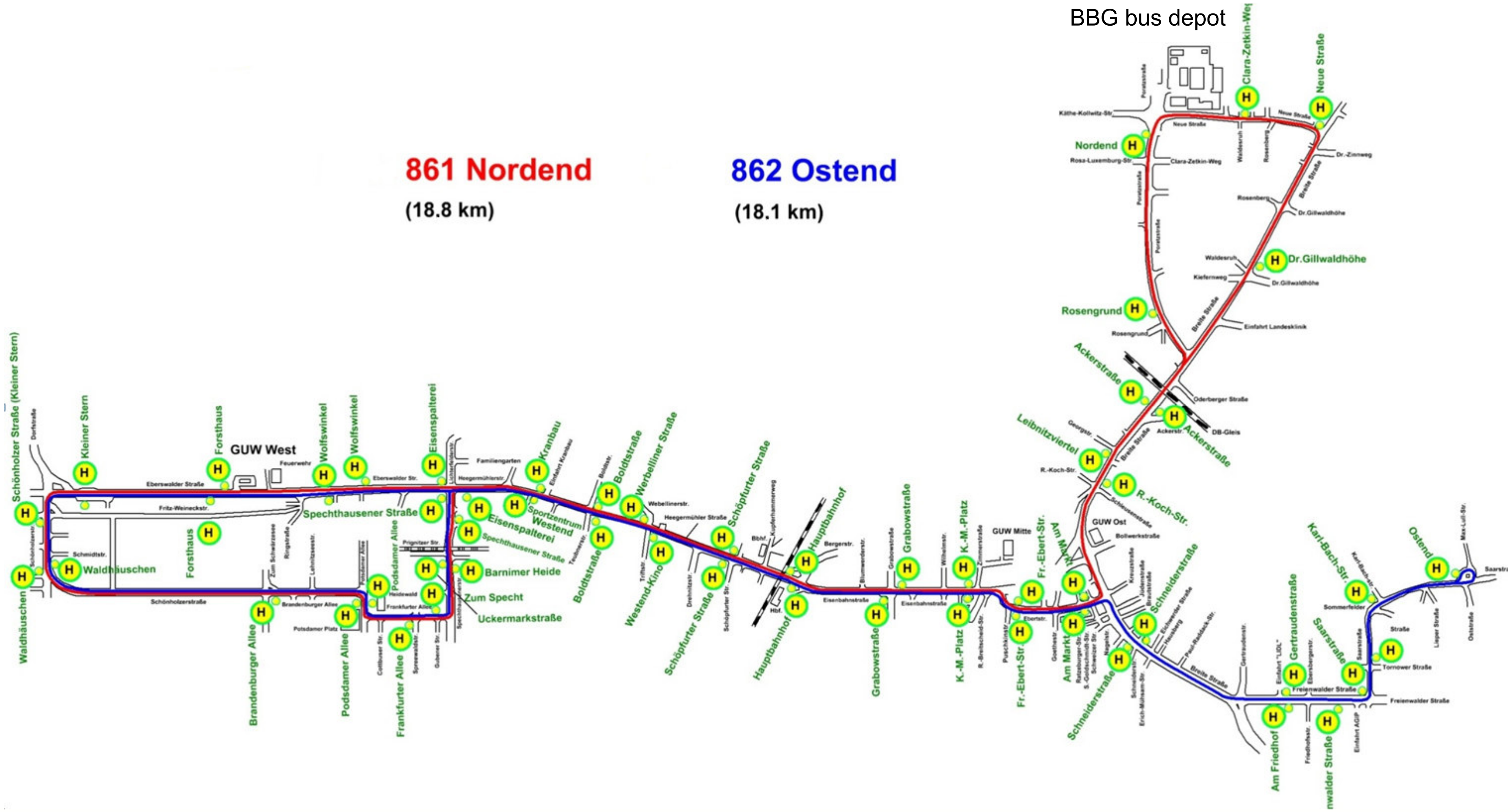
Horizon 2020 Programme

Introduction
Eberswalde

- Approx. 39.000 inhabitants
- County Seat
- 1 out of 3 German trolleybus towns
- Elongated urban structure

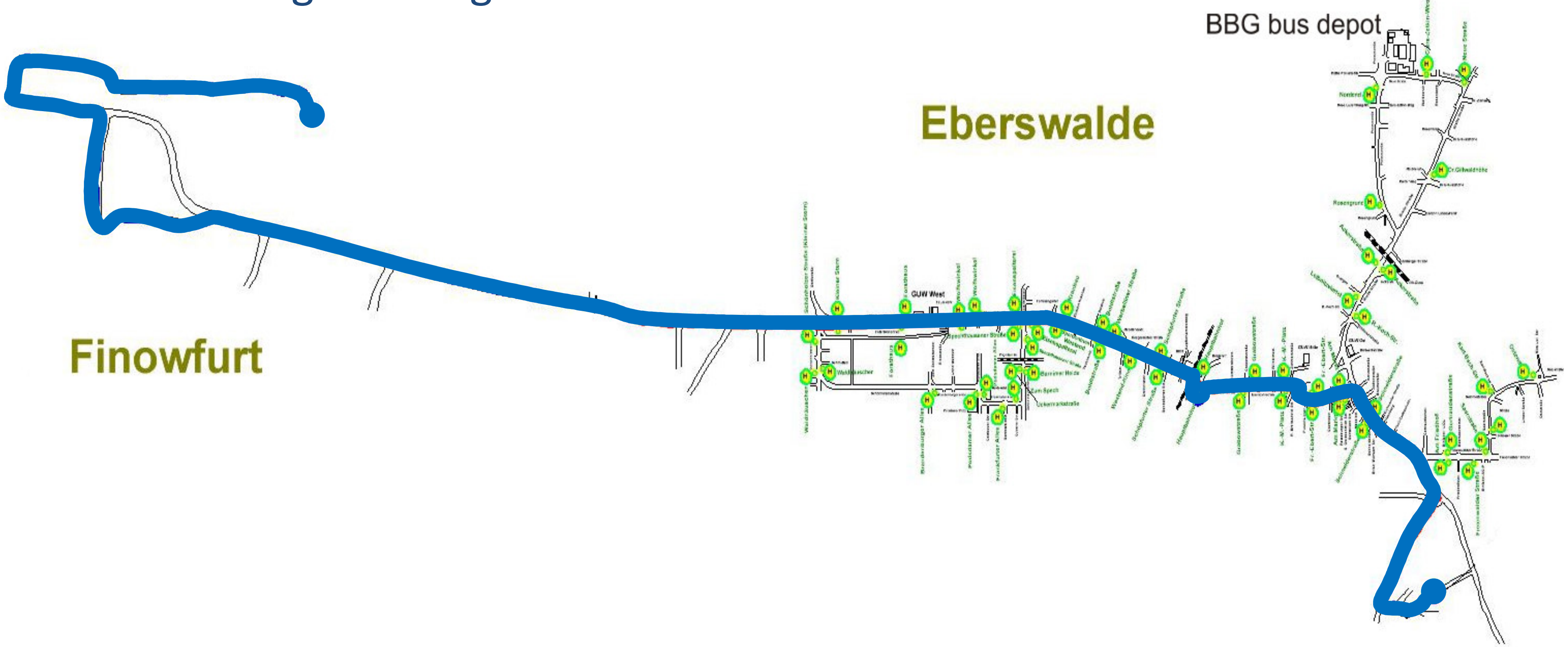
- Eliptic Use Case on hybrid trolleybus operation

Introduction
The existing trolleybus network



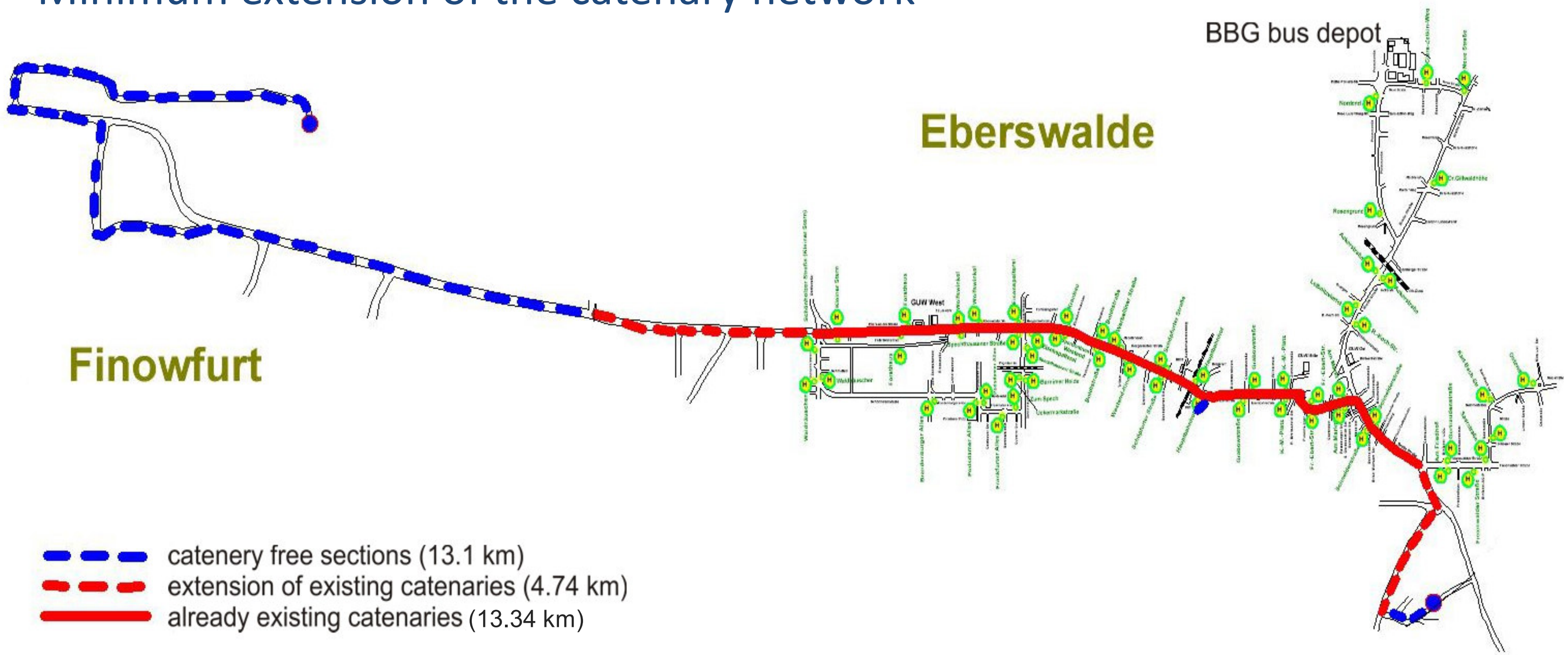
Introduction
The diesel bus line 910

- Partly parallel to the trolleybus lines
- Length: approx. 14.7 km (depending on terminal stop in Finowfurt)
- Connects neighbouring Finowfurt with Eberswalde



The Use Case
Extension of trolleybus operation

- By combining line 910 with the trolleybus catenary network
- Use of trolleybuses with energy storage instead of APU
- Minimum extension of the catenary network



The vehicles

Pre-configured Solaris trolleybuses

- 12 buses in operation
- One bus already equipped with a battery
- Retrofitting of additional buses – subject to feasibility study
- Recharging under catenary

The vehicles

Pre-configured Solaris trolleybuses

- Length / total weight: 18 m / max. 28 t
- Driven axle: 2nd, asynchronous motor
- Power (con. / max.): 250 / 300 kW
- Torque (con. / max.): 1734 / 2600 Nm

The vehicles

Pre-configured Solaris trolleybuses

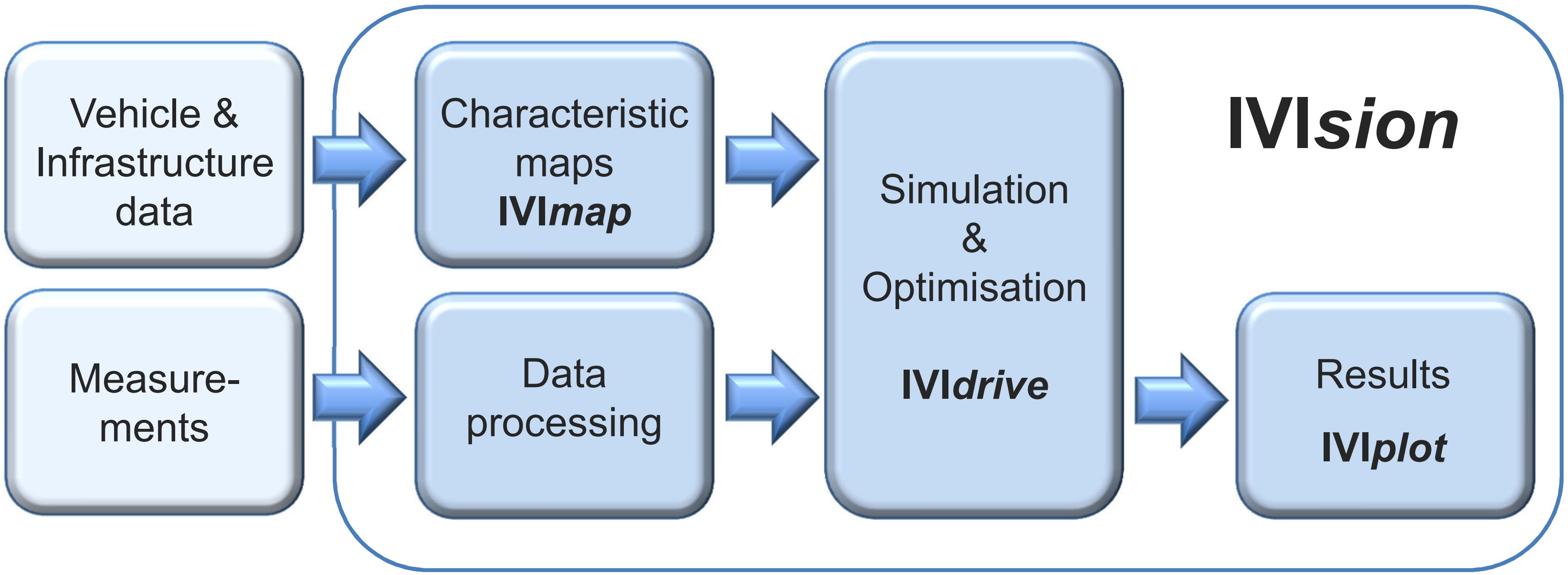
- Battery: LiFePO4
- Energy content: 70.4 kWh (42.2 kWh usable)
- Weight: 1020 kg
- Power: 38 kW (charging) / 140 kW (discharging)

The vehicles
Pre-configured Solaris trolleybuses

- Braking energy storage: Super capacitors
- Energy content: 0.57 kWh
- Average power: 150 kW (discharging)

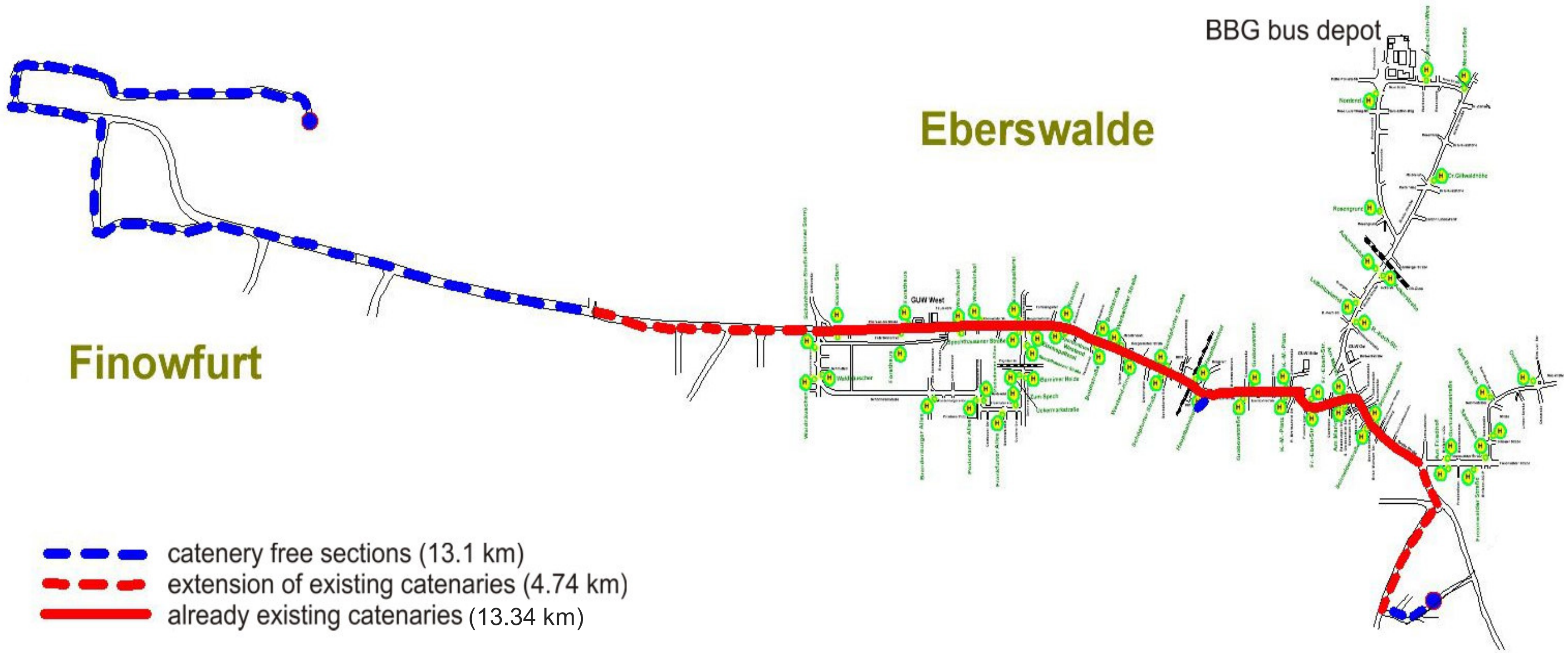
Feasibility study
Technical feasibility

- Vehicle simulation
- Based on measured speed-distance-patterns
- Using Fraunhofer IVI*sion* vehicle simulation model



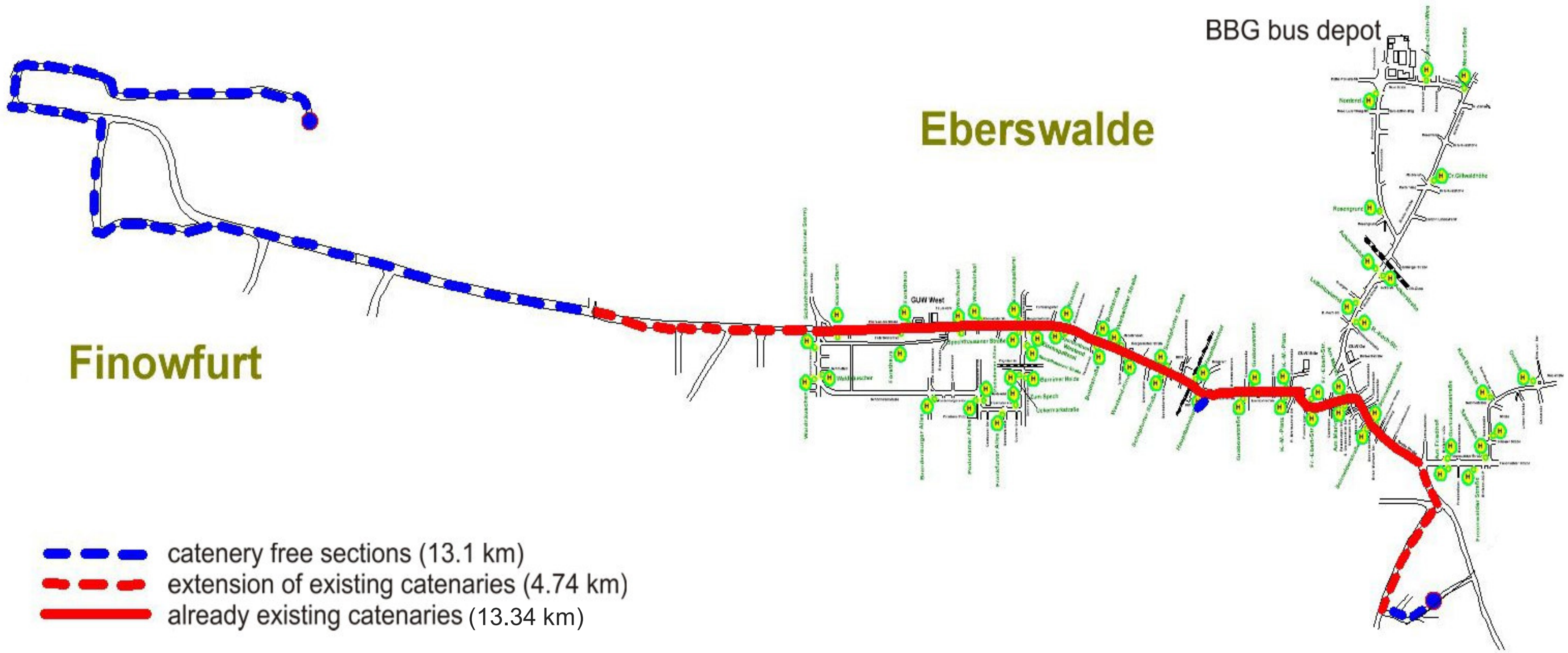
Feasibility study
Core questions

- Is the battery big enough to cover the catenary free section to / from Finowfurt?
- Is there enough time under the catenaries to recharge the battery?



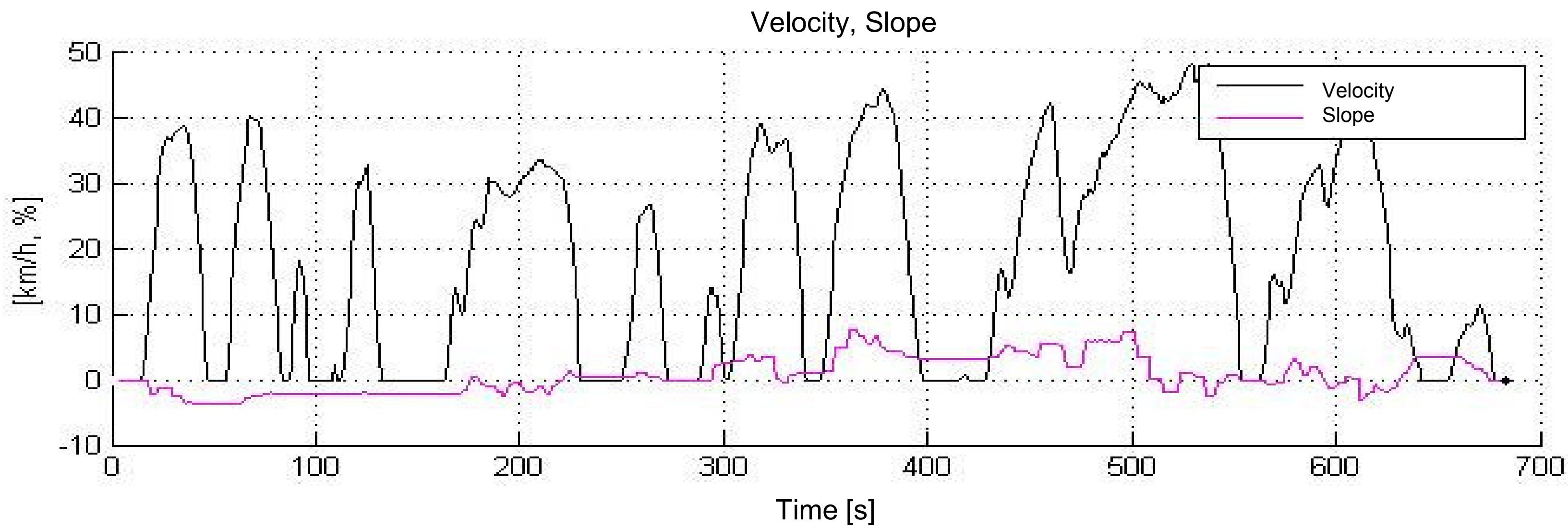
Feasibility study
Secondary questions

- How long must the additional catenary be?
- Is a charging station at the terminal stop in Finowfurt necessary?
- Are additional trolleybuses necessary? ➡ Yes, pre-decided by BBG!



Feasibility study
Approach

- Field measurements:
  - speed-distance-patterns / speed-time-patterns
  - passenger demand
- Configured vehicle model and catenary network using IVI*sion*
- Vehicle simulations using schedules provided by BBG



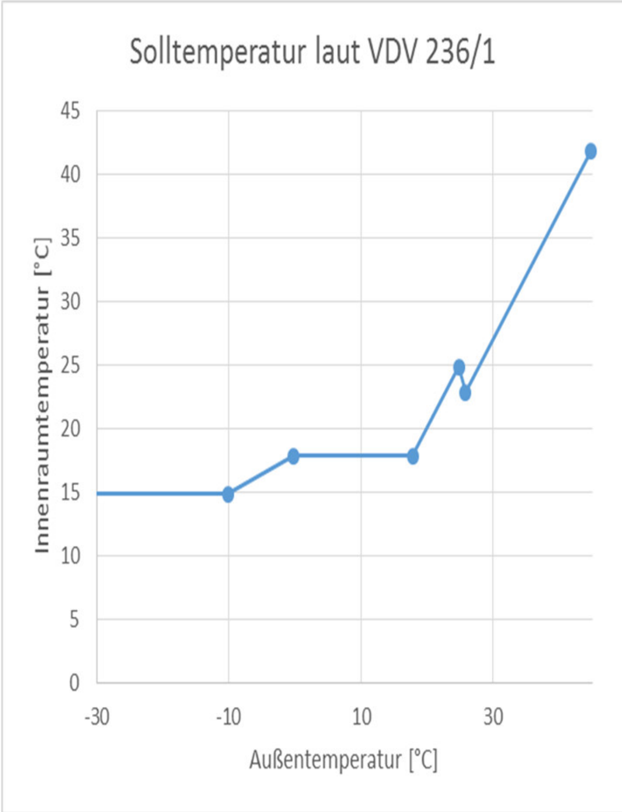
Catenary
4 Layouts

Layout	Extension to the west	Extension to the east
O1 Existing catenary	Kleiner Stern	-
O2 Extension west	Großer Stern	-
O3 Extension east #1	Großer Stern	Tramper Chaussee
O4 Extension east #2	Großer Stern	Bernauer Heerstrasse

- max. electric power taken from catenary at 600 V
  - while driving: 400 A ; 240 kW (could be higher)
  - during stops: 150 A; 90 kW

Vehicle Parameters
HVAC

Version	Component	Installed heating / AC power
K 1	Heat pump	Heating 2x 30 kW AC 2x 24 kW
	Electric heater	Heating 38 kW
K 2	Diesel heater	Heating 50 kW
	24 V-AC unit	AC 3 x 5 kW



- Objective: Fully electric operation!

Ambient Conditions
3 Scenarios

Ambient Conditions	Temperature	Solar Irradiation
Scenario S1	-24°C to -17°C	overcast
Scenario S2	15°C to 17°C	overcast
Scenario S3	23°C to 36°C	sunny

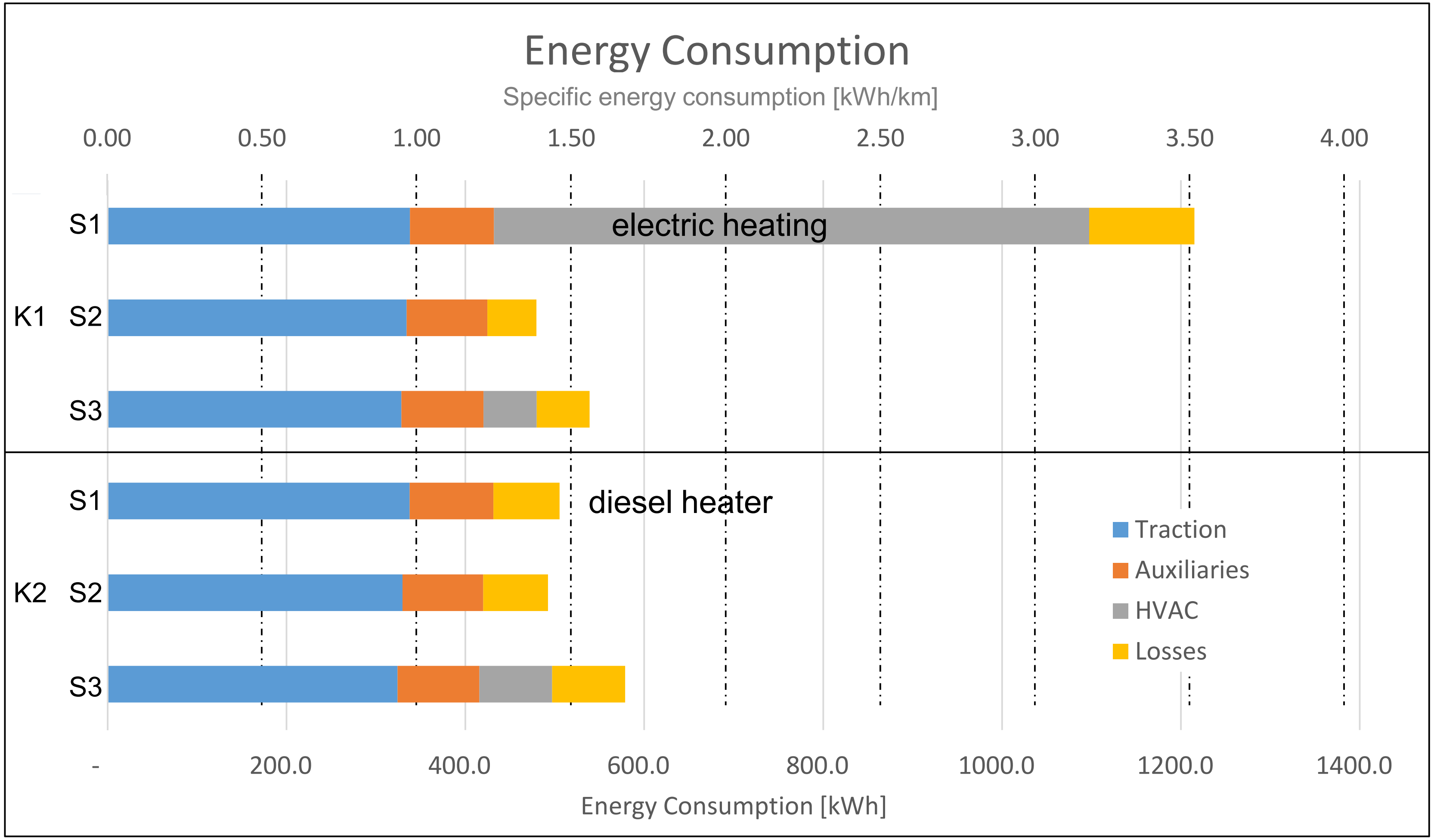
- „worst case“ Scenarios (S1 and S3)
  - safe operation in the winter time
  - determination of the highest energy demand

Boundary Conditions
Vehicles and passengers

- Vehicles
  - 3 schedules
  - L910_11: starts 4:17 Uhr; 19.5 h; 350 km
  - L910_12: starts 5:47 Uhr; 14 h; 260 km
  - L910_53: starts 5:17 Uhr; 19.5 h; 350 km

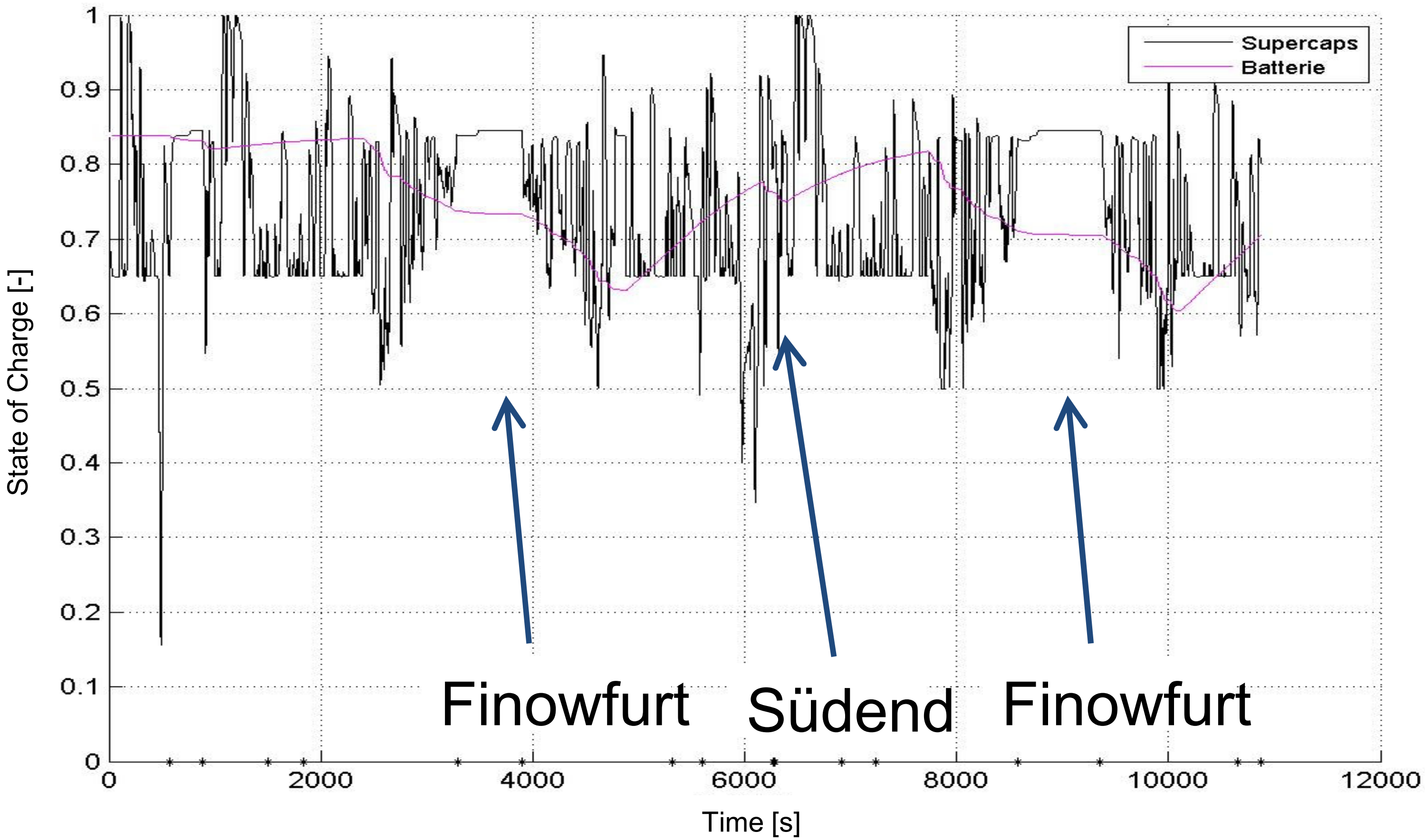
- Number of passengers: 2 scenarios
  - constant 25 / 75 passengers
  - per passenger: 50 – 100 W heat emission
  - heat losses influenced by the duration of opened doors
  - journeys to and from bus depot without passengers

Results
Energy consumption



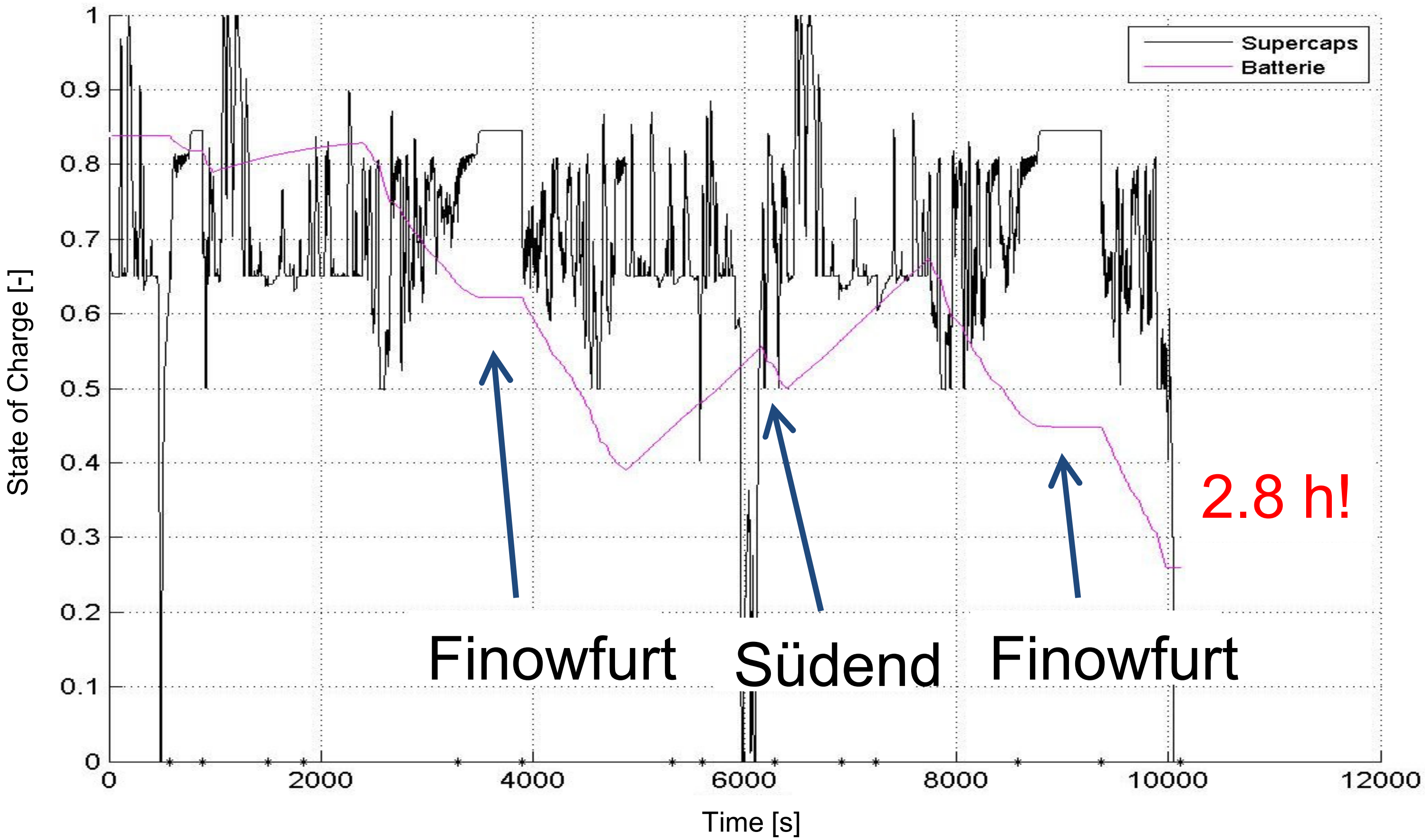
Results
State of Charge

- Electric heating – mild wheather conditions (S2)



Results
State of Charge

- Electric heating – cold wheather conditions (S1)



Conclusions
Answers to the questions

- Is the battery big enough to cover the catenary free section to / from Finowfurt?

  Yes!

- Is there enough time under the catenaries to recharge the battery?

  No! Charging power (38 kW) too low!

- How long must the additional catenary be?

  Longer than possible!

- Is a charging station at the terminal stop in Finowfurt necessary?

  It would help, but very high investment cost.

Conclusions
Solution

- Battery with higher charging power
- Elimination of the supercapacitor storage
- Use of the SC-converter to recharge the battery

- Battery charging power and usable energy content to be determined in additional analysis.

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Horizon 2020 Programme

This project has received funding from the European Union's Horizon 2020 research an innovation programme under grant agreement No 636012