



Holistic TCO-Based Optimization for Mixed ICEV/BEV/FCEV Heavy-Duty Fleet Operations

Theo Koch, Lutz Eckstein

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Institute for Automotive Engineering (ika)
RWTH Aachen University

BEV



Mercedes
eActros



Scania
45 R BEV



MAN
eTGX



IVECO
S-eWay



Volvo
FH Electric



DAF
XF Electric



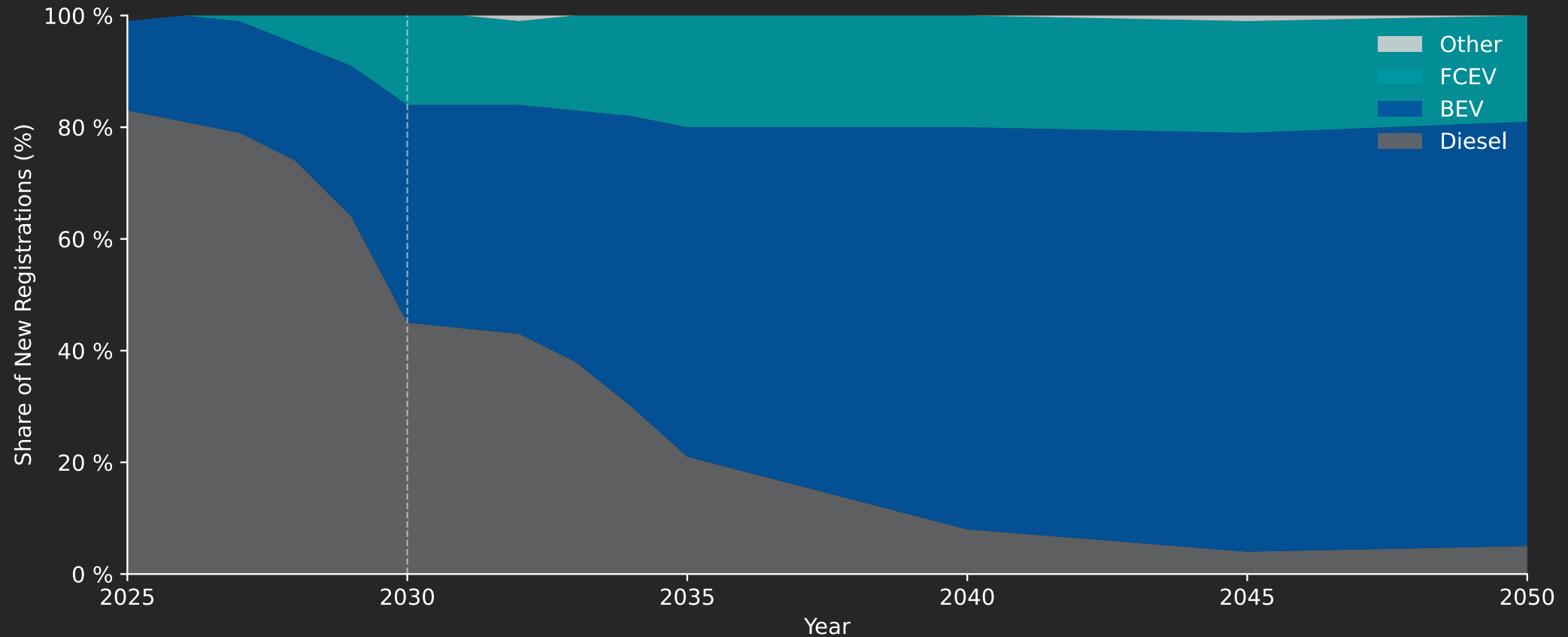
Renault
E-Tech T

FCEV

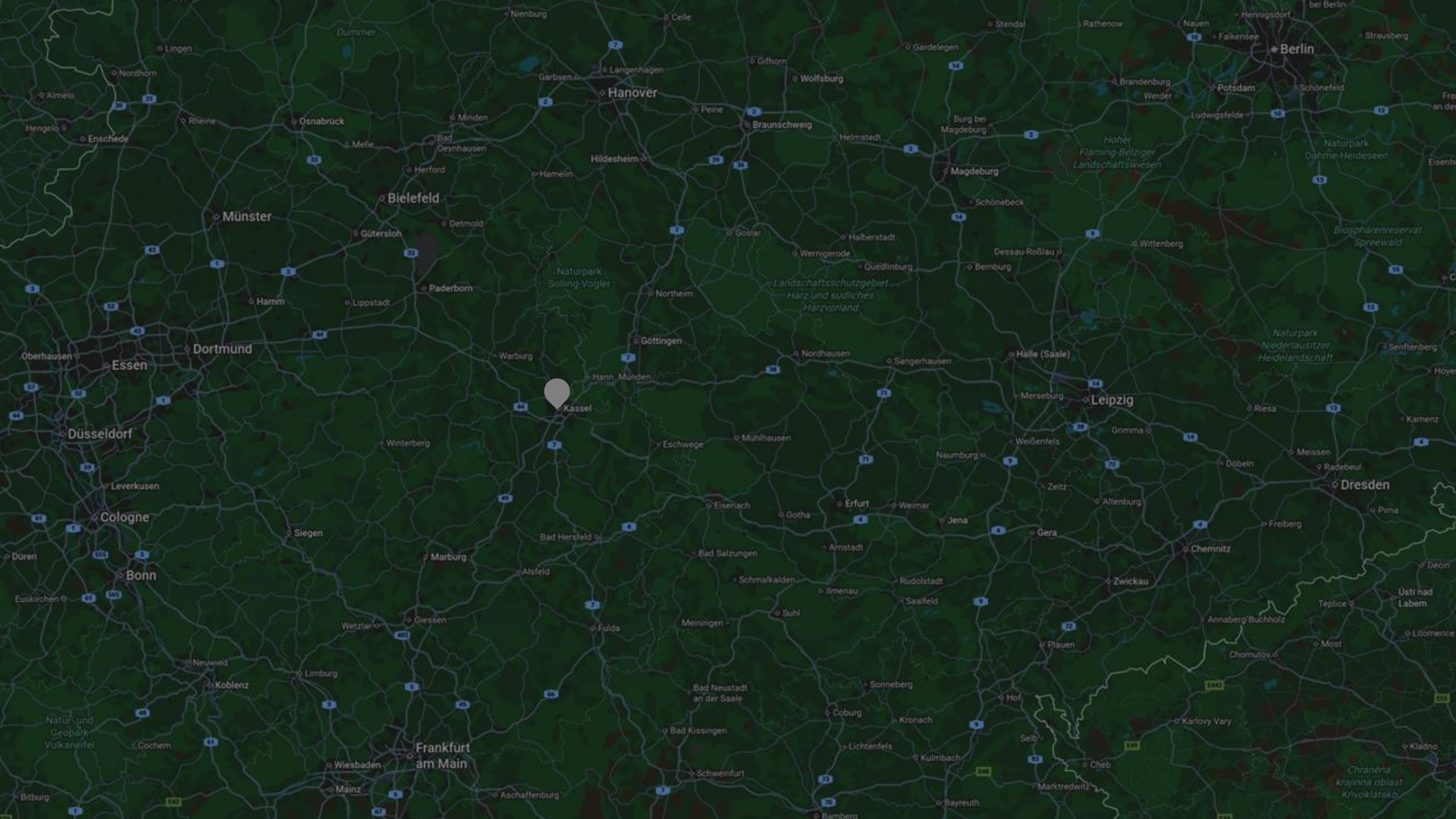


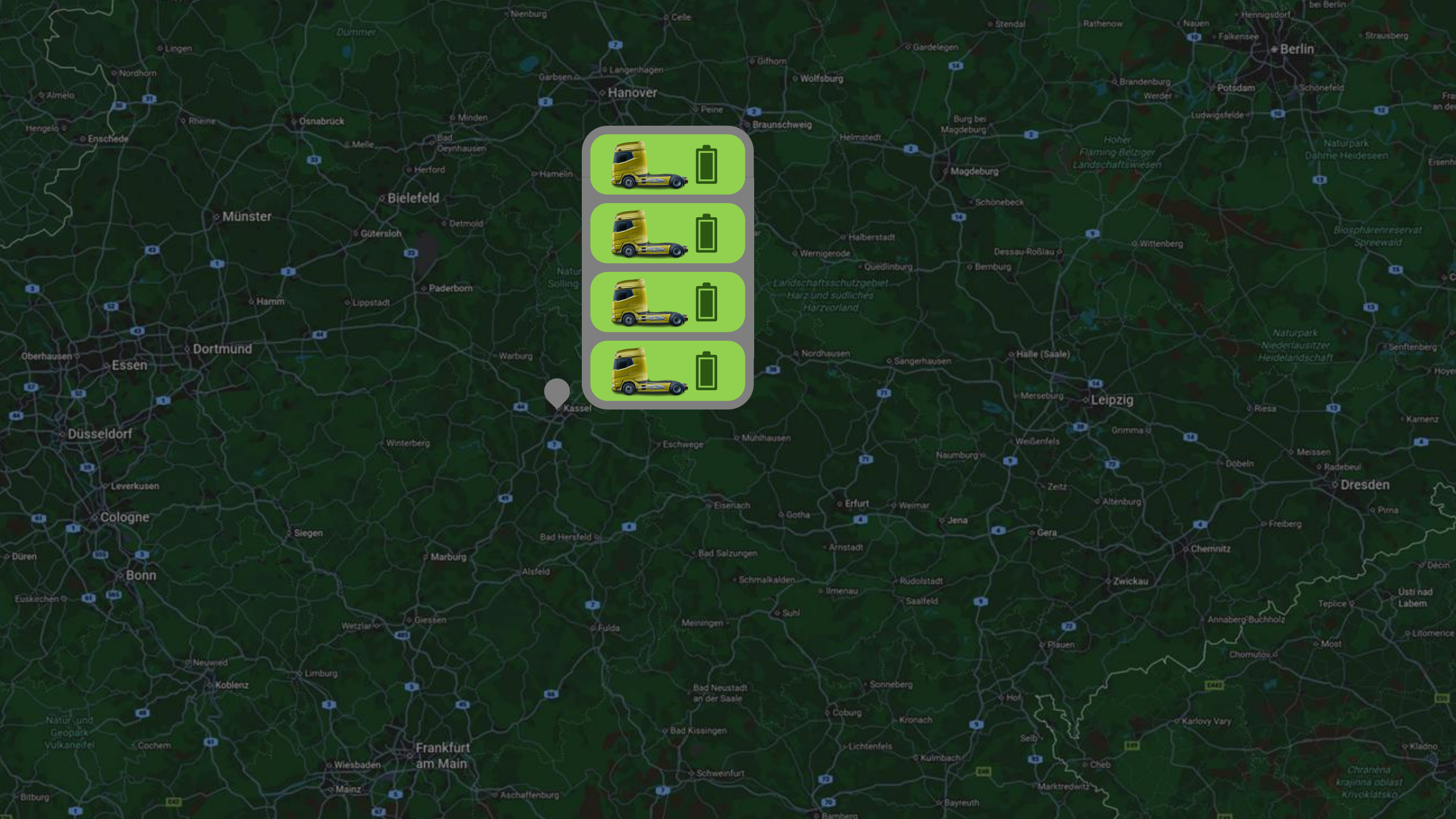
Mercedes
NextGenH2

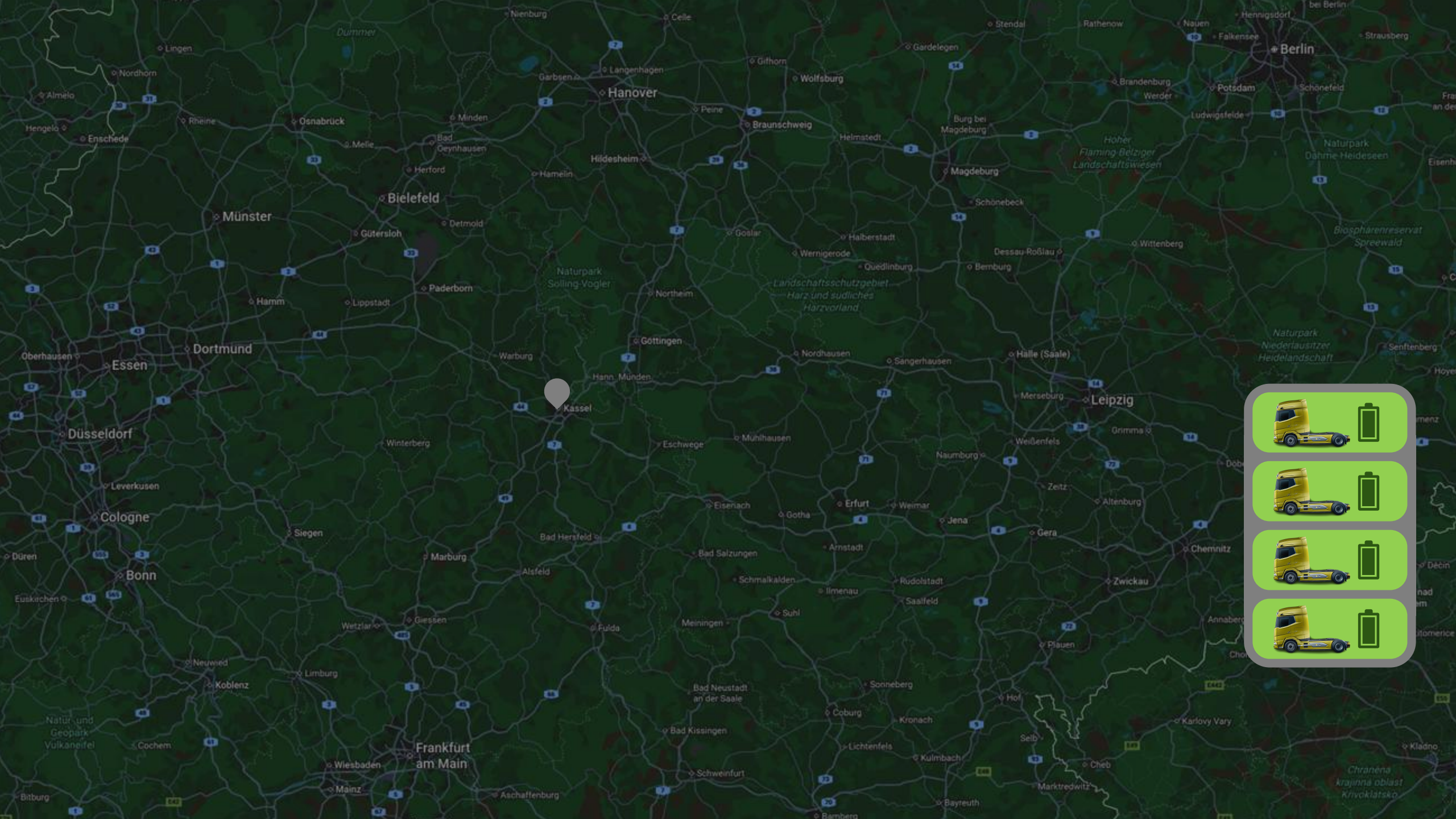
Projected powertrain distribution of new truck registrations >12 t gross vehicle weight, including rigid trucks and tractor-trailers, in MMS and MWMS



For a fixed fleet operator's order book, how do fleet composition and prospective techno-economic developments affect the operational feasibility and total cost of mixed ICEV / BEV / FCEV fleet operation?





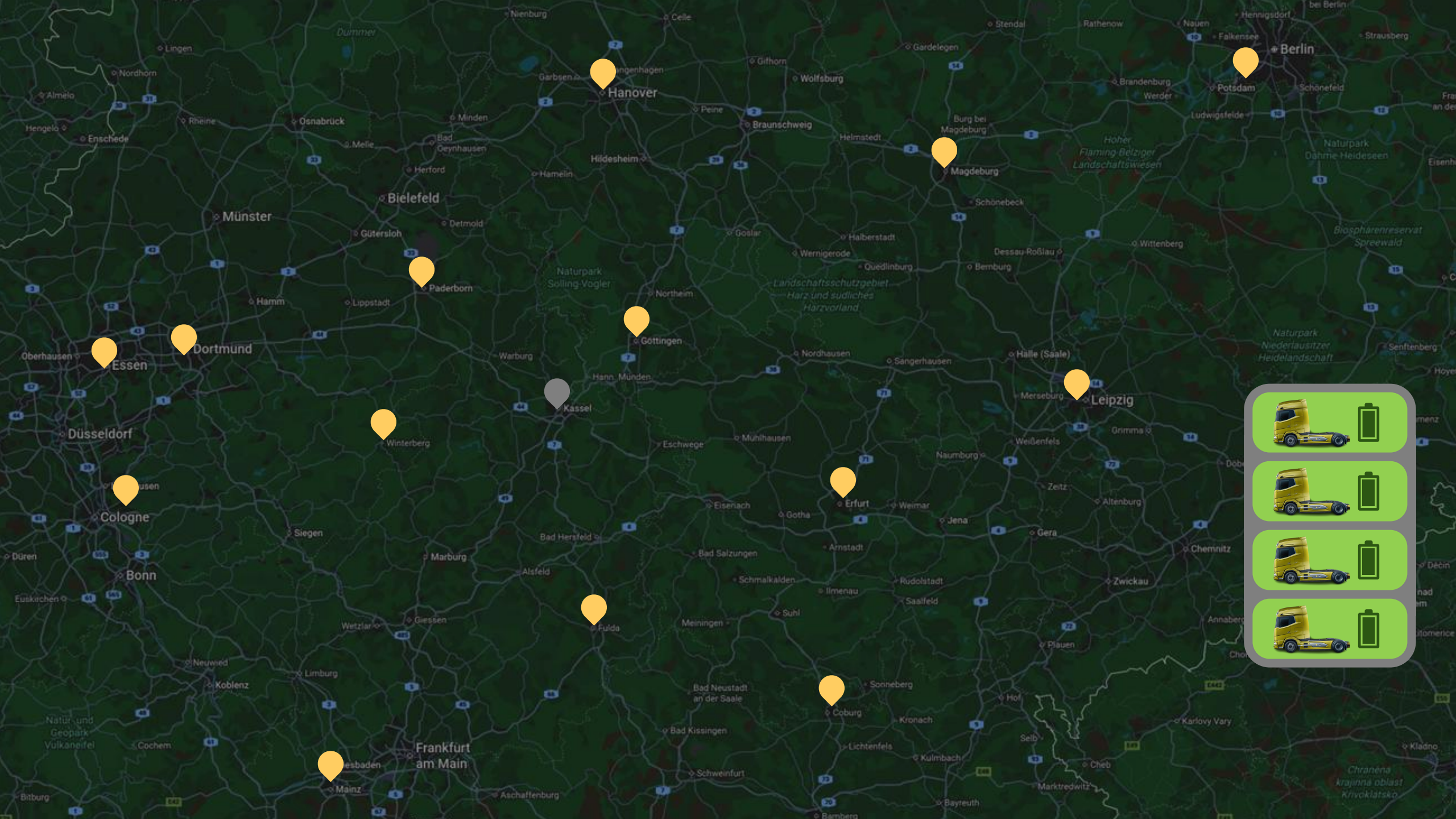










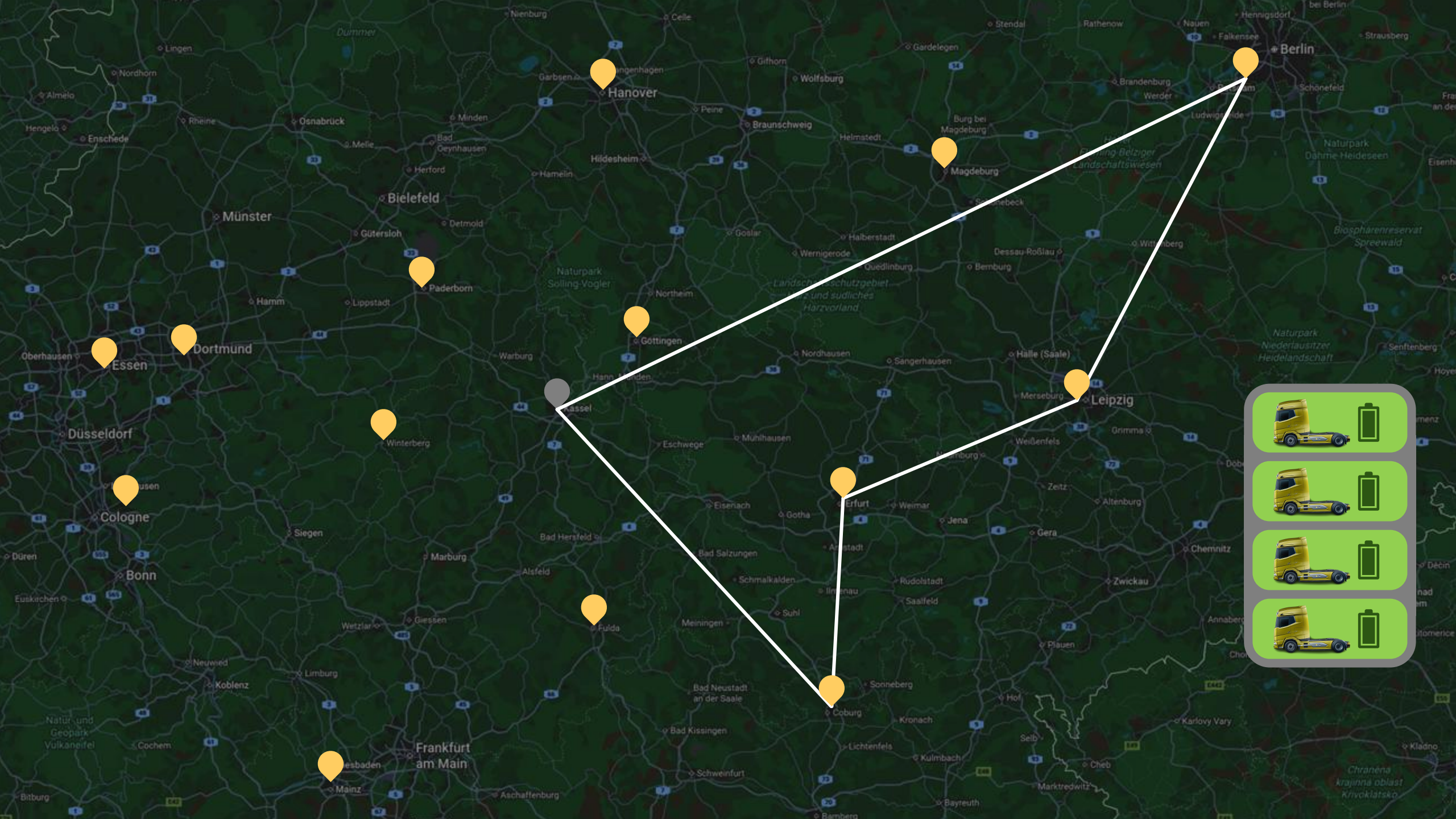


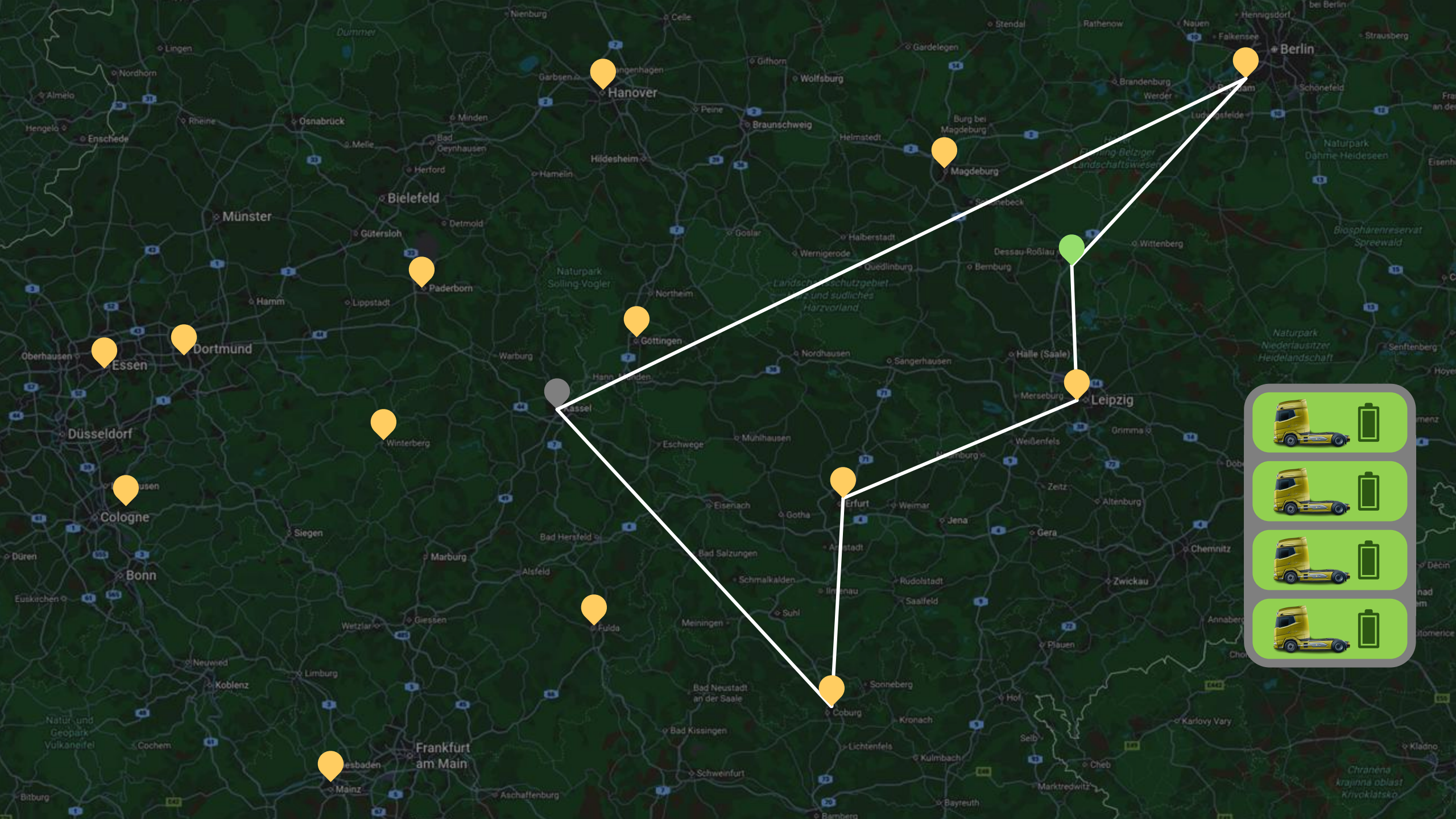










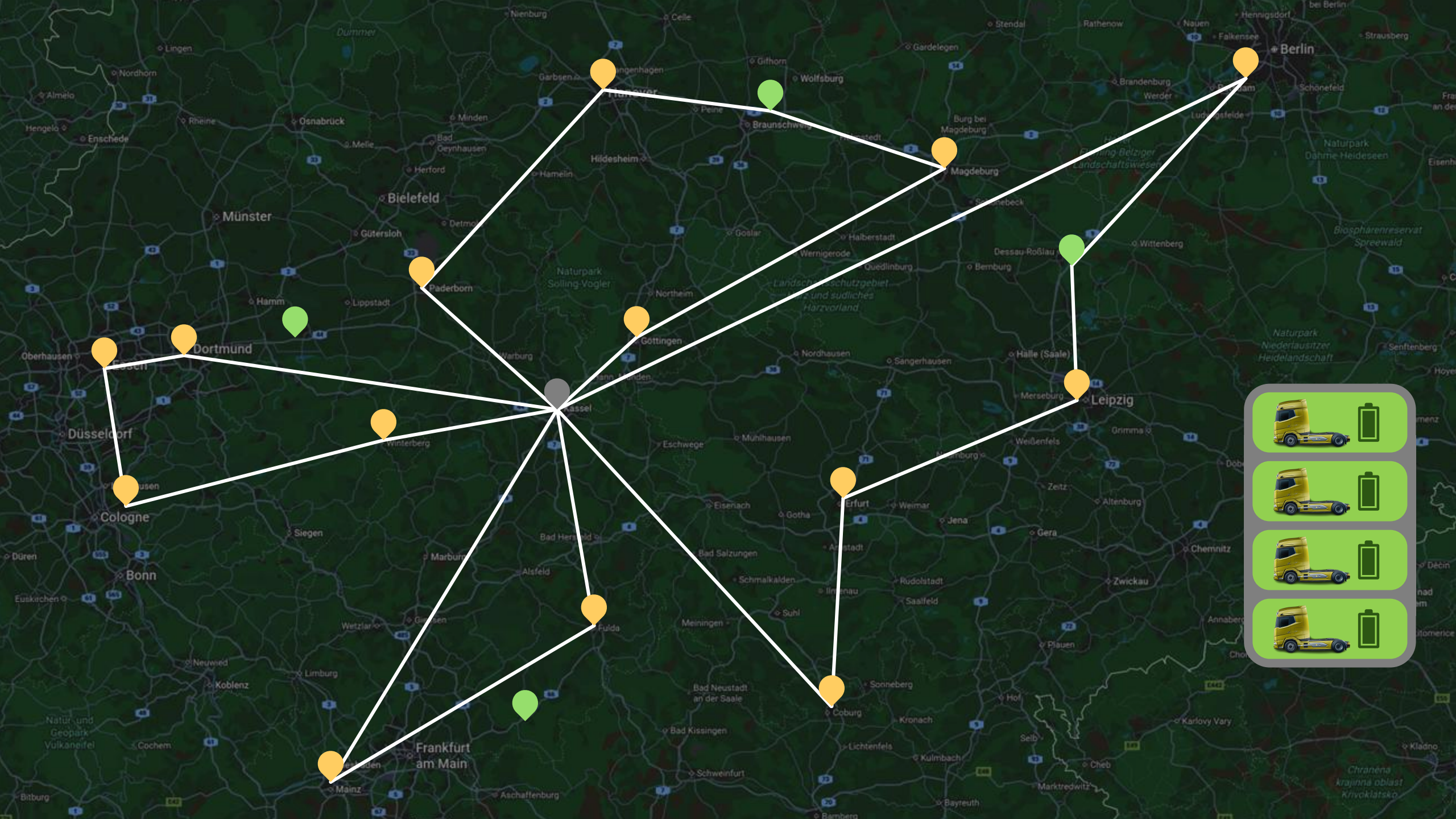




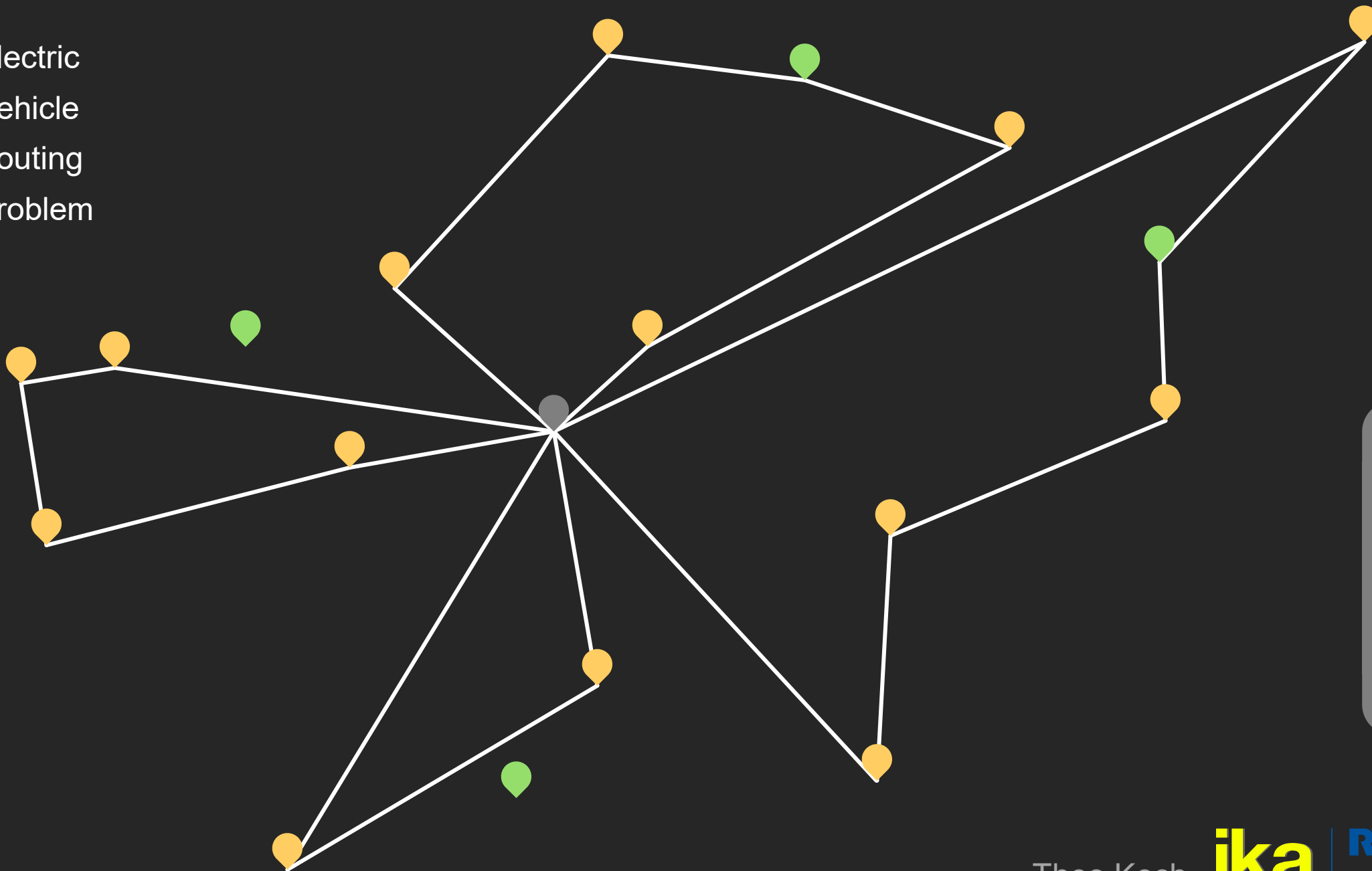




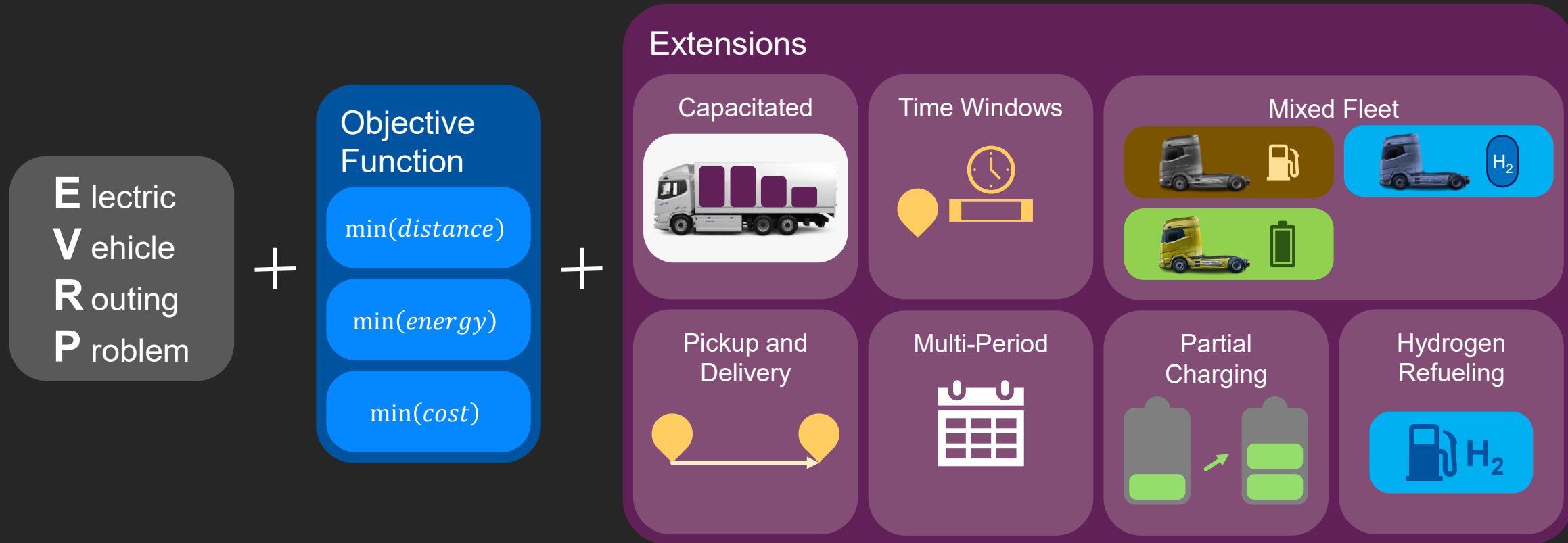




Electric
Vehicle
Routing
Problem



Electric
Vehicle
Routing
Problem



Exact Methods

Pros

- Guarantee optimal solution
- Provable bounds on solution quality

Cons

- Computationally expensive
- Struggle with complexity

Best for

- Small instances
- Benchmarking

Metaheuristic Methods

Pros

- Good balance of quality and speed
- Can escape local minima

Cons

- No optimality guarantee
- Require parameter tuning
- Stochastic (results vary)

Best for

- Large-scale real-world problems
- Complex constraints

Heuristic Methods

Pros

- Fast execution
- Simple to implement

Cons

- No solution quality guarantee
- Problem-specific design needed

Best for

- Initial solution generation
- Real-time decisions

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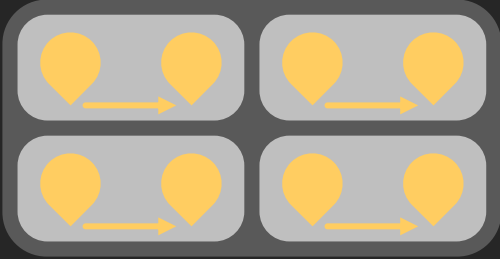
Implementation Framework



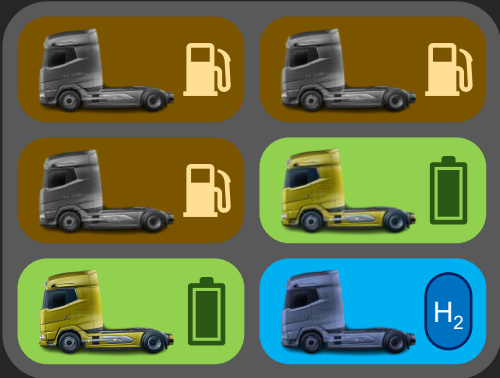
Locations



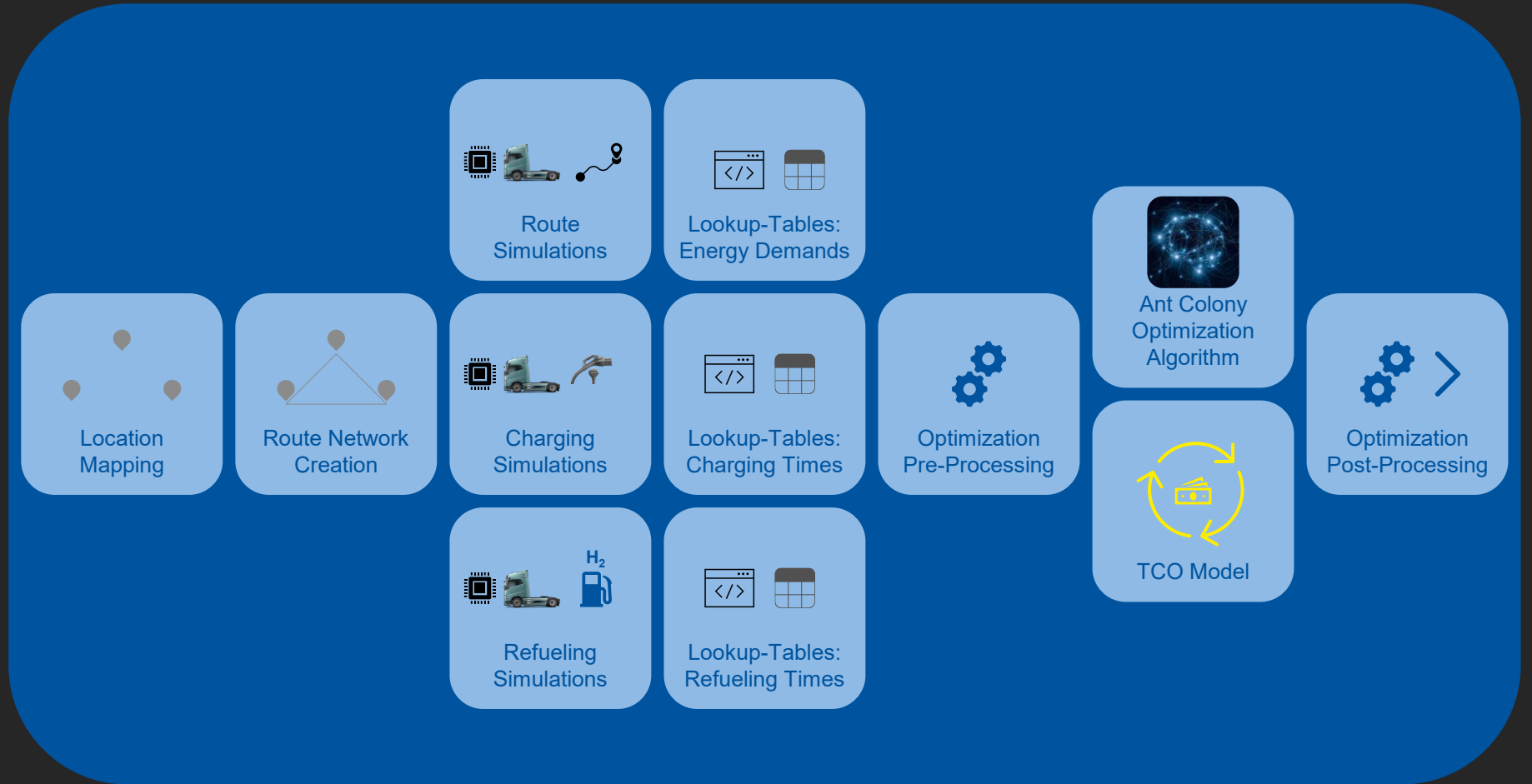
Orders



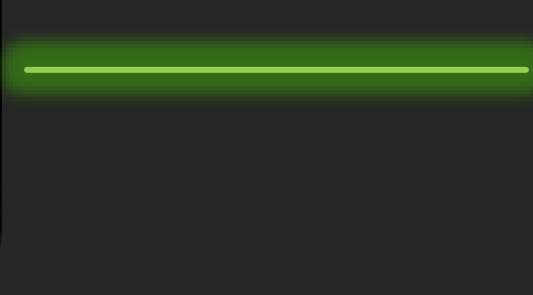
Vehicles



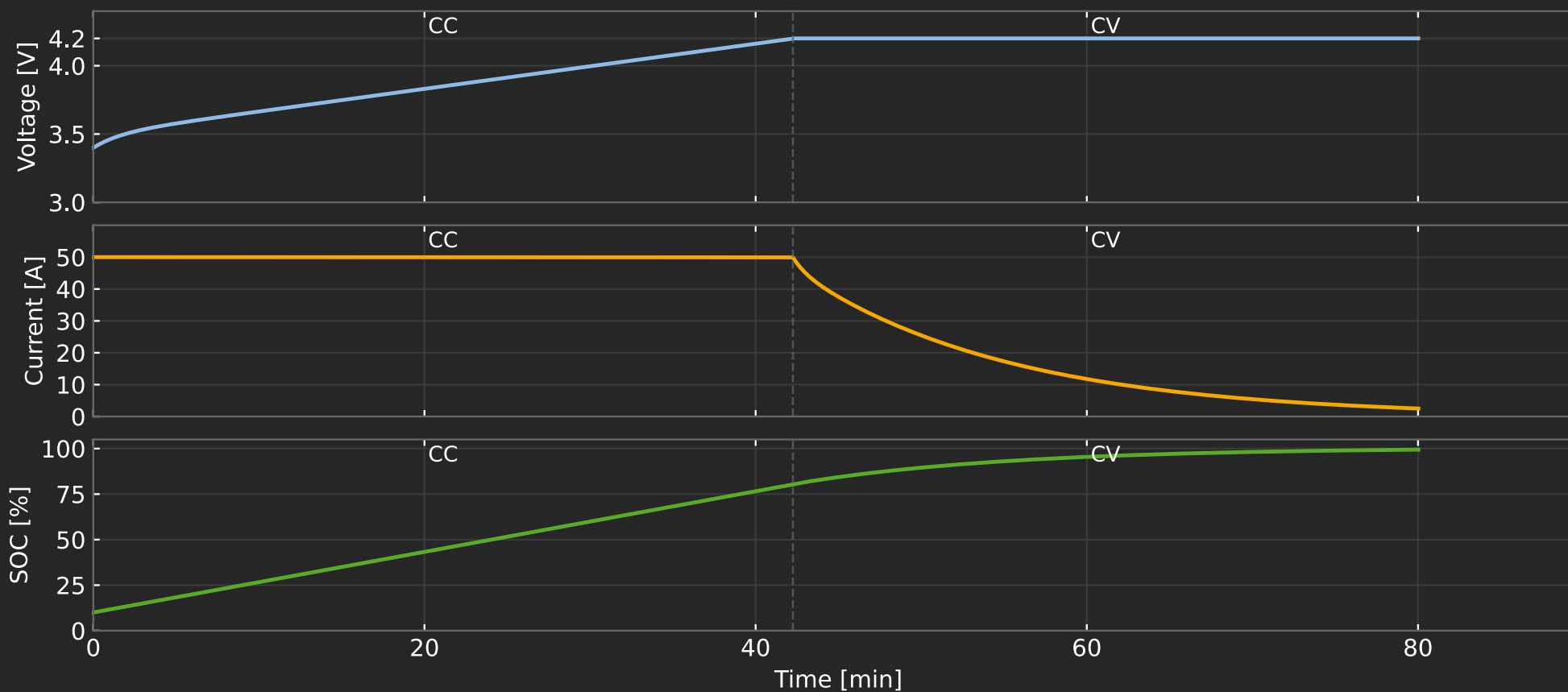
Implementation Framework

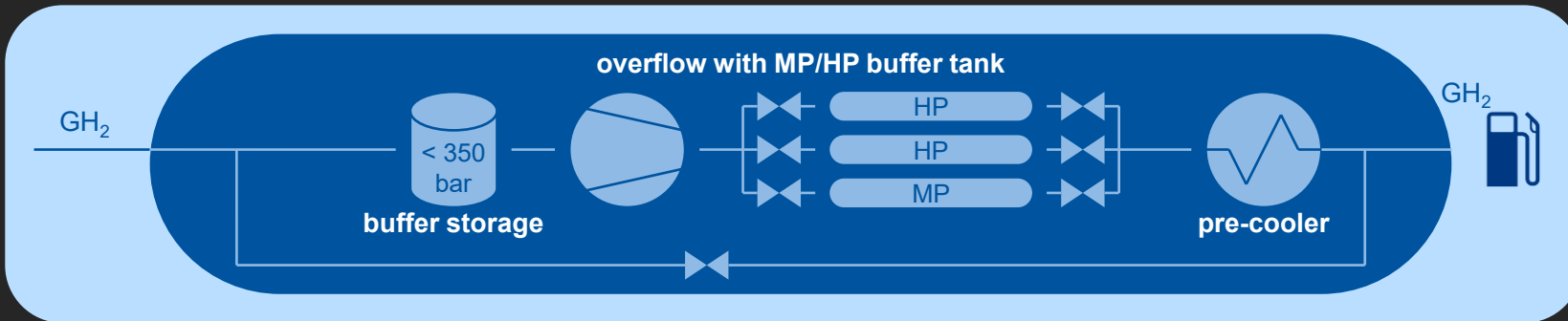


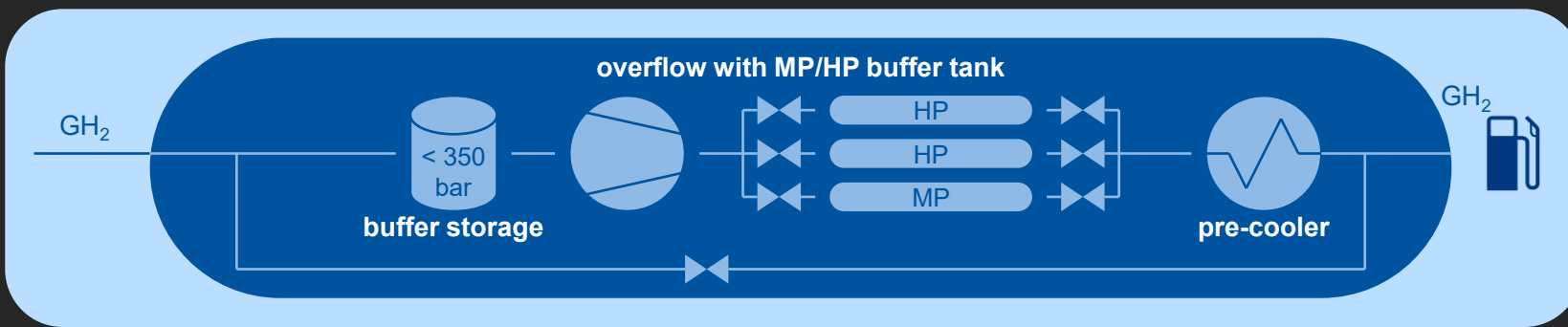




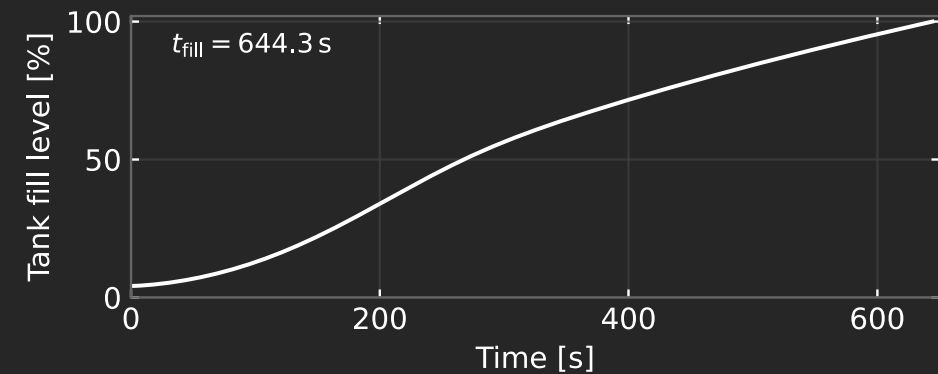
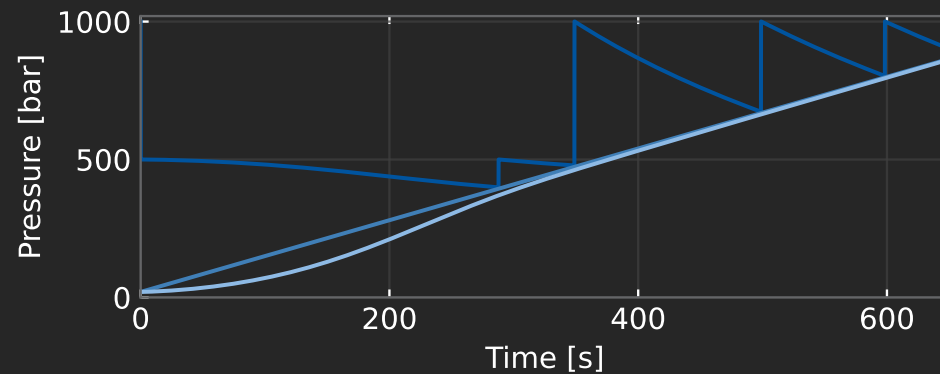
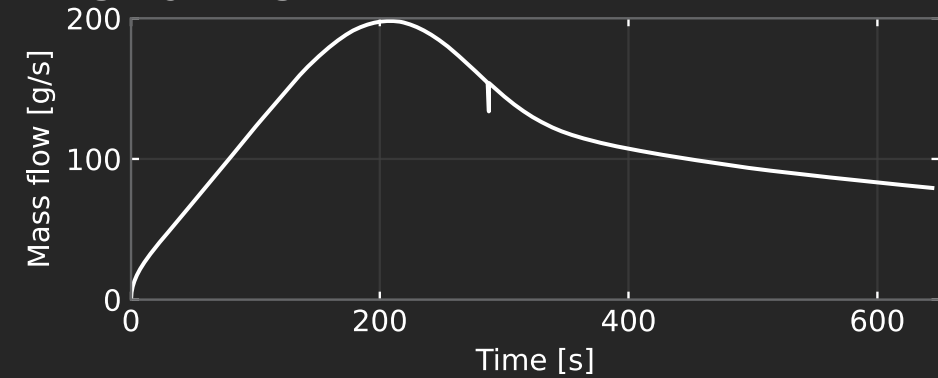
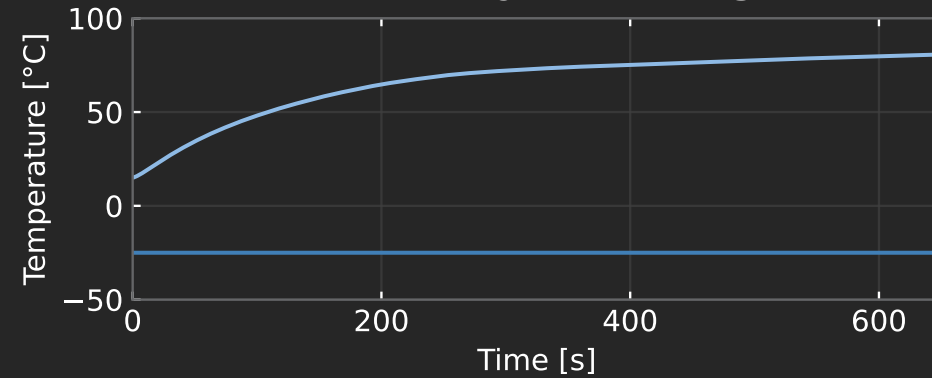
Typical Constant Current – Constant Voltage (CC – CV) Charging Profile



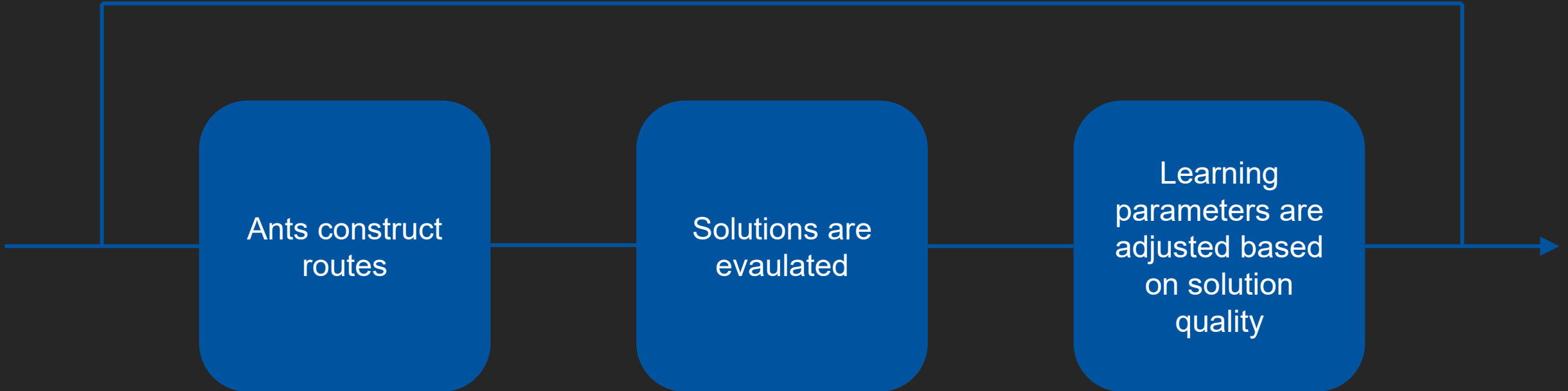




Exemplary Refueling Process with 85 kg Hydrogen Transferred



— Station storage — Dispenser — Vehicle tank



Solutions are
evaluated

Total Costs per Vehicle

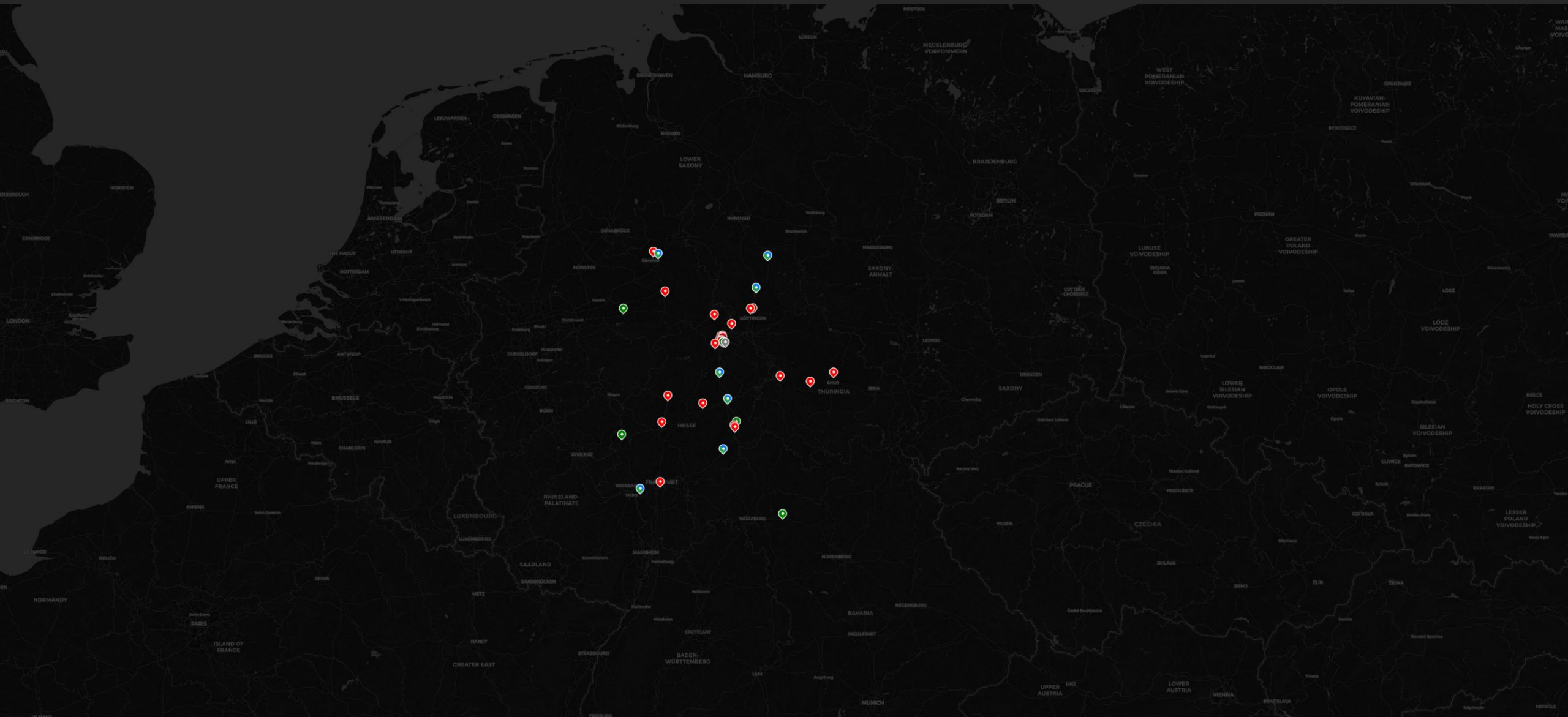
$$TC_v = C_{CAPEX} + C_{energy} + C_{toll} + C_{CO2} + C_{labor} + C_{insurance}$$

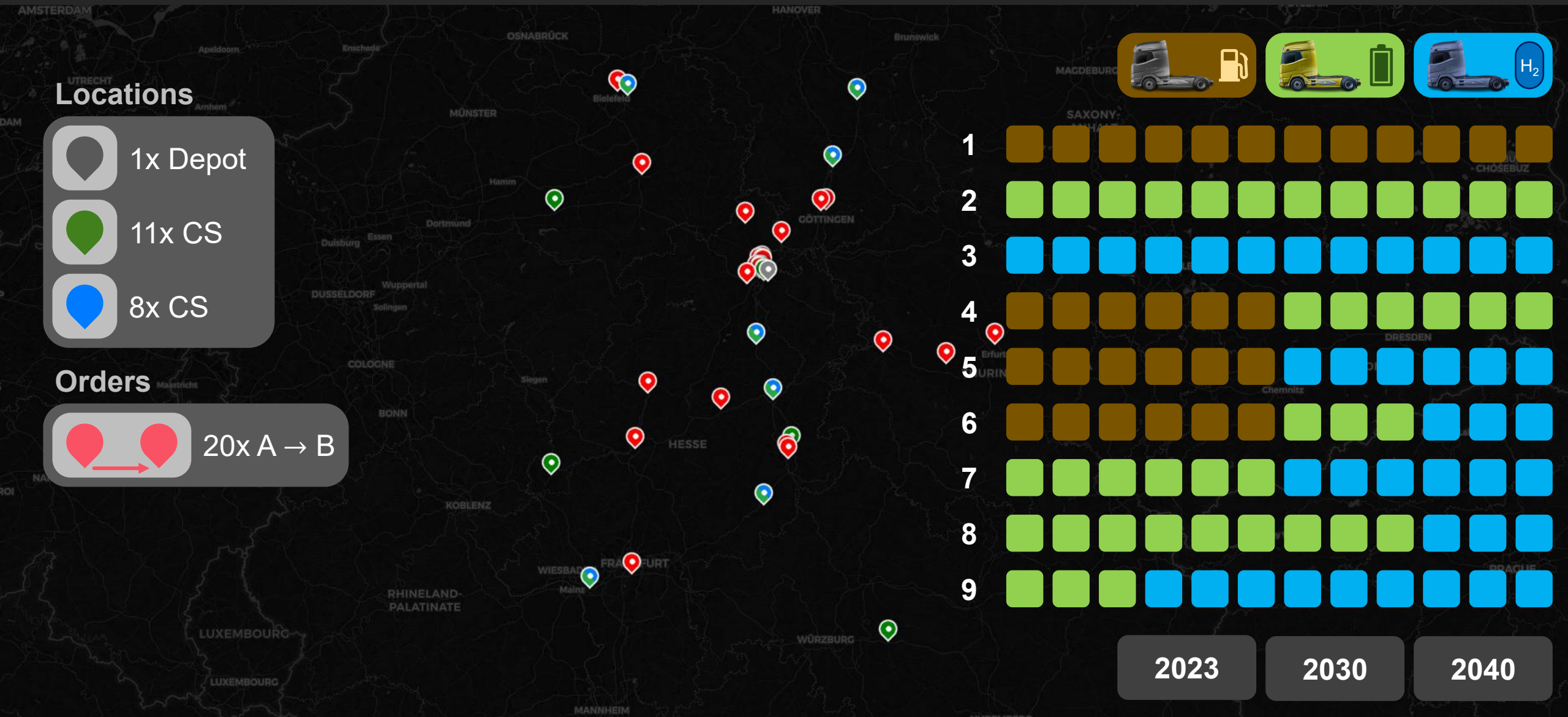
Total Costs

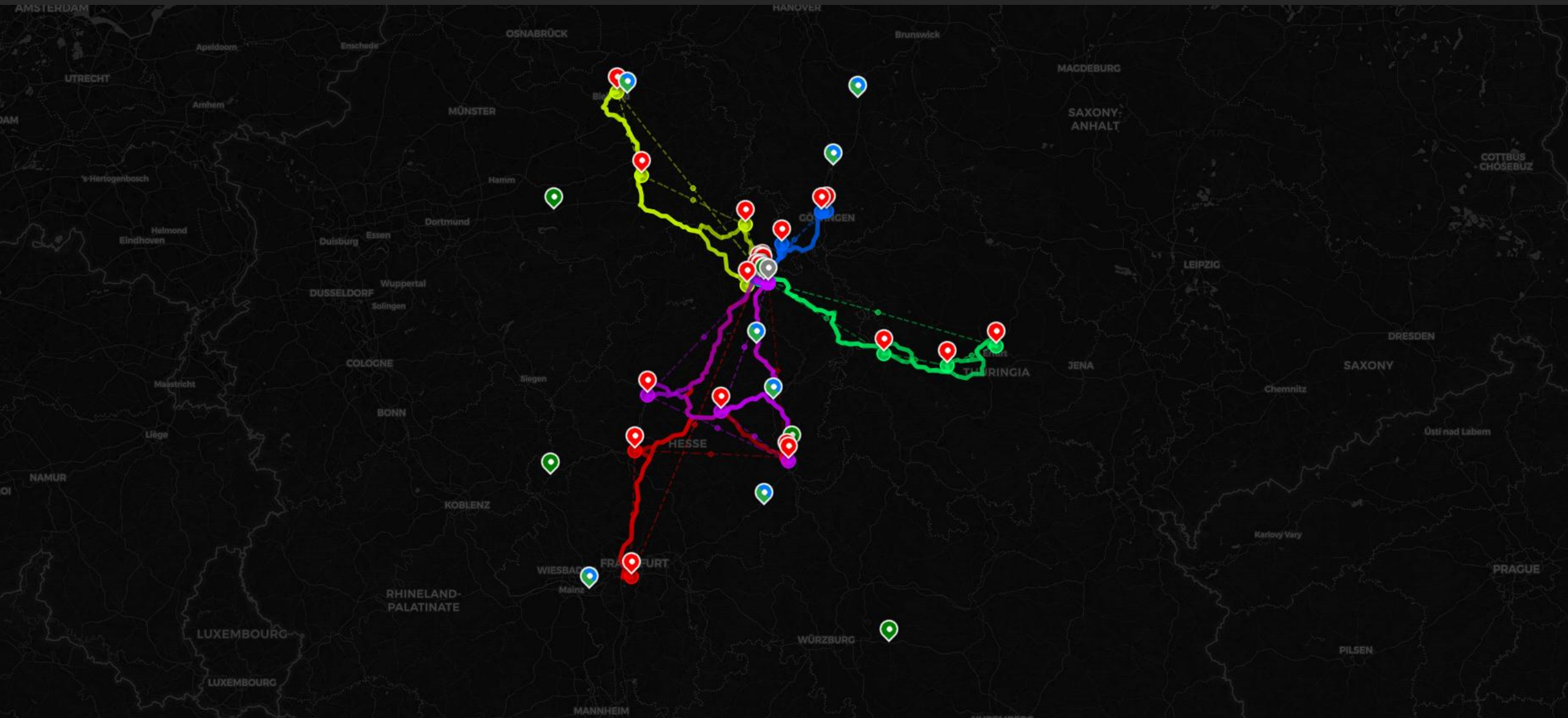
$$TC = \sum TC_v$$

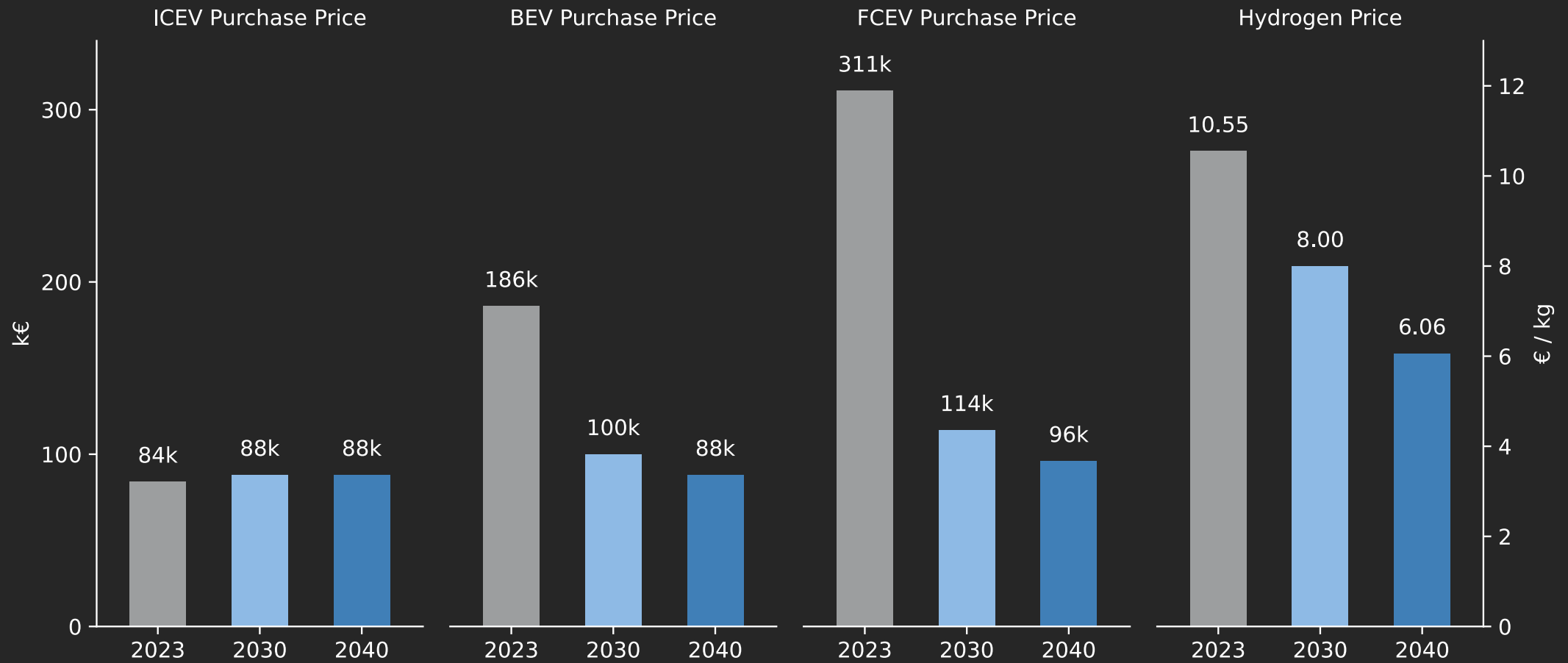
Objective Function Value

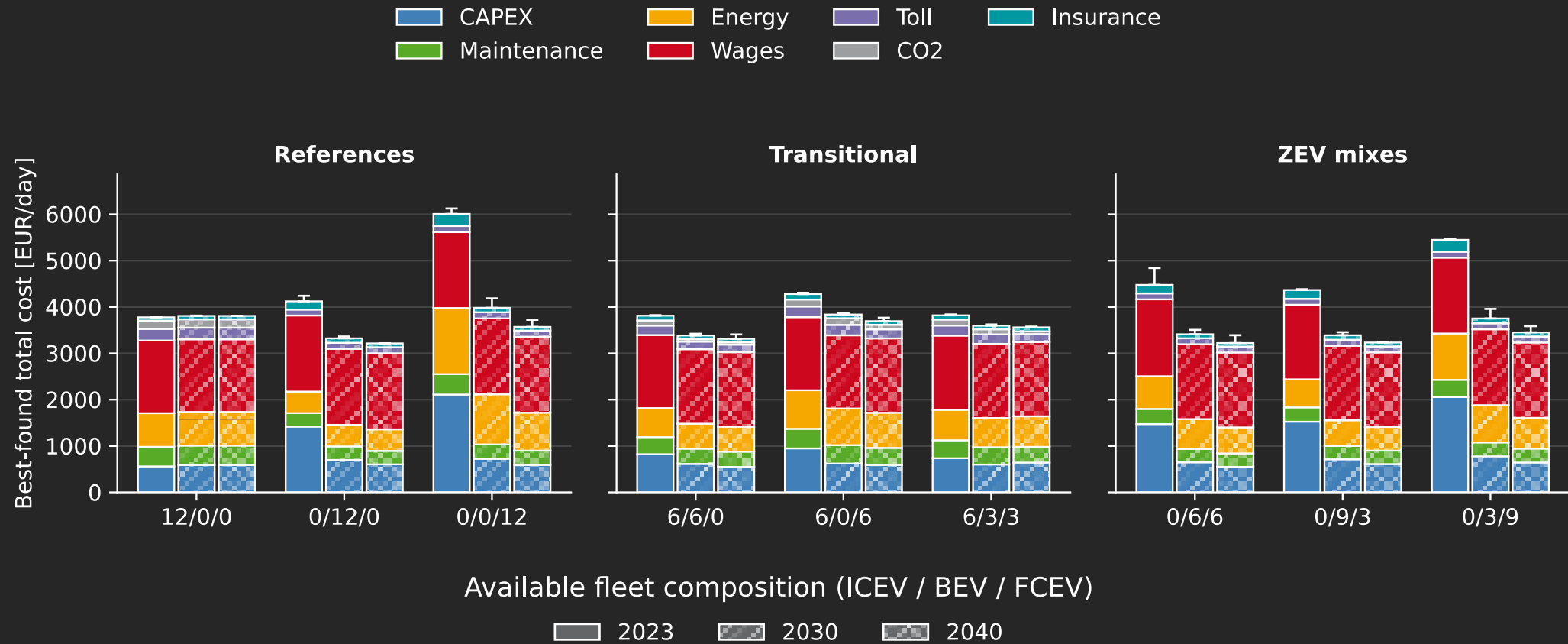
$$OFV = TC + C_{penalty}$$

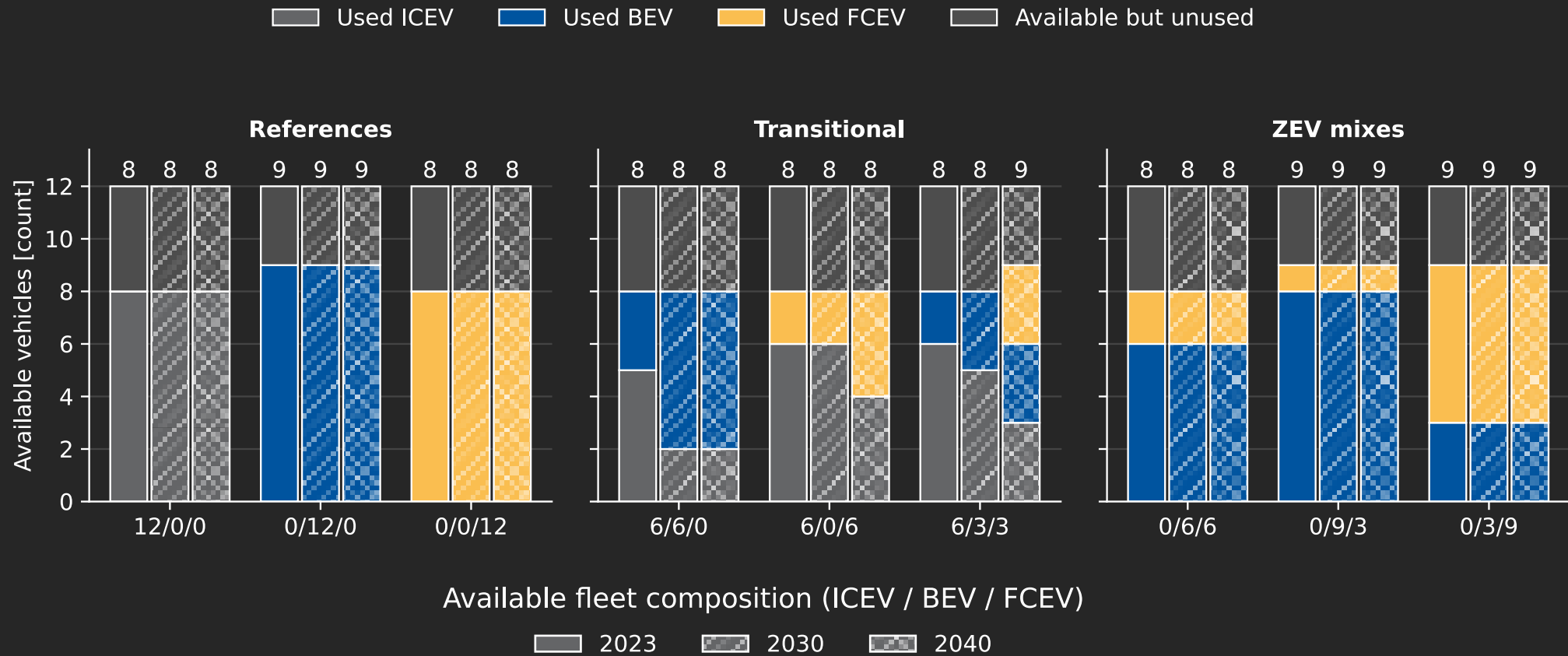


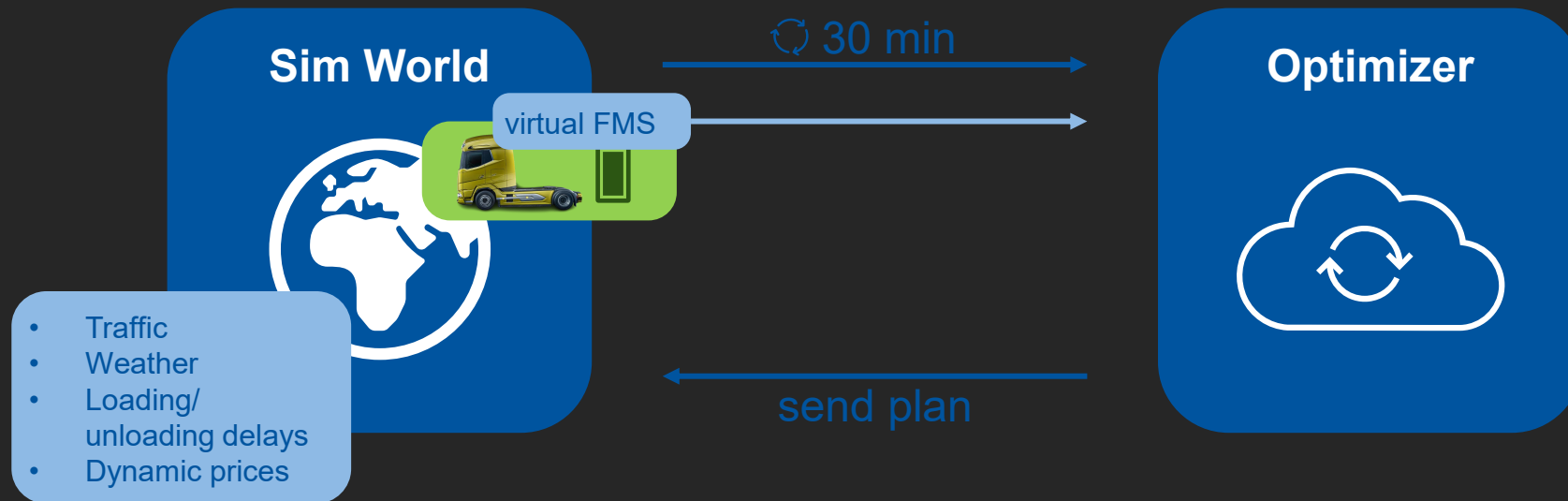




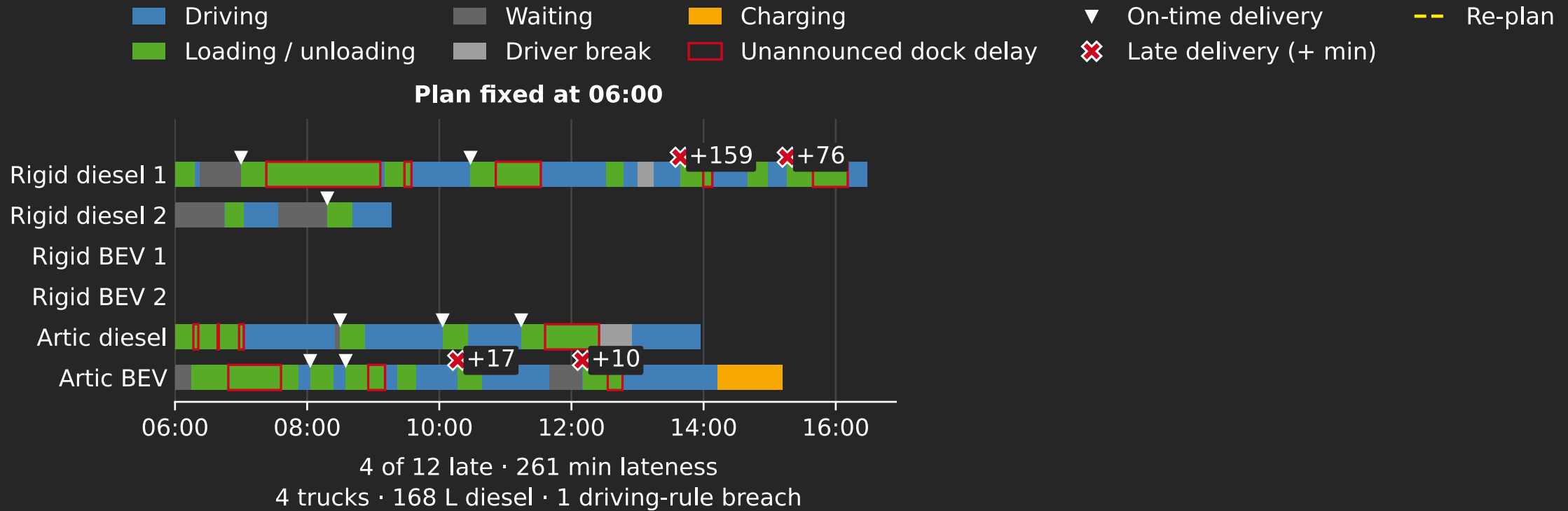








Same 06:00 plan, same day: heavy traffic and 5.4 h of unannounced dock delays



Thank you very much for your attention.

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Business Card

- [1] Hannah Förster u. a. Treibhausgas-Projektionen 2025 für Deutschland (Projektionsbericht 2025). Techn. Ber. Umweltbundesamt, 2025, S. 334. DOI: 10.60810/OPENUMWELT-7906.
URL: <https://openumwelt.de/entities/publication/aba5337a-4bb0-458d-adf8-e176d69194a9> (accessed on 01. 06. 2026)
- [2] Noll, B., del Val, S., Schmidt, T. S., Steffen, B.: Analyzing the competitiveness of low-carbon drive-technologies in road-freight: A total cost of ownership analysis in Europe. Applied Energy 306 (2022), pp. 118079
- [3] Basma, H., Rodriguez, F.: A total cost of ownership comparison of truck decarbonization pathways in Europe