Charging infrastructure planning

Combination of opportunity and overnight charging, experiences from Gothenburg Sweden

Gunnar Ohlin
Programme Manager Electrification, Lindholmen Science Park
Coordinator of the ElectriCity cooperation in Gothenburg, Sweden
https://www.electricitygoteborg.se/

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E-bus evolution in Gothenburg

2010

Hybrid Buses

2013

Plug In Hybrid Buses

2015

Full Electric Buses

2018

High Capacity E-Buses

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Alternative ways to charge e-buses

1. Depot charging
2. Opportunity charging
3. Dynamic charging, for example via overhead catenary wire system (trolley buses)

This presentation focusses on 1 and 2 and a combination of the two.

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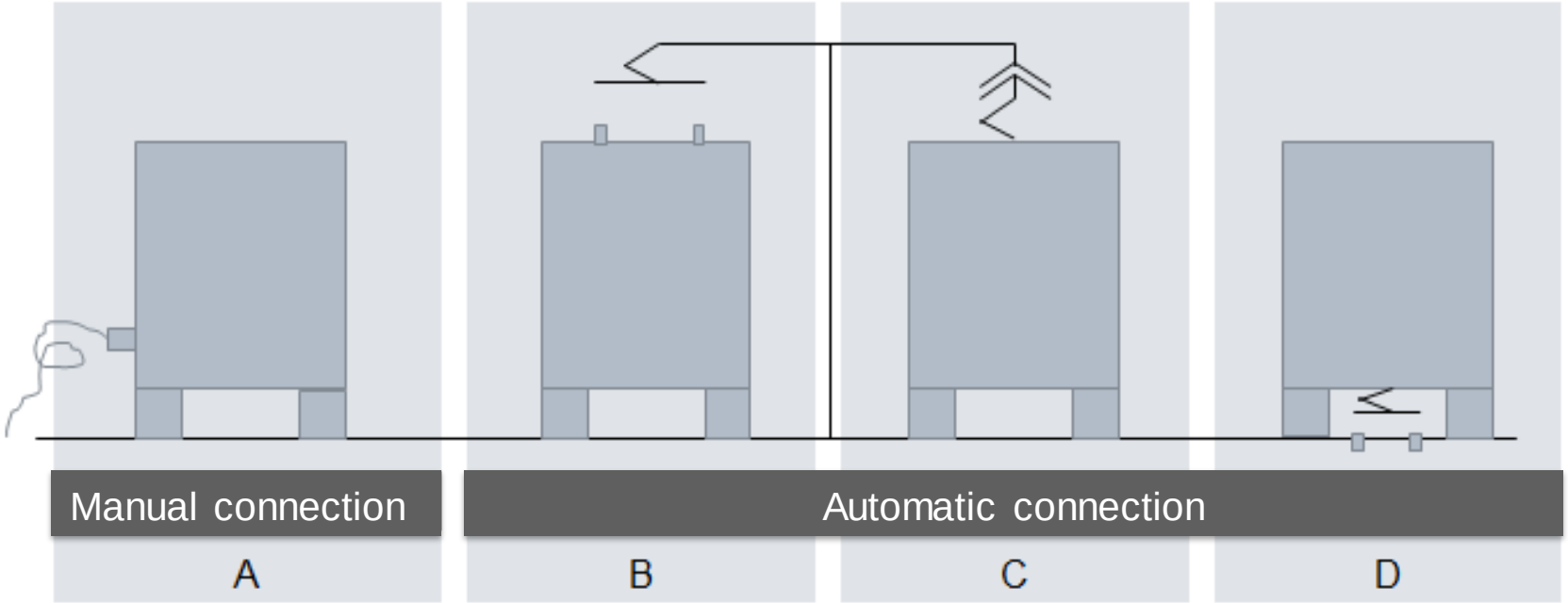
Alternative ways to connect charger to vehicle



Source: Cenelec (European Committee for Electrotechnical Standardization)

1. Manual connection – mainly for use in depot
2. Automatic connection – opportunity charging on route but also applicable in depot

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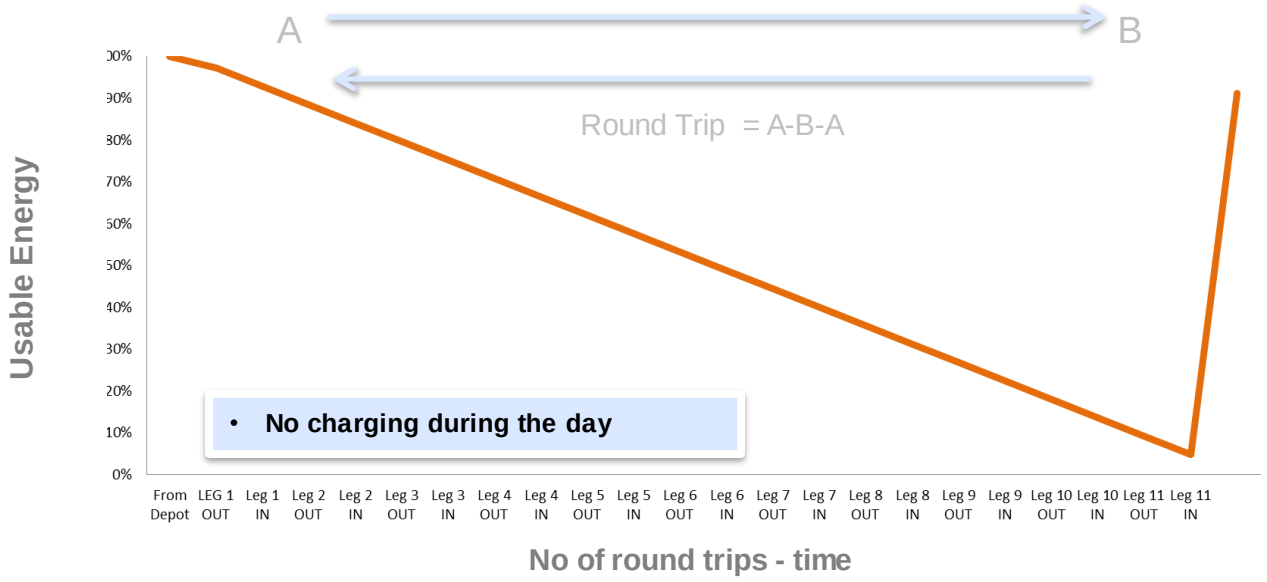
Depot charging - fundamentals

1. Charging over night or during longer breaks, especially between peak hours
2. Charging at lower power levels, normally below 100 kW, and over longer time
3. Large batteries
4. High and centralised power need in the depot, typically during the night



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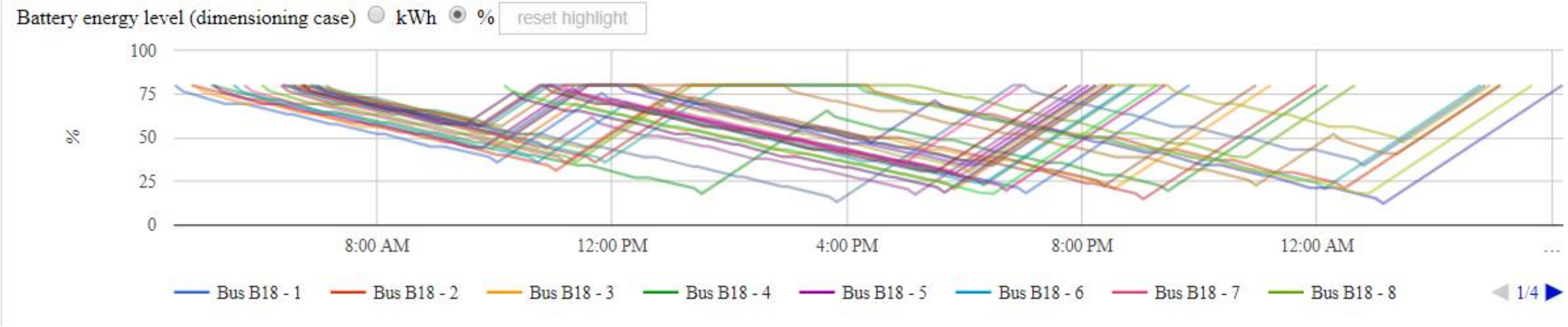
Deopt charging – fleet simulation



Each line represents SoC - State of Charge of one bus.

- *Charging once or twice in the depot during the day reduces battery size*
- *Location of depot close to where the buses operate is <u>critical</u>*
- *No need of charging outside depot – flexibility in operation, easy to plan*

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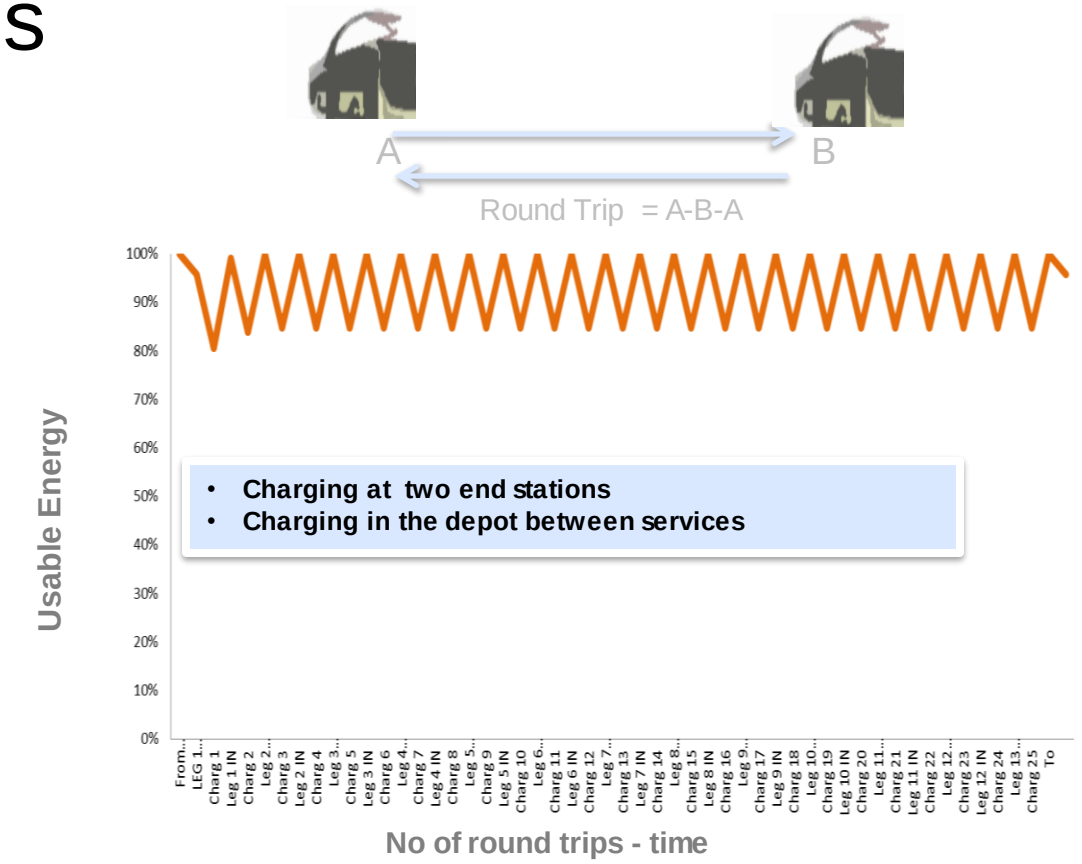
Opportunity charging - fundamentals

1. Charging at end stations during short breaks or close to end stations during longer driver/vehicle breaks
2. Charging at higher power levels, up to 450 kW
3. Smaller batteries
4. Most of the power supplied to the vehicle while in operation outside depot, geographically distributed power need
5. Limited power need in the depot during the night



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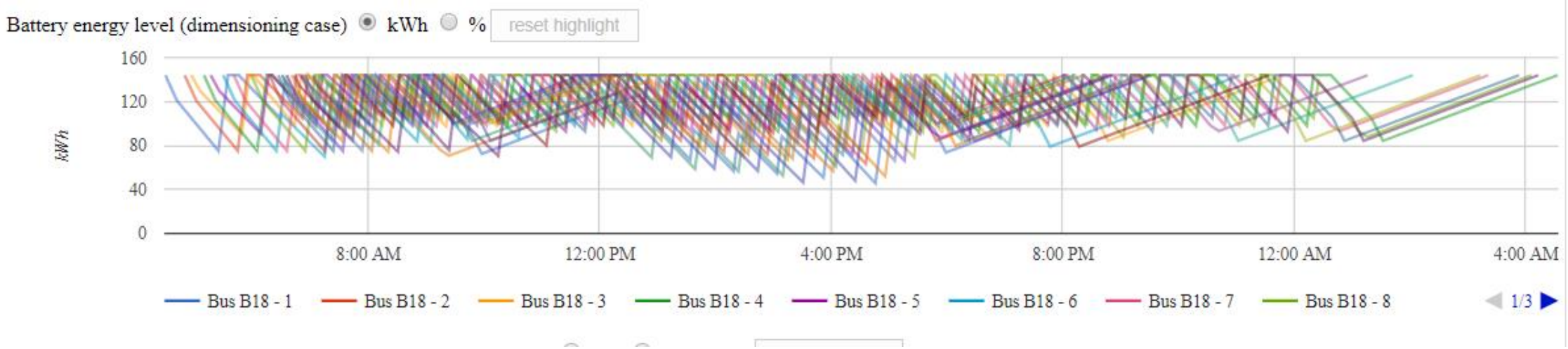
Opportunity charging – fleet simulation



- *Suitable for example when depot is too far from where buses shall operate*
- *More complex to operate, less flexibility in operation*
- *Technically possible to run 24/7*

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E-bus use cases in Gothenburg

1. 2015 ElectriCity Demonstration Arena – Route 55
2. 2018 ElectriCity Demonstration Arena – Route 16

3. 2019 Electric buses on bus route 60 – a busy city bus route
4. 2020 Large scale deployment with 145 high capacity articulated buses

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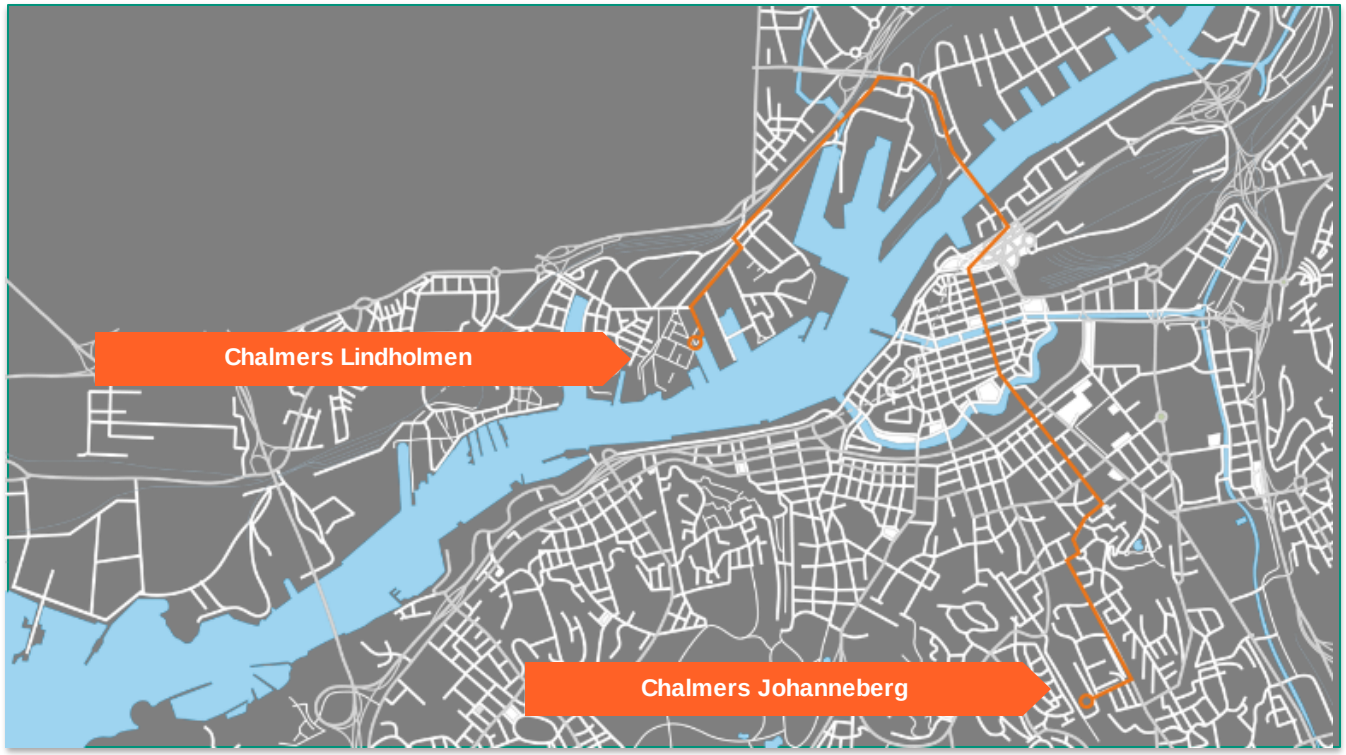
2015 ElectriCity Demonstration Arena – Route 55

- Connected two campuses: Chalmers Johanneberg and Chalmers Lindholmen
- A 7.6 km route passing through central Gothenburg
- Opportunity charging at each end stop
- Fast charging for 3-6 minutes, 300 kW OppCharge
- One bus every 10 minutes
- In operation between June 2015 and Dec 2020



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2015 ElectriCity Demo Arena – Route 55

Opportunity charging at each end stop – Indoor bus stop with high power charger

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2018 ElectriCity Demonstration Arena – Route 16

- High capacity articulated buses – 18.7 m
- Opportunity charging at end stops
- Charging power up to 450 kW
- Limited charging during peak hours – larger batteries
- Increased charging time between peak hours
- In operation June 2018 – Dec 2020

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2019 Electric buses on bus route 60 – a busy city bus route

- 8.5 km long bus route with one bus every 4-6 minutes
- 30 buses in operation (including routes 59, 60, 62)
- 4 opportunity charging stations, 3 at end stations + 1 in depot
- Combination of low power AC charging <u>and</u> high power DC charging with automatic connection in the depot

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2020 Dec - Large scale deployment

- 145 high capacity articulated buses
- 34 bus routes
- 19 opportunity charging stations
- 4 depots

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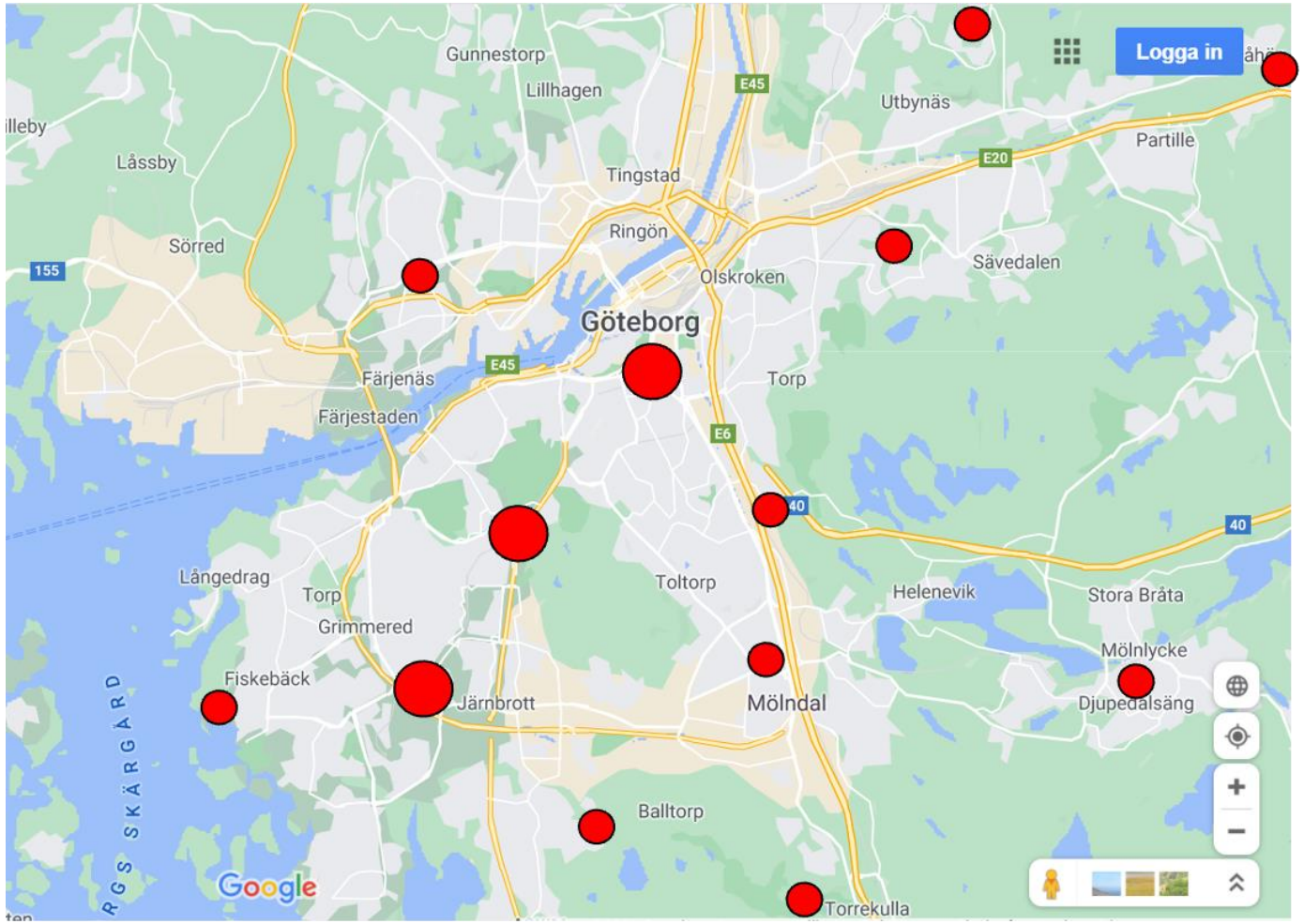
2020 Large scale deployment

- Opportunity charging at end stops
- Opportunity charging close to bus operation during longer breaks
- Depot charging with 60/120 kW

Opportunity charging to minimize productivity losses when the depot location is too far from where the buses operate.



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2020 Large scale deployment

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Which strategy is the best? No simple answer

Depot charging

+ More similar to diesel operation
+ Depot installation normally less complicated
+ Not route dependent

- Range limitation, more usable energy onboard required
- High power requirement in single location
- Redundancy aspect – all charging at the depot

Opportunity charging/Charging on route

+ No daily range limitation, can run ”24/7”
+ Less usable energy may be required onboard
+ Power and energy need is distributed

- Installation and construction in public environment
- Maintenance
- Route dependent

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Overall trend

- Depot charging is increasing in preference
- Opportunity charging have its merits and is the preferred solution in some cities
- A combination of charging strategies may be a good solution, for example low and high power charging in the depot via pantograph and micro depots close to where buses operate to reduce productivity losses

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Thank you for listening!

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