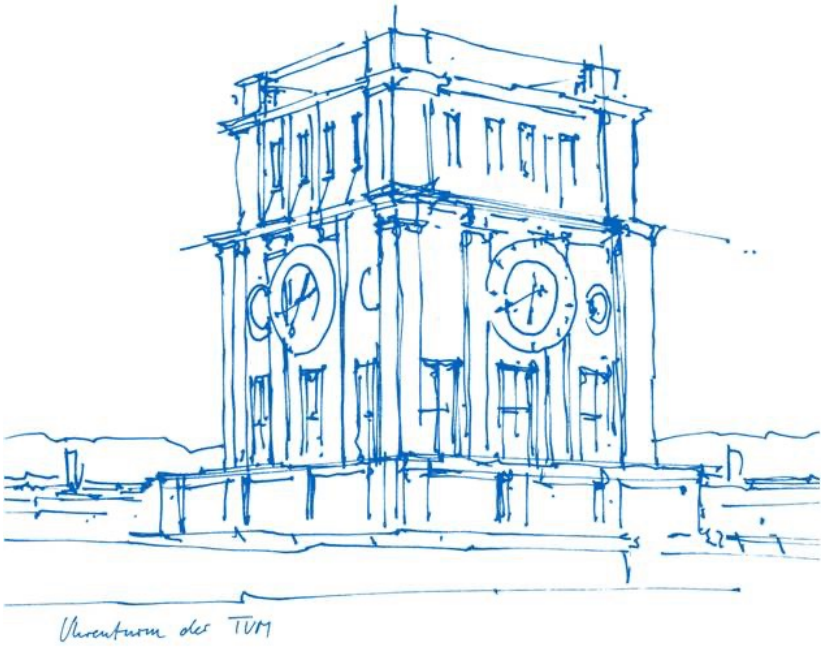
Strategy beats power:
Cooling system design for battery-electric long-haul trucks

Olaf Teichert

Oslo, 13 June 2022

EVS35
OSL2022



Motivation

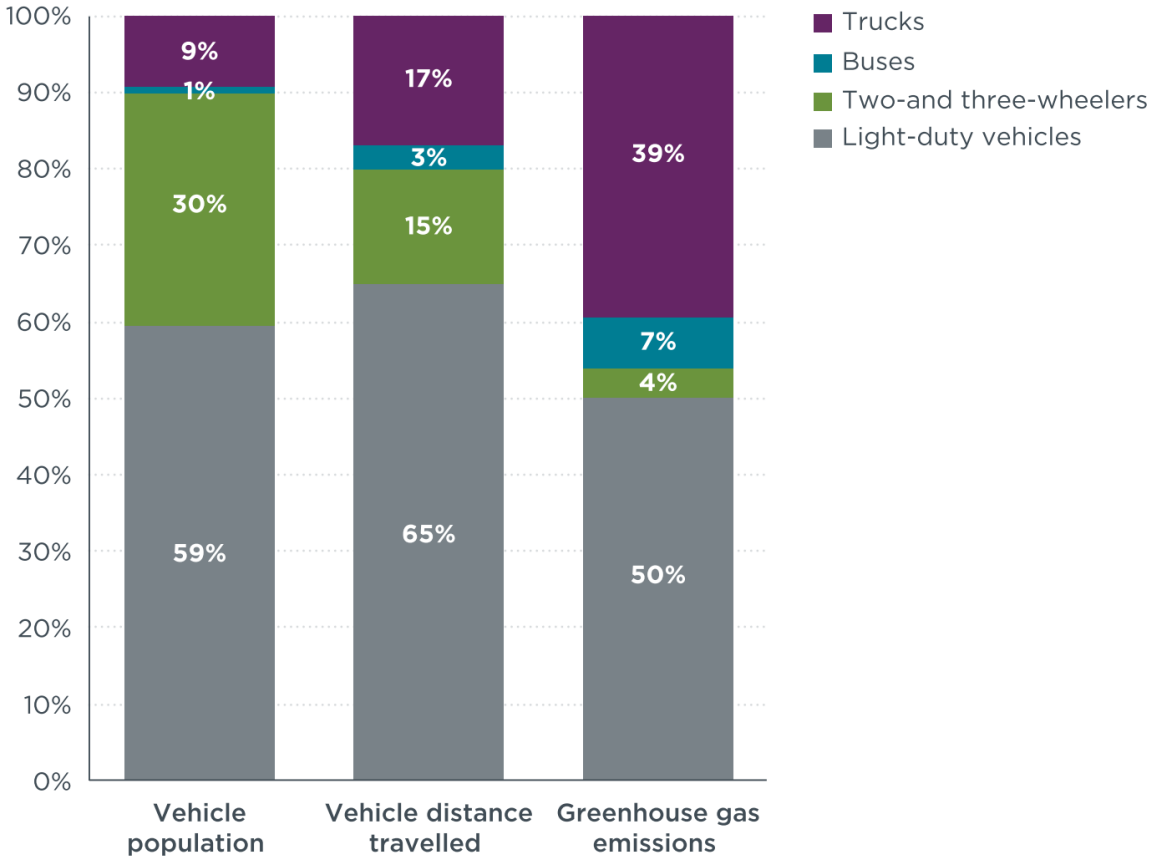
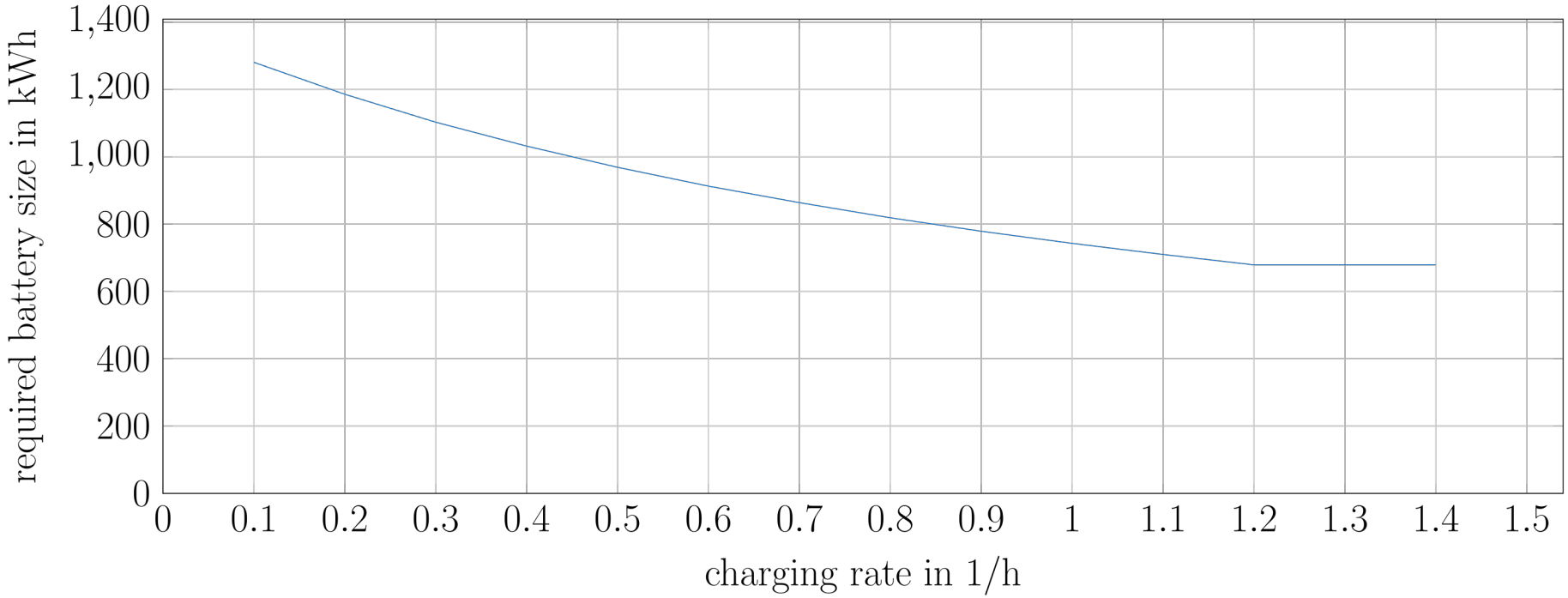


Figure 1. Global vehicle stock, distance traveled, and life-cycle road transport greenhouse gas emissions by vehicle type in 2015.

Source:
Moultak, Marissa, Nic Lutsey, and Dale Hall. "Transitioning to zero-emission heavy-duty freight vehicles." *Int. Counc. Clean Transp* (2017).

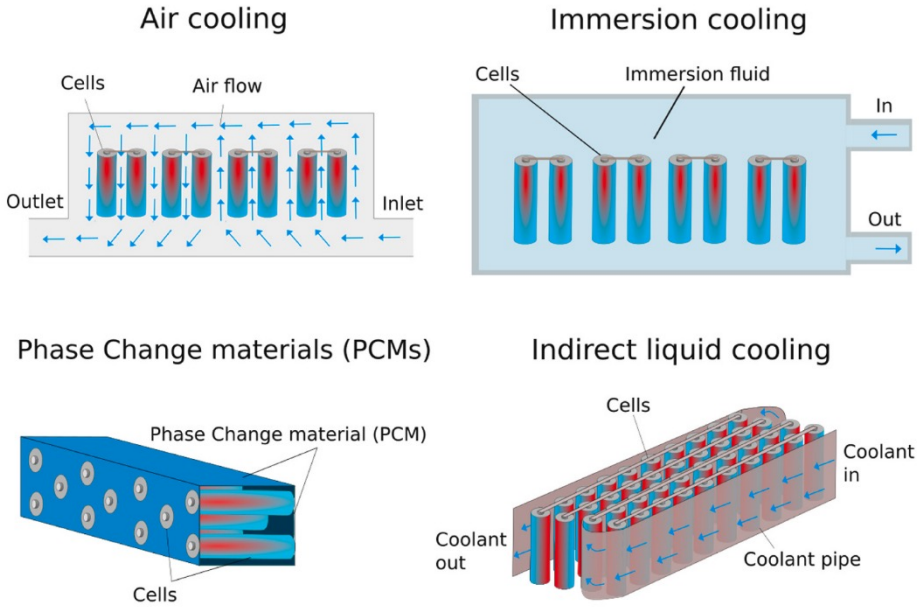
Motivation

EU Driving time and rest regulation



Ohmic losses → Battery temperature → **Accelerated aging**

Motivation



Source: Roe, Charlotte, et al. "Immersion cooling for lithium-ion batteries–A review." *Journal of Power Sources* 525 (2022): 231094.

Installed cooling power

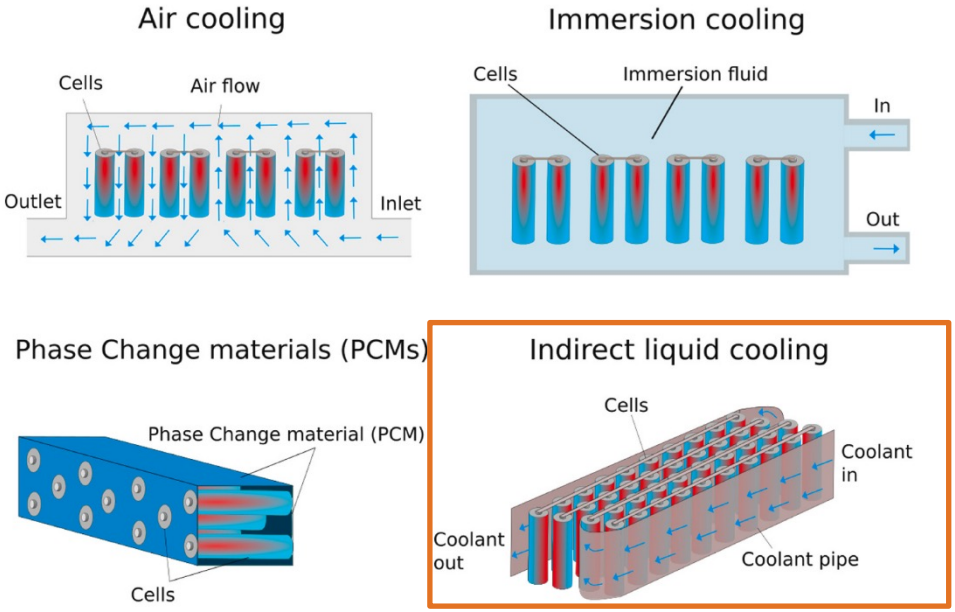
Cooling threshold

Connection to ambient air

Installed heating power

Heating strategy

Scope



Source: Roe, Charlotte, et al. "Immersion cooling for lithium-ion batteries–A review." *Journal of Power Sources* 525 (2022): 231094.

Installed cooling power

Cooling threshold

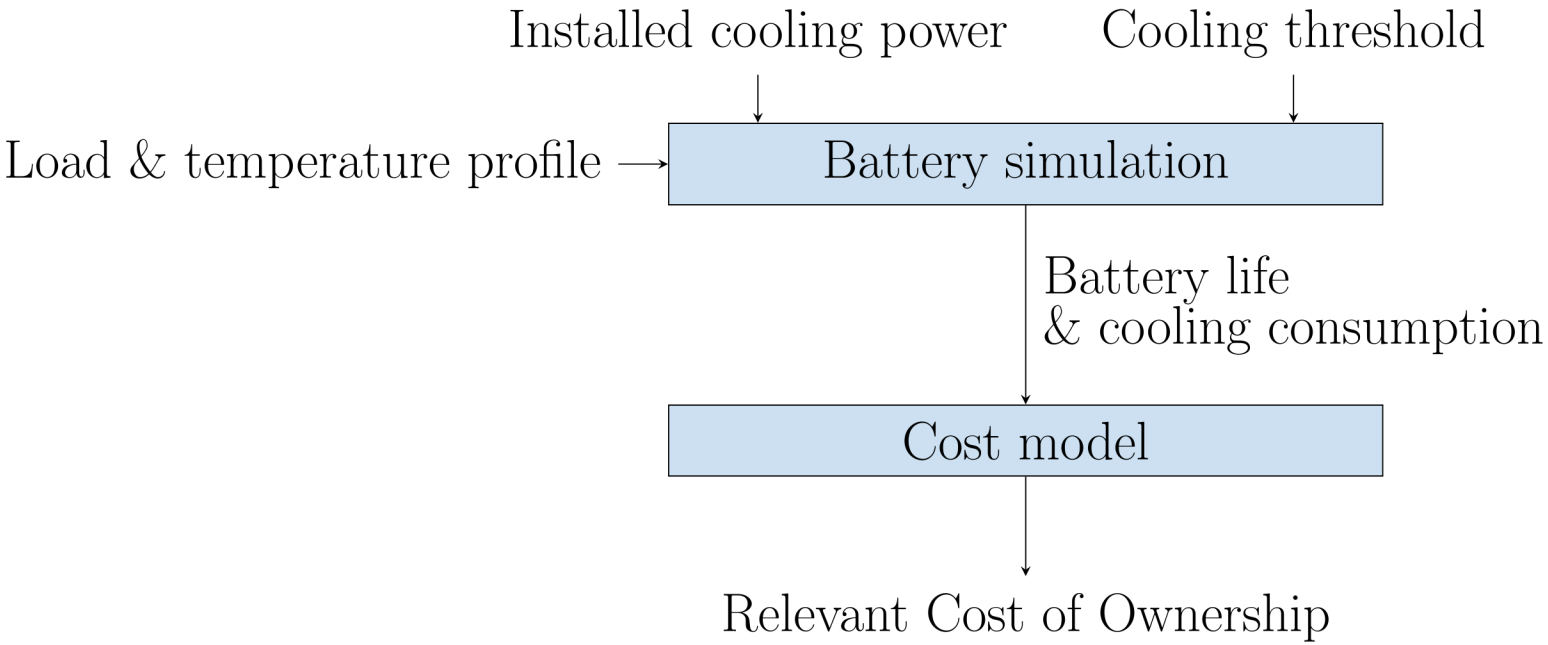
Connection to ambient air:
-> scaled up from EV

~~Installed heating power~~

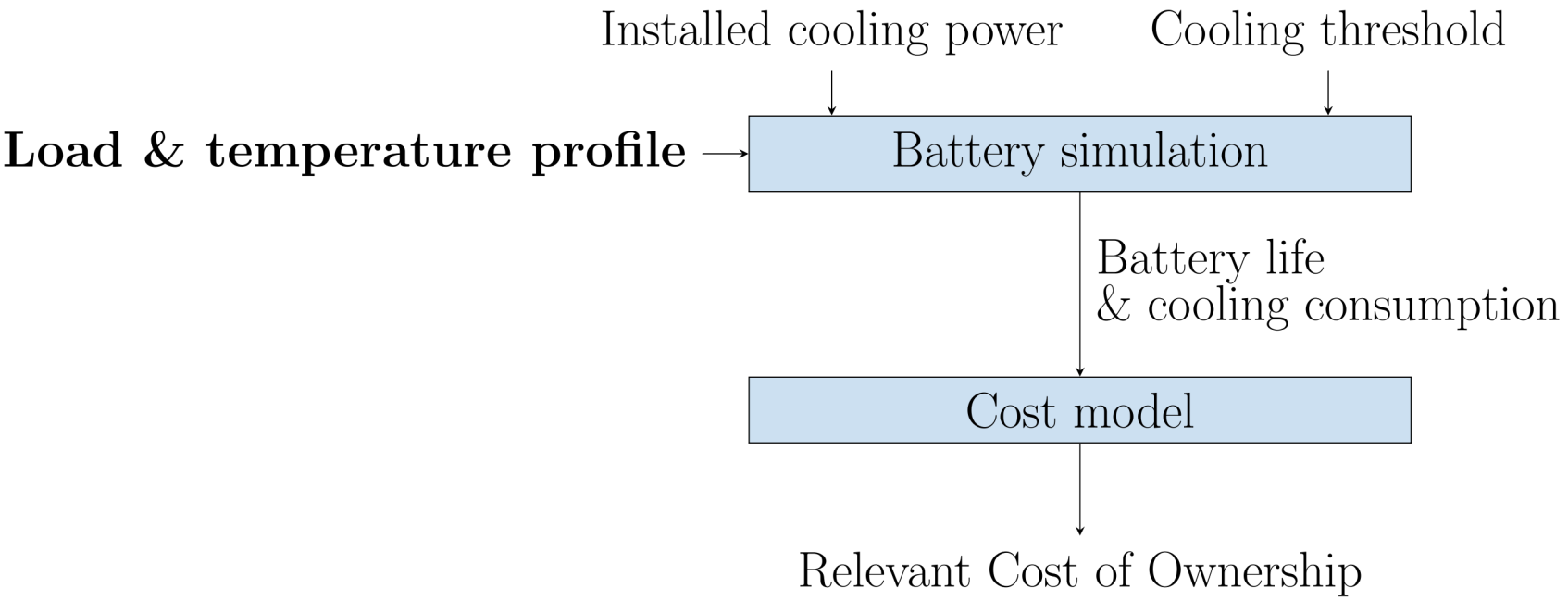
~~Heating strategy~~

Which installed cooling power and cooling threshold result in the lowest system cost?

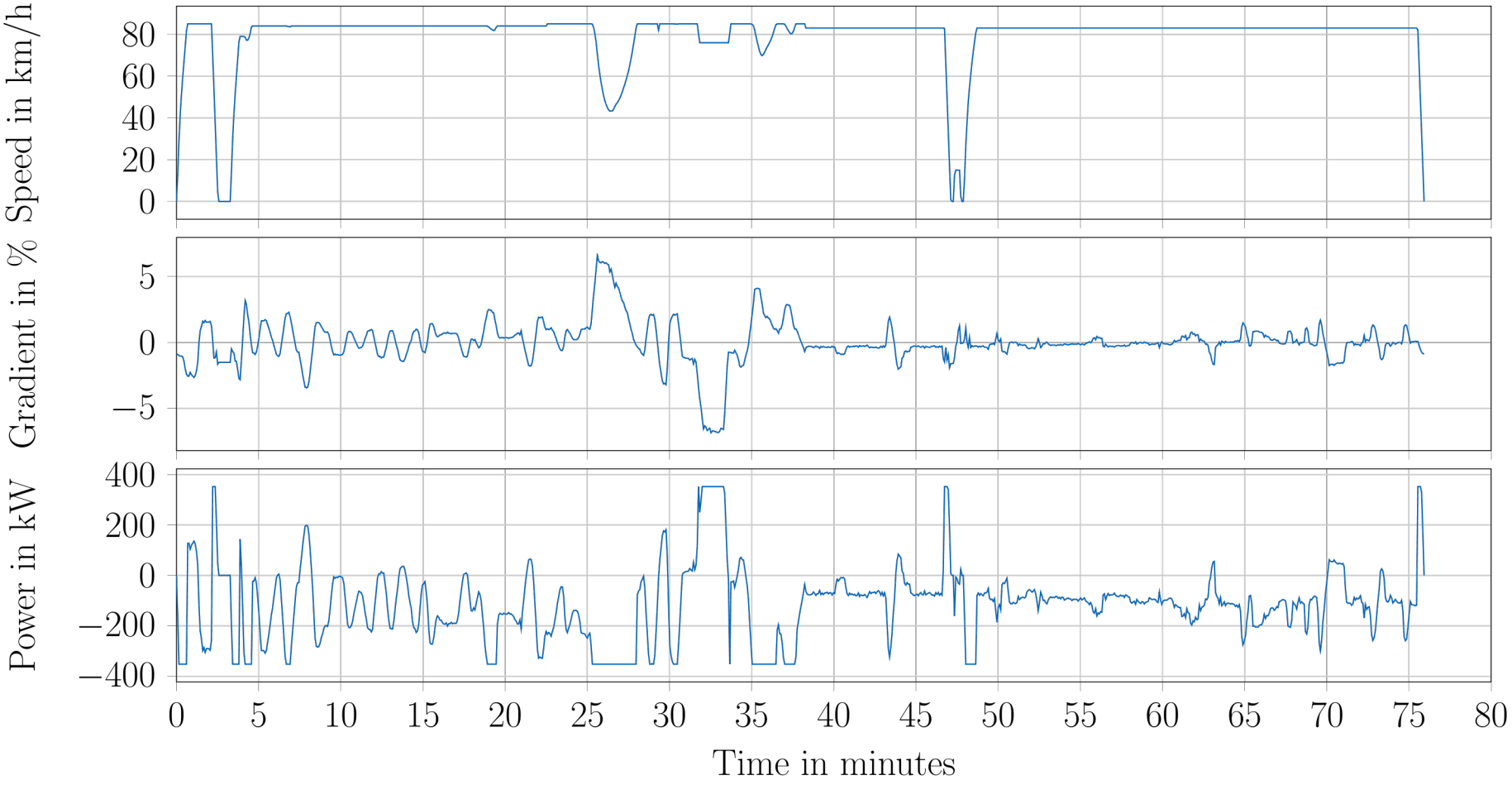
Method


Installed cooling power
Cooling threshold
Load & temperature profile
Battery simulation
Battery life
& cooling consumption
Cost model
Relevant Cost of Ownership

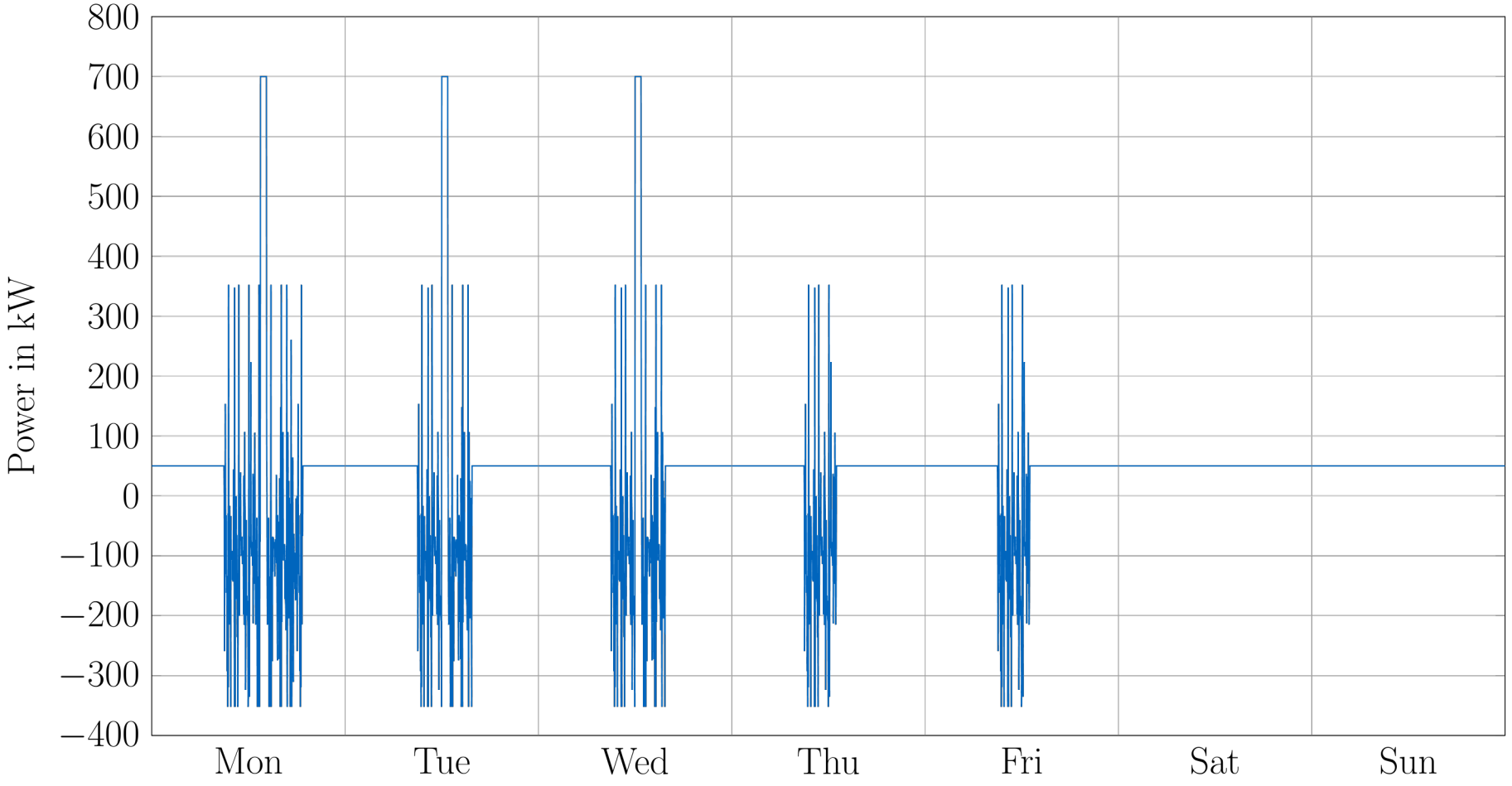
Method


Installed cooling power
Cooling threshold
Load & temperature profile
Battery simulation
Battery life
& cooling consumption
Cost model
Relevant Cost of Ownership

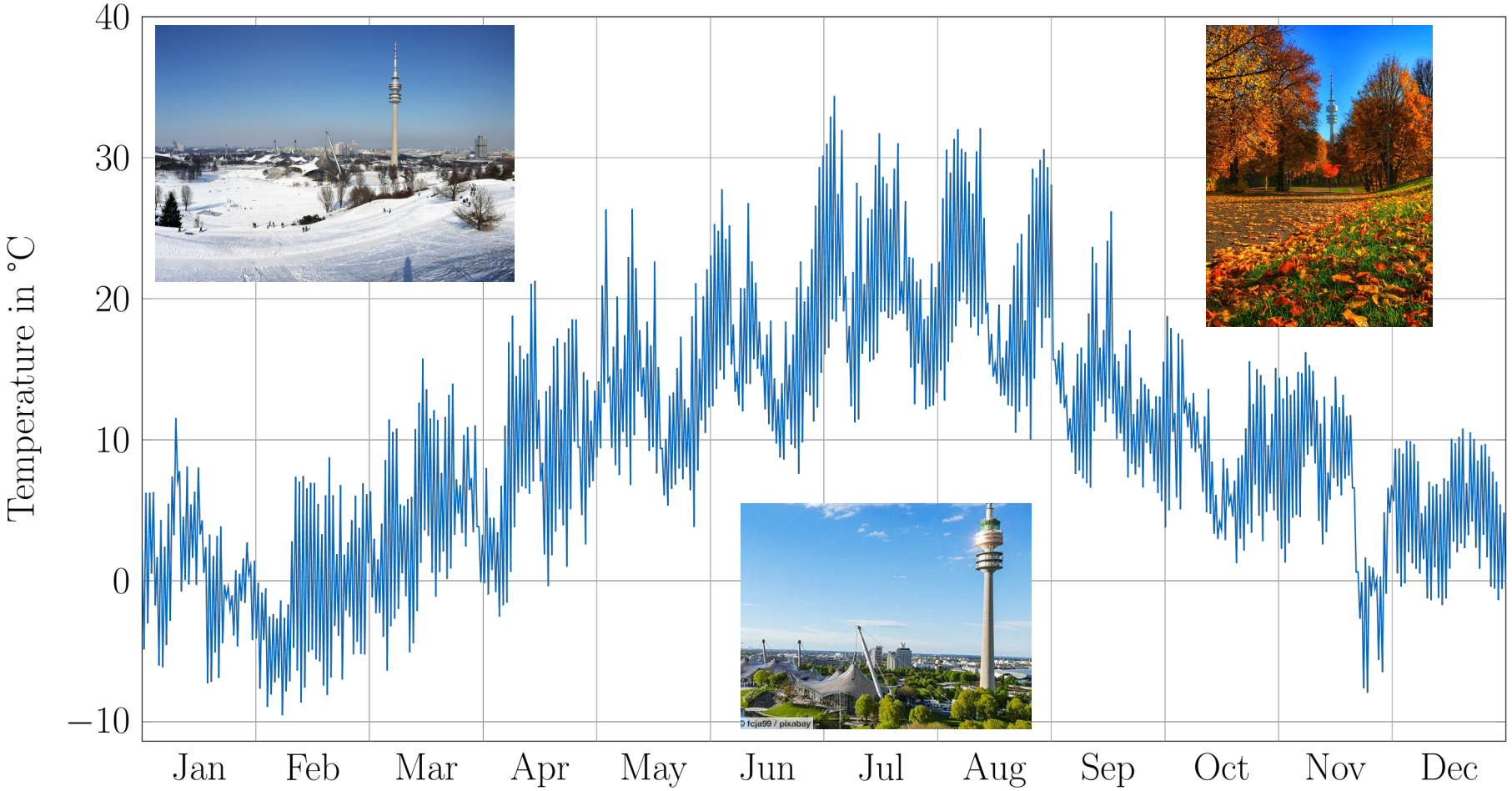
Load profile: truck simulation



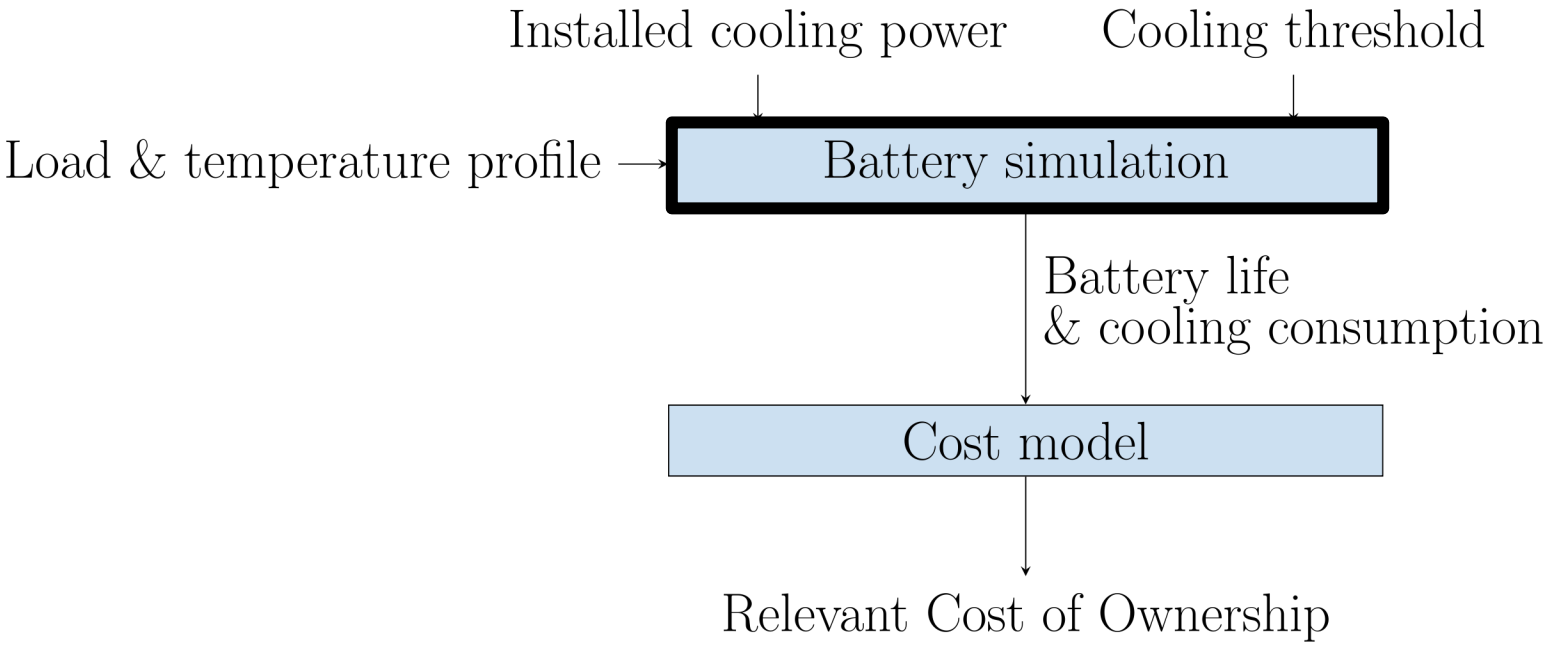
Load profile: truck mobility pattern



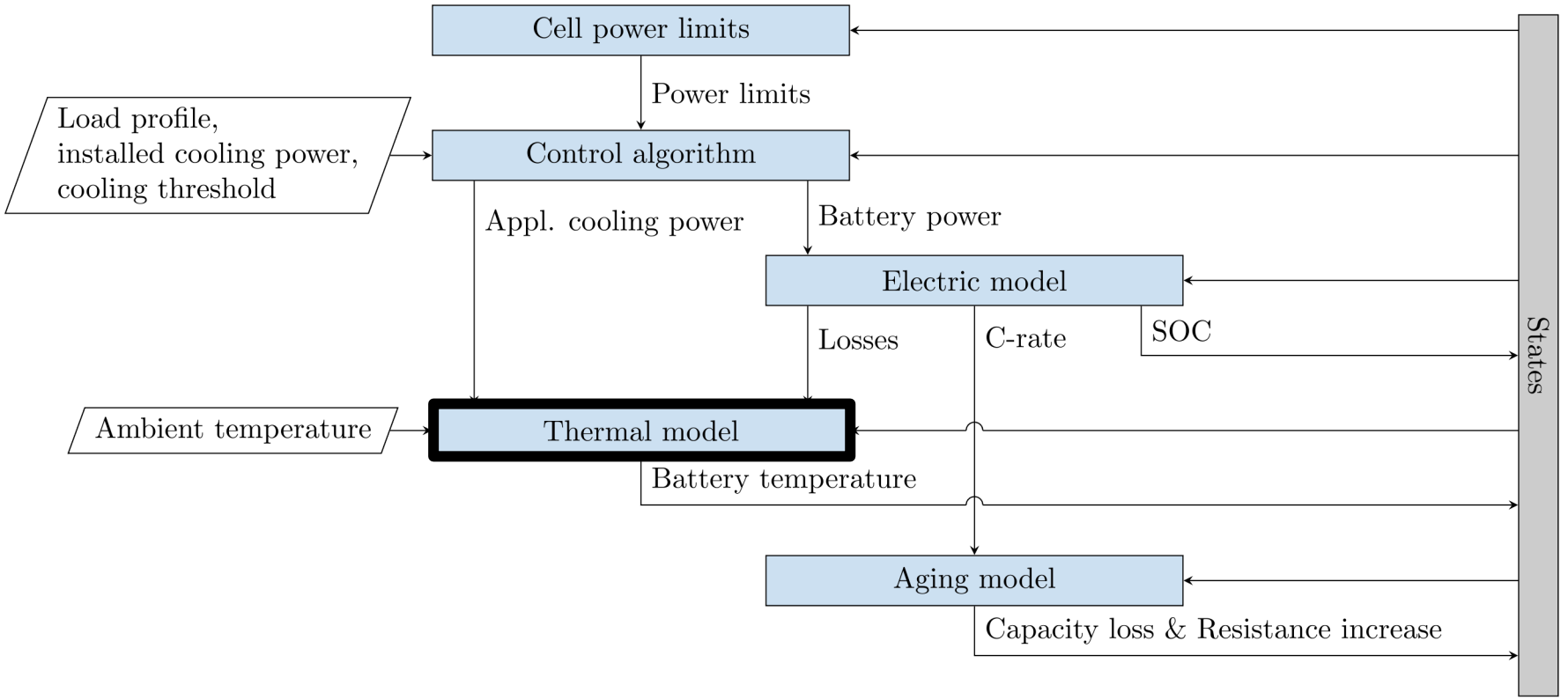
Temperature profile of Munich



Method

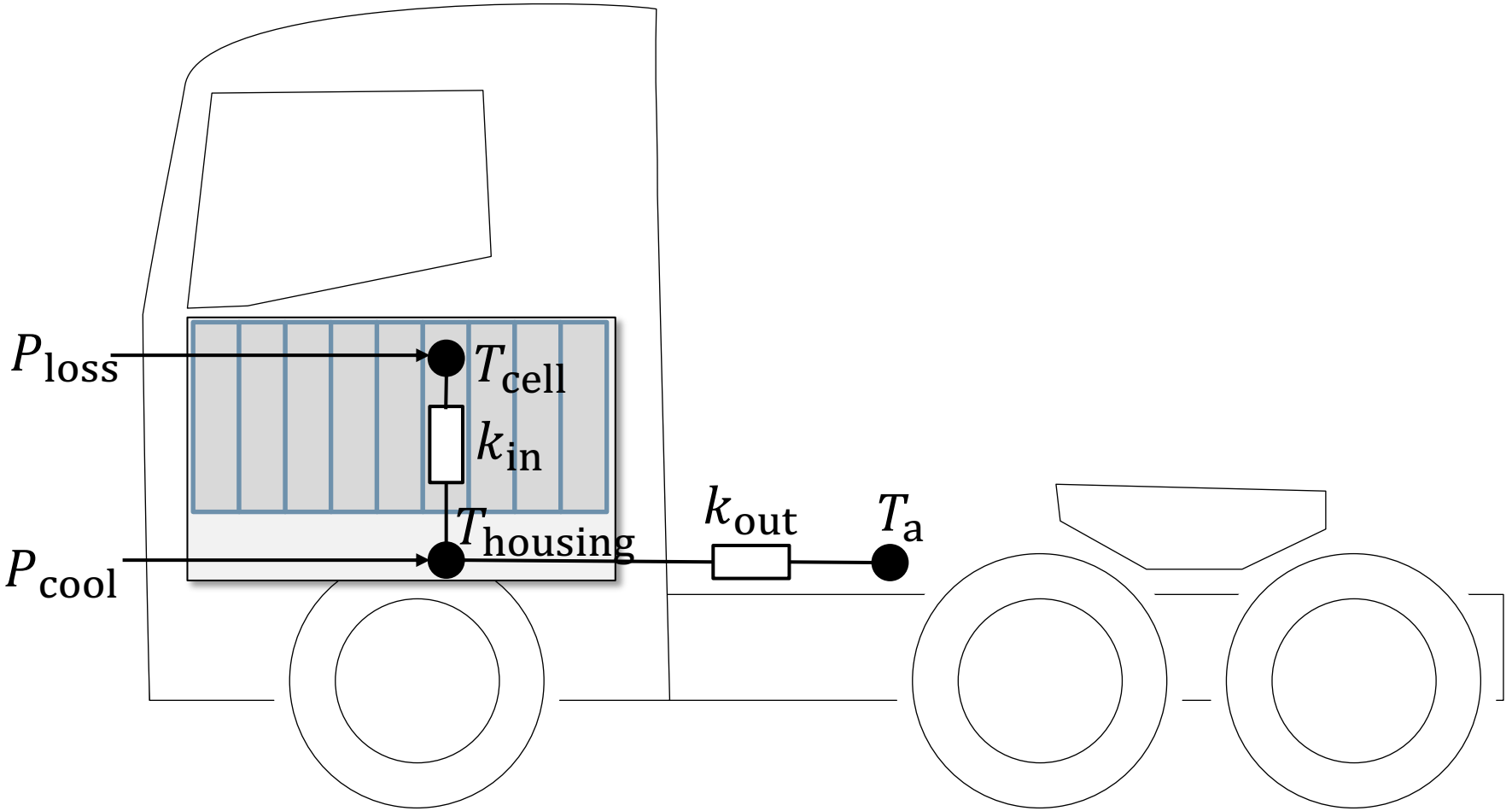

Installed cooling power
Cooling threshold
Load & temperature profile
Battery simulation
Battery life
& cooling consumption
Cost model
Relevant Cost of Ownership

Battery simulation

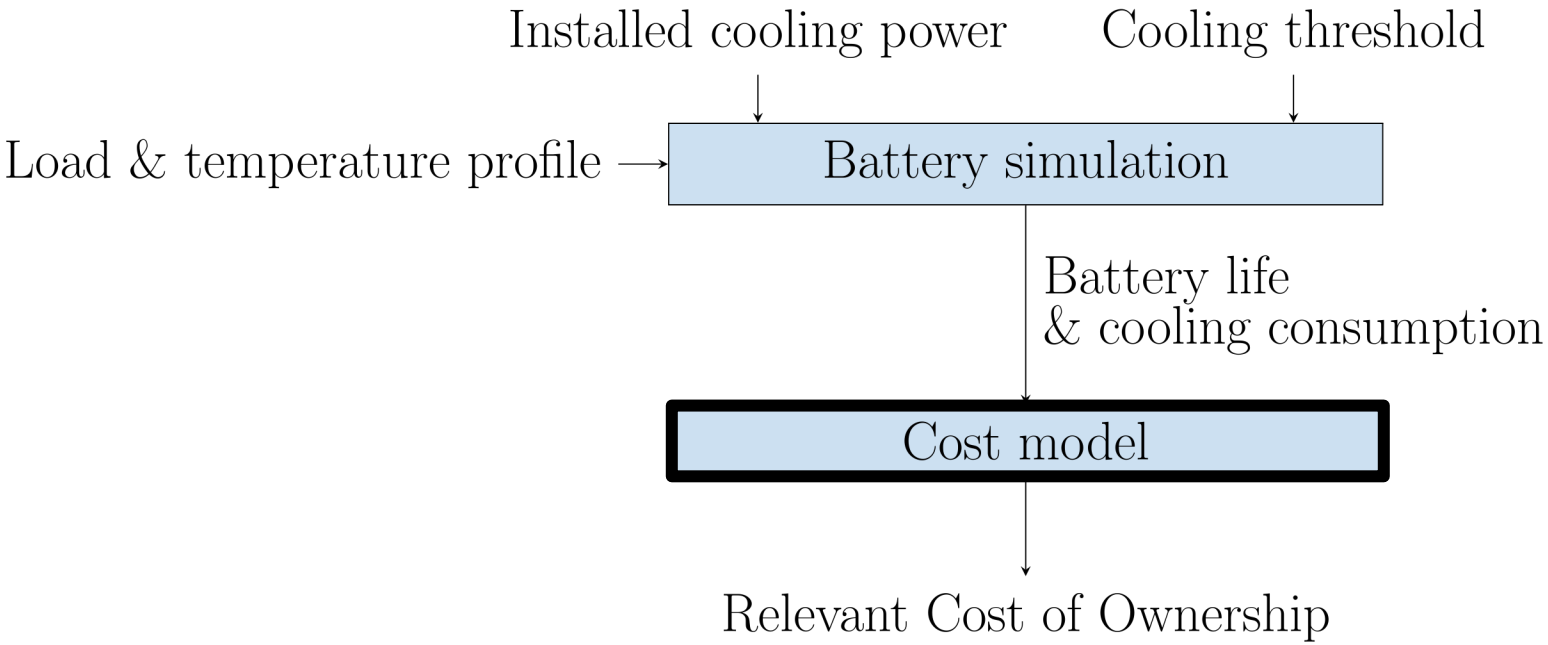


Simulation steps are repeated until EOL condition of the battery is reached

Thermal model

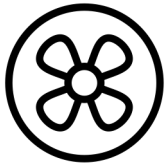


Method


Installed cooling power
Cooling threshold
Load & temperature profile
Battery simulation
Battery life
& cooling consumption
Cost model
Relevant Cost of Ownership

Cost model

Annual battery depreciation



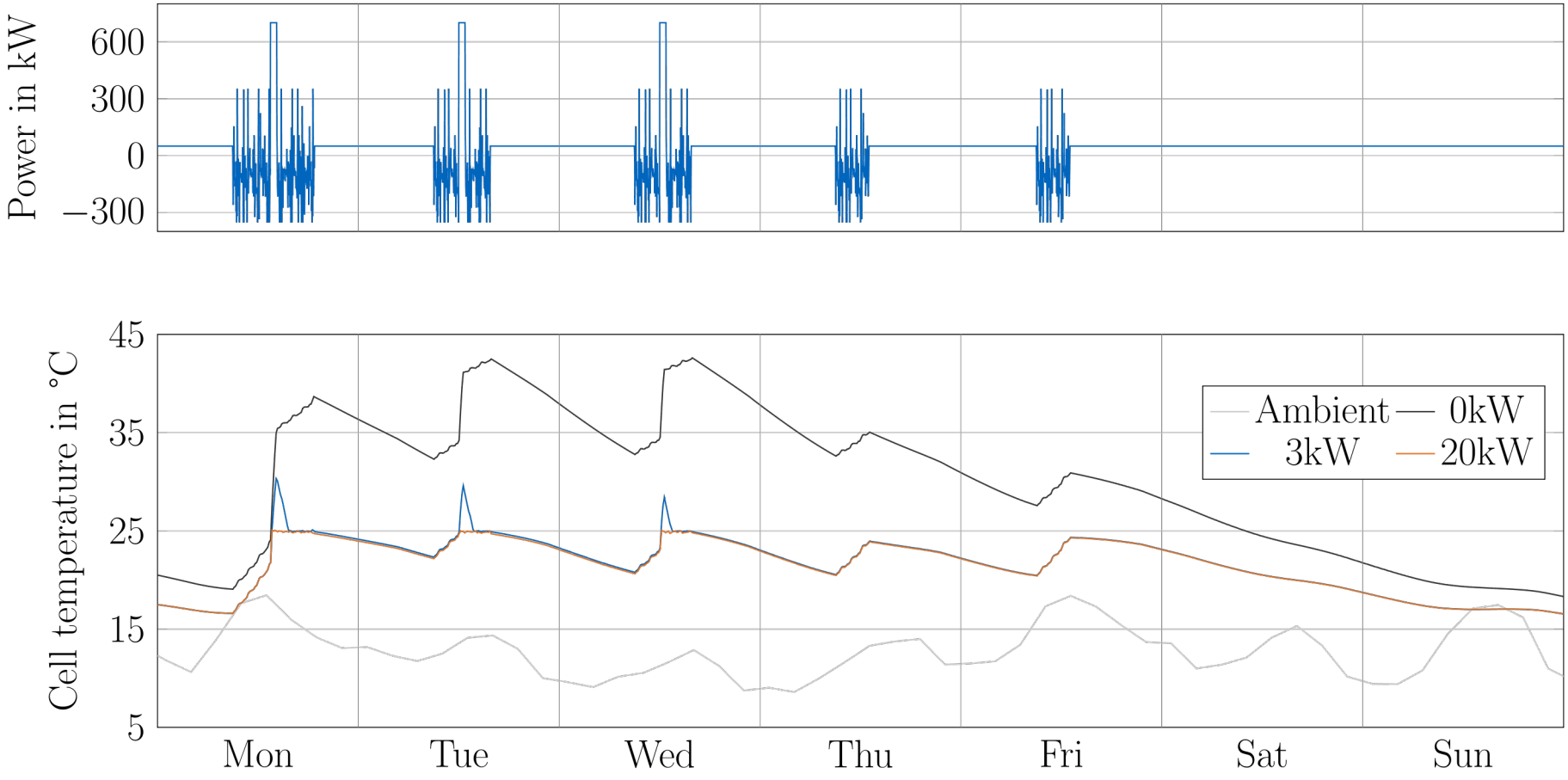
Annual cooling system depreciation

Annual cooling system energy consumption

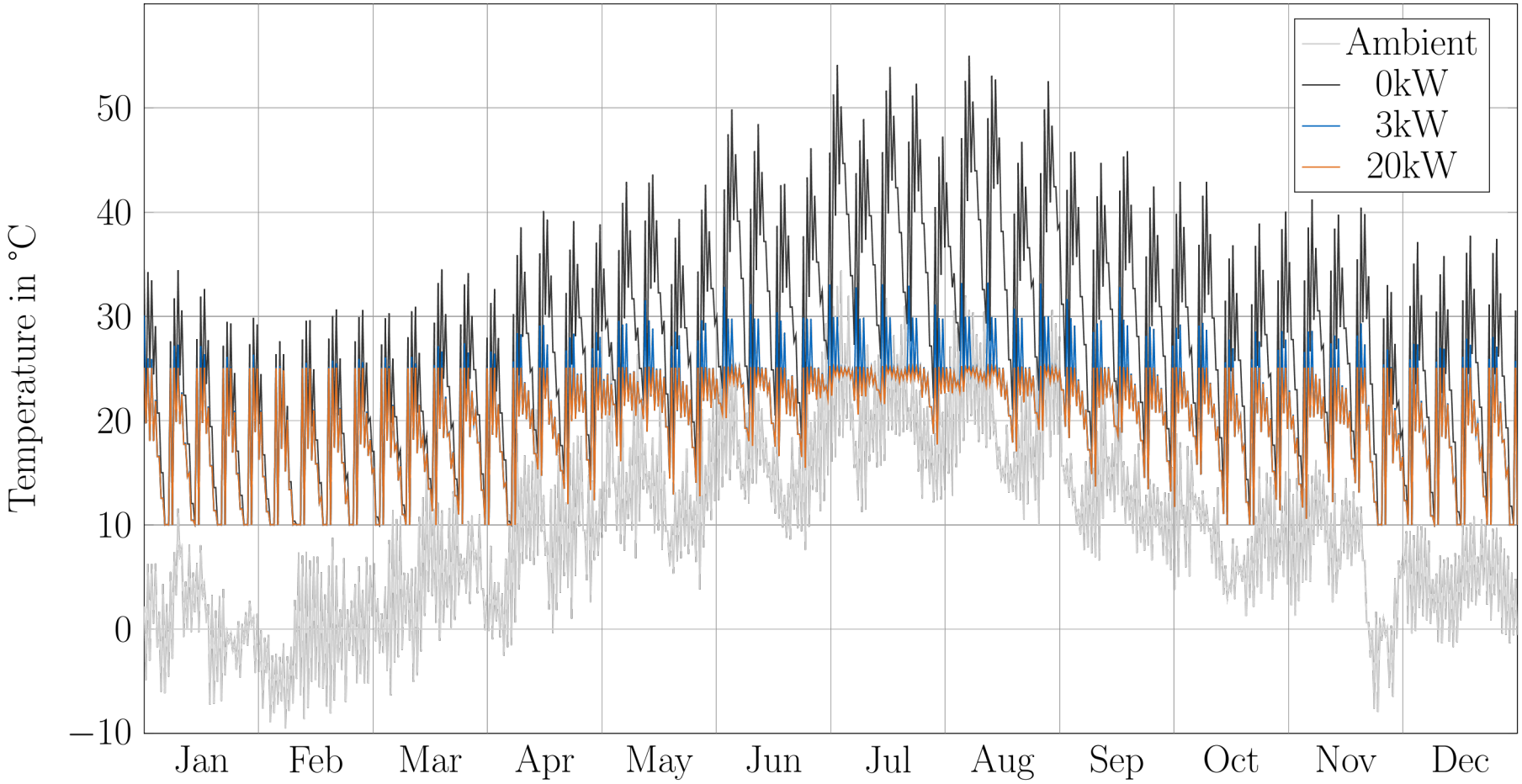
+

Relevant Cost of Ownership

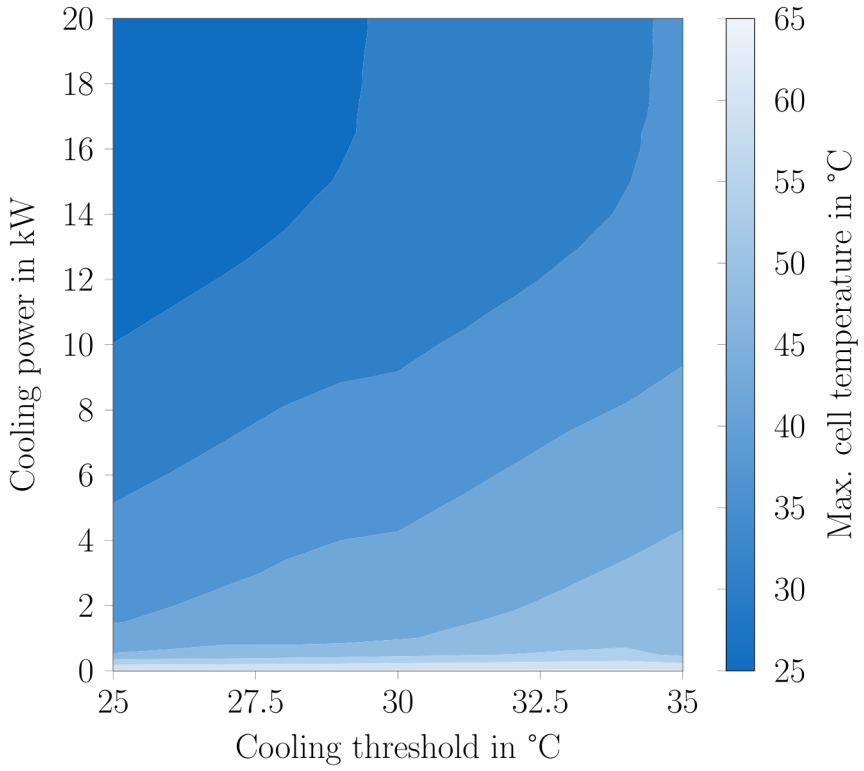
Results simulation 1-week

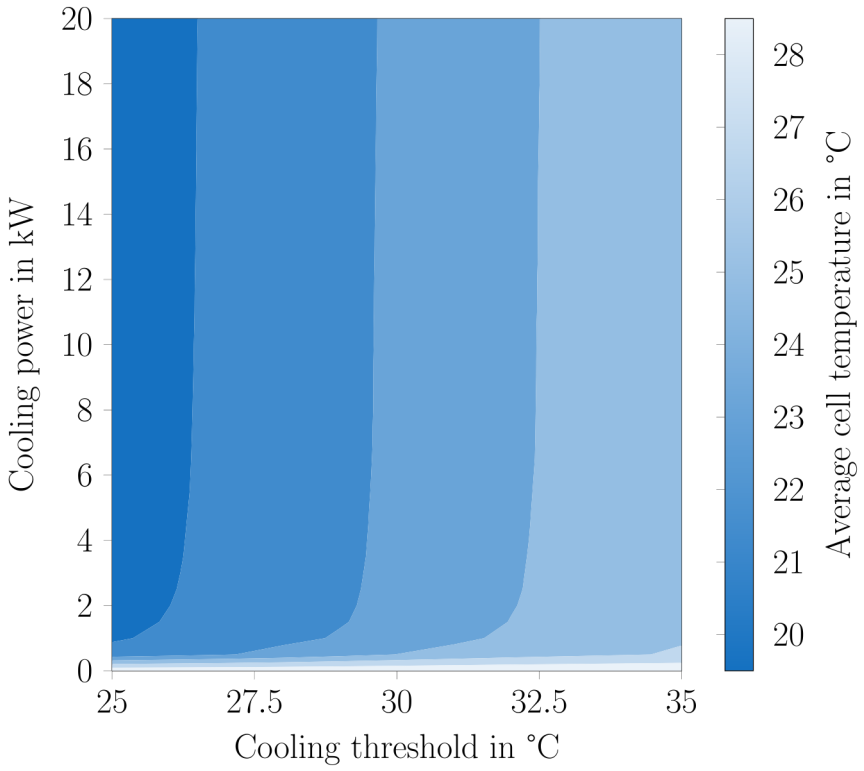


Results simulation 1-year

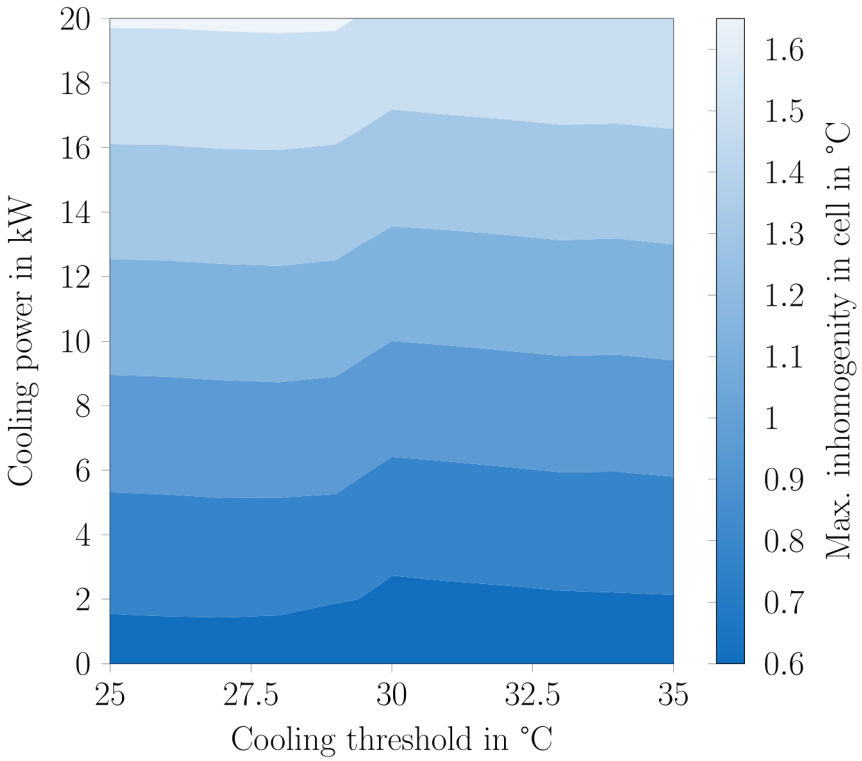


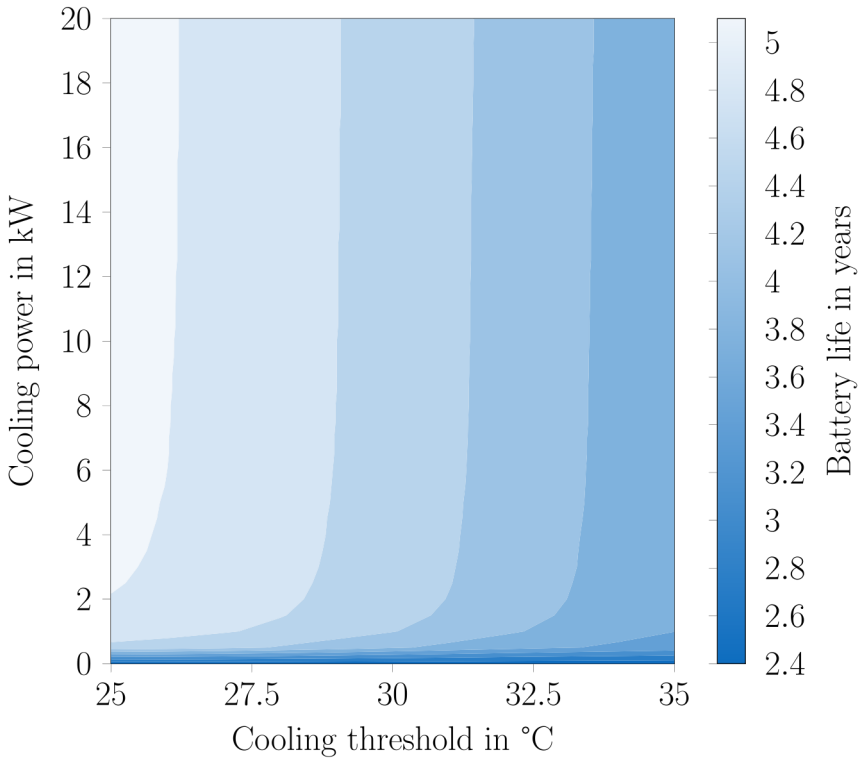
Results: Max. & avg. cell temperature



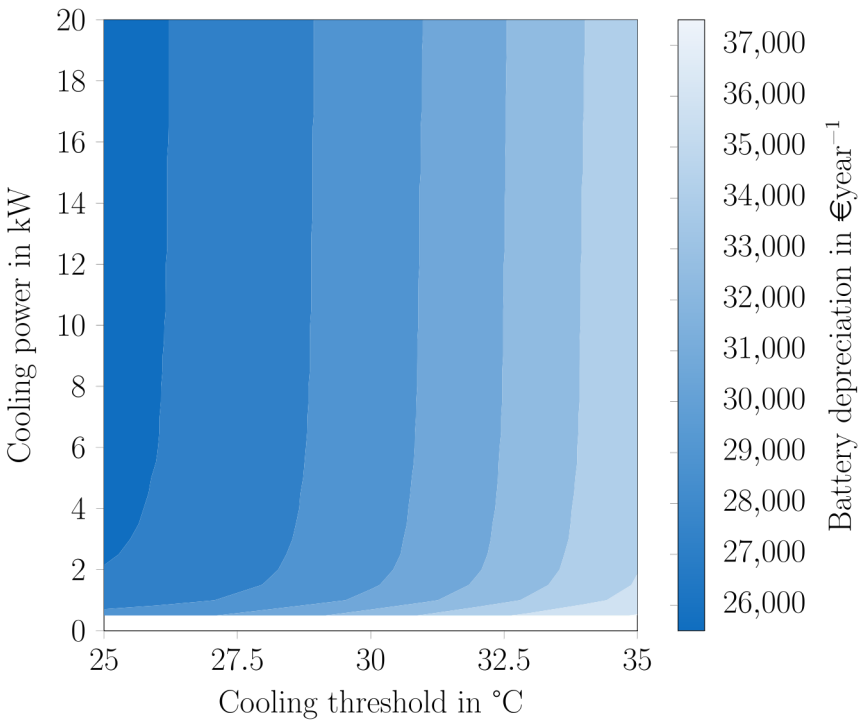


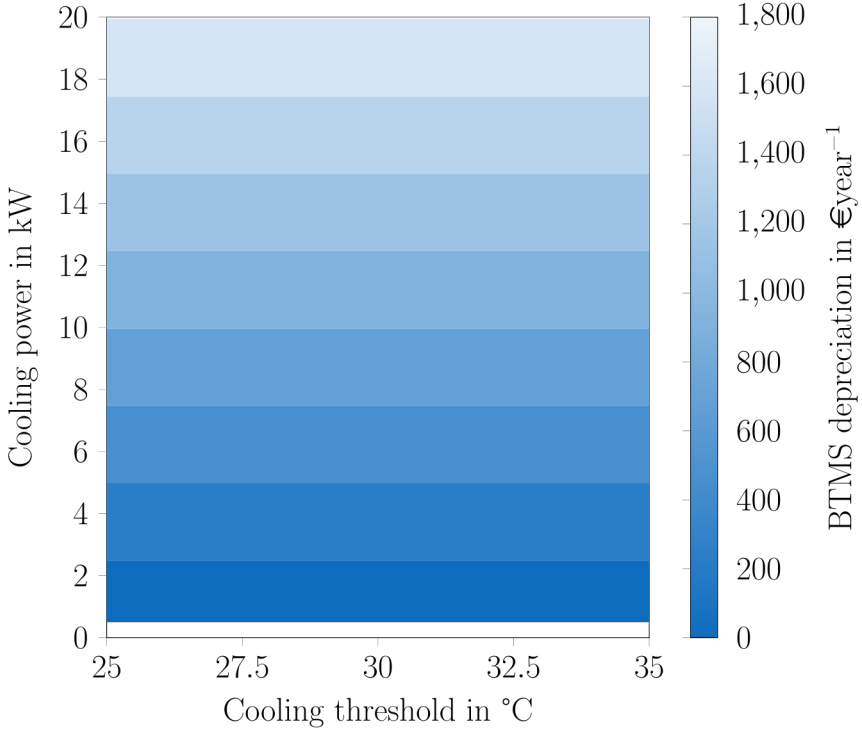
Results: Homogeneity and battery life



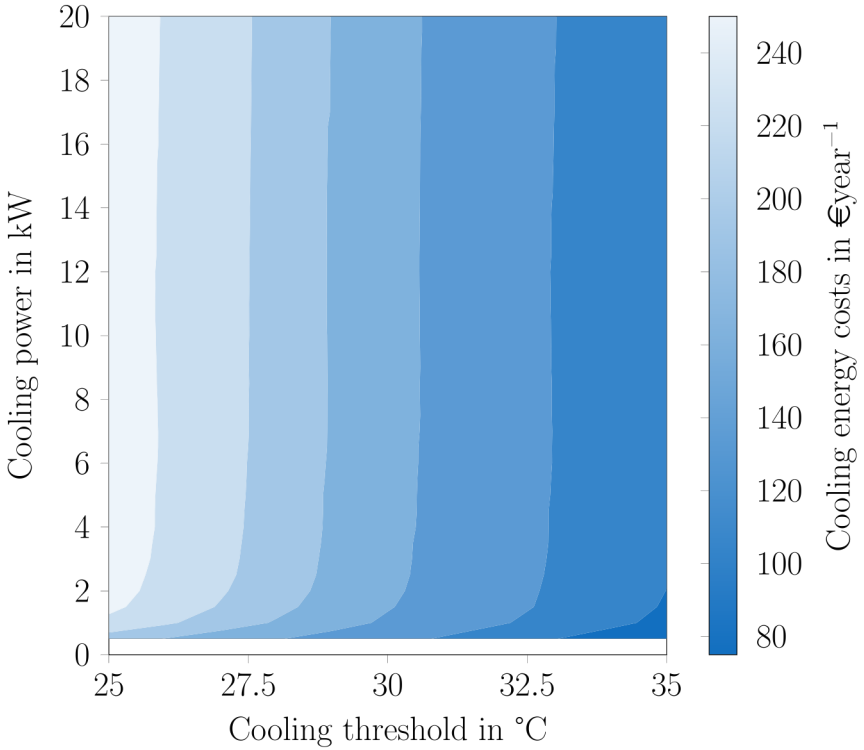


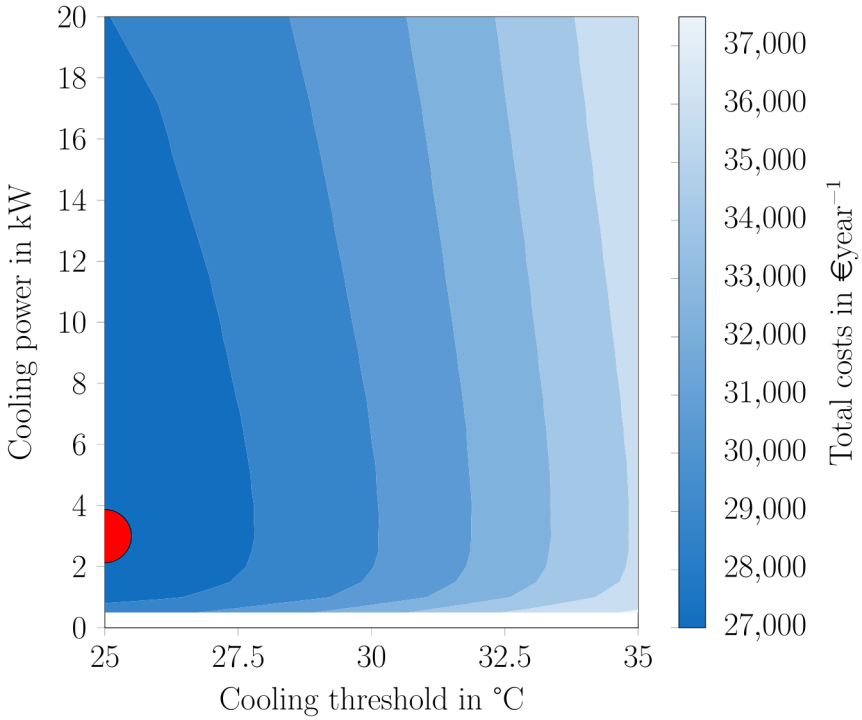
Results: Battery & BTMS depreciation





Results: Energy costs & TCO





Conclusions

1. The optimal installed cooling power is 85% lower than peak ohmic losses

2. The optimal cooling threshold matches the lower limit of the aging model's validity

3. The cooling threshold (strategy) has a larger impact than the installed cooling power

Future work

Aging model:

- Semi-empirical aging models at temperatures below 25 °C
- Semi-empirical aging models of cells charged with more than 1C
- Path dependency of aging behavior

Thermal model:

- Simulation of multiple cells per pack
- Cooling system energy consumption dependent on humidity & temperature difference to ambient

Thank you!

Contact

Olaf Teichert, M.Sc.

Technical University of Munich
TUM School of Engineering & Design
Institute of Automotive Technology

Olaf.teichert@tum.de
+49 (0)89 289 15871

This work was sponsored by

SPONSORED BY THE

Federal Ministry
of Education
and Research

BattNutzung
BetterBat