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Effects of Heavy-Duty Vehicle Electrification on Infrastructure: The Case of Switzerland

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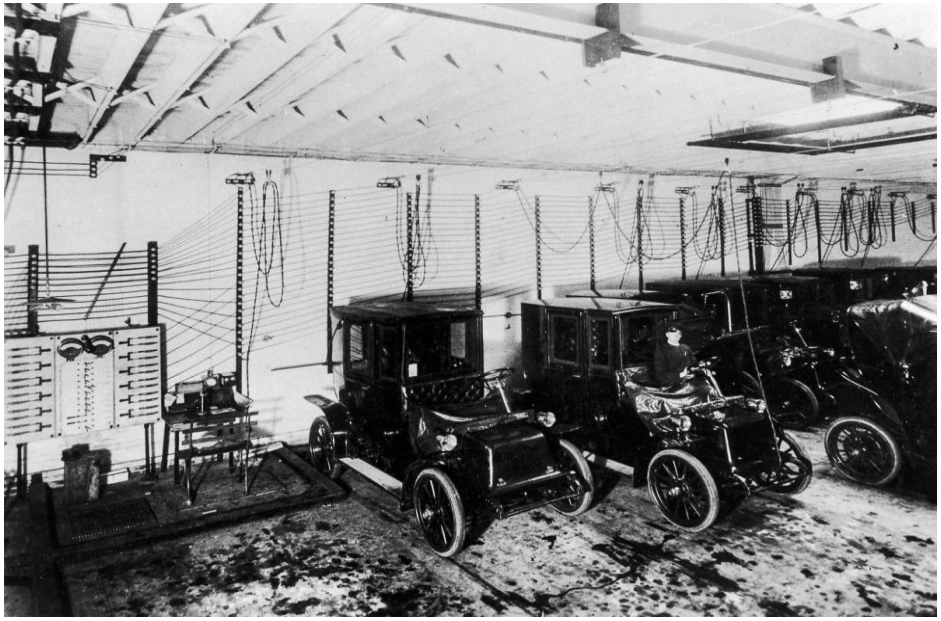
What if we electrify this?

Source: http://www.dieselmasters.net

Demand for new infrastructure



Electric vehicles recharge at a charging station - 1909[1]

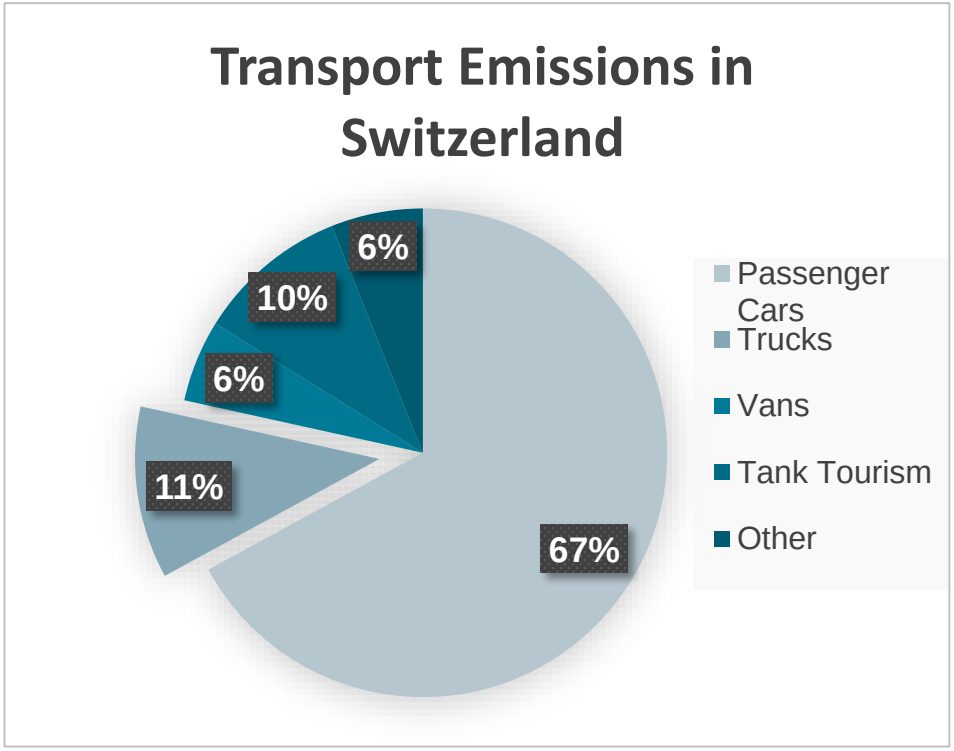
Battery swapping technology developed for Mercedes LE 206 Buses - 1972[2]

[1] Schenectady Museum: Hall of Electrical History Foundation
[2] https://insideevs.com/check-blast-past-1972-mercedes-benz-le-306-electric-van/

Agenda

- → Why truck electrification is important
- → Our approach to estimate the electrification potentials and impacts on infrastructure
- → Results (How electrification can be achieved and which effects will this have on infrastructure)
- → The most important findings and next steps

Why is truck electrification important?



- → Grows almost twice as fast as the motorized individual mobility in Switzerland (a demand increase of 33% expected until 2040[1])
- → Globally, it's expected to grow 160% until 2050 (demand correlated with GDP growth[2])
- → Causes 24% of the transport CO_2 emissions in the EU (buses also included)
- → Almost all the vehicles are powered by Diesel

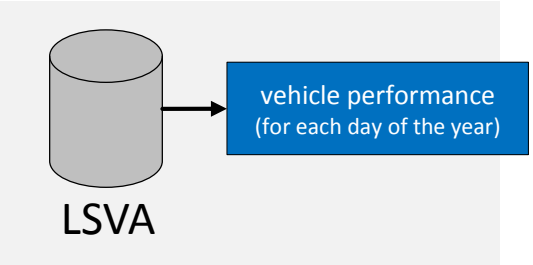
[1] ARE (Bundesamt für Raumentwicklung), Perspektiven des schweizerischen Personen- und Güterverkehrs bis 2040
[2] ITF Transport Outlook 2017
[3] IEA - The Future of Trucks - 2017

What we do…

- → Analyze the mobility of all heavy-duty vehicles in Switzerland
- → Substitute their conventional powertrain with a battery electric powertrain
- → Investigate how much energy they need from their new powertrain for their missions
- → Determine for each vehicle if it is electrifiable or not
- → Analyze the impacts of the electrified vehicles on the infrastructure
- → The first and only study – to our knowledge – doing this in this level of detail (whole fleet)

The HDV fleet electrification model

distance driven
LSVA monitoring data

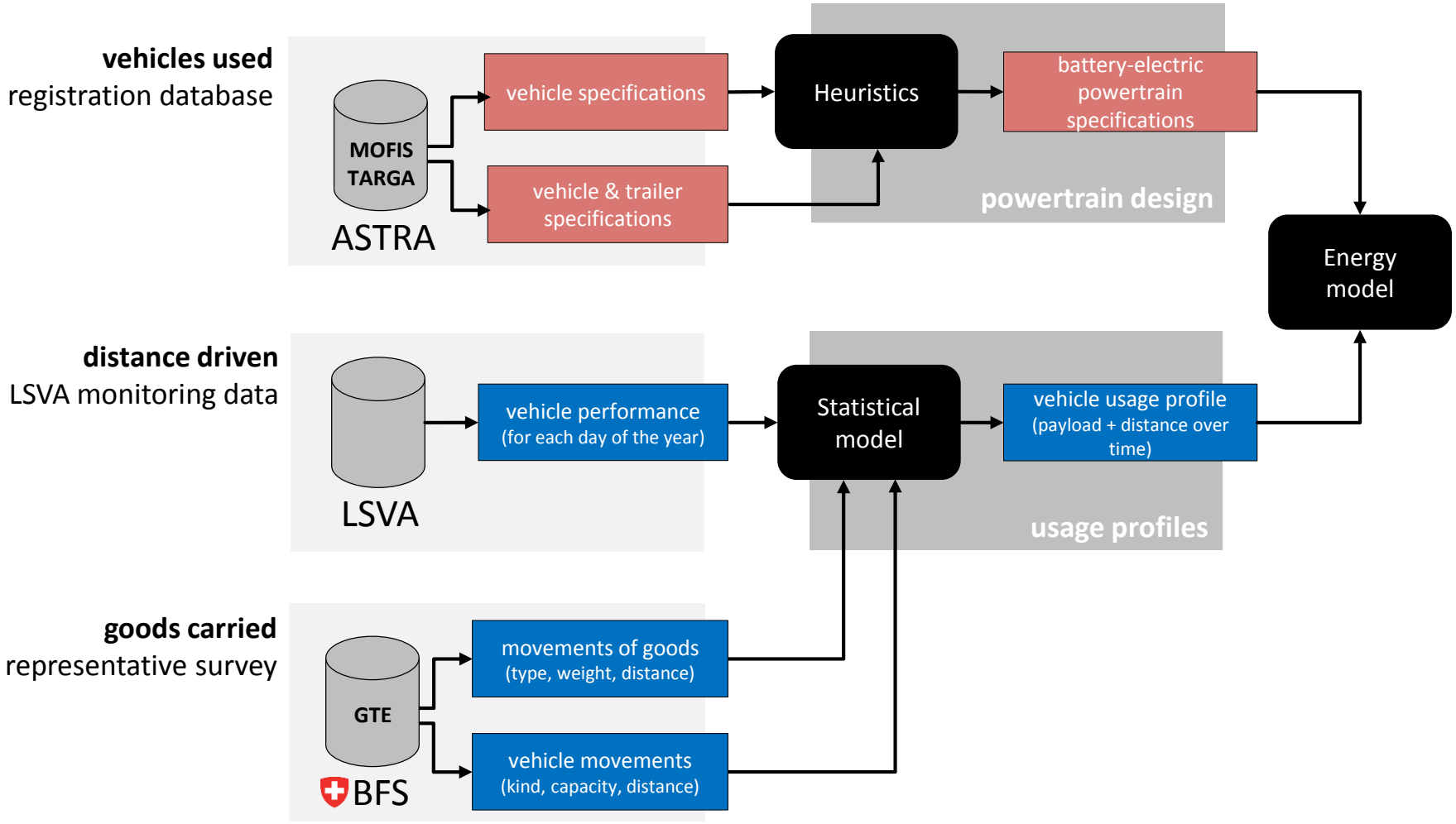


LSVA – Performance-related heavy vehicle charge

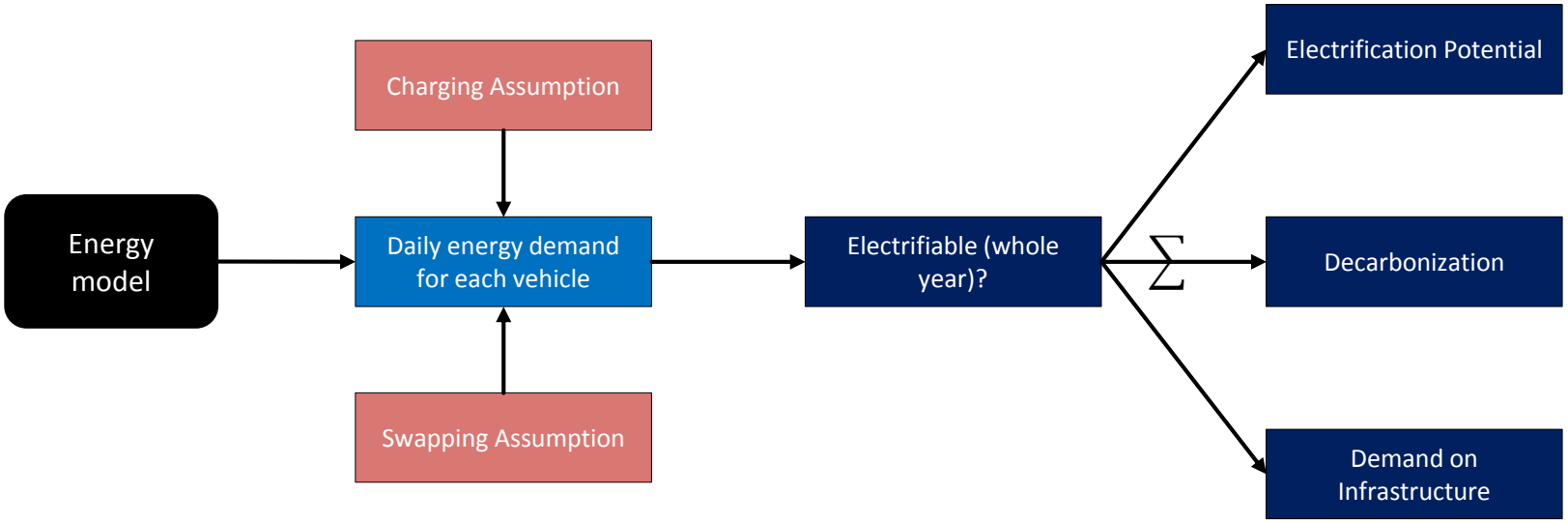
- → A federal tax for heavy-duty vehicles (vehicles with a max. permissible weight of more than 3.5 tons and used to transport goods)
- → Depends on the
  - i. maximum permissible weight
  - ii. emissions level
  - iii. kilometres driven in Switzerland and Liechtenstein
- → Records the distance a vehicle drives at least once per day
- → A similar tax system is used in ten countries[1] around the world, but only three of them (Switzerland, New Zealand and Belgium) charges vehicles on all roads
- → Gives Switzerland a complete coverage of the distances driven by each heavy-duty vehicle in Switzerland for every day of the year

[1] Countries using a performance-related heavy vehicle charge (tax) are:
New Zealand, Switzerland, Austria, Germany, Czech Republic, Poland, Slovakia, France, Belgium and the U.S.A.

The HDV fleet electrification model



The HDV fleet electrification model



What we found out about electrification potentials

→ Three technologies will affect the electrification potential of the heavy-duty fleet:

1. Battery energy density
2. If battery swapping technology is available
3. Available charging power

→ Here, we analyze different scenarios considering these properties to show the effect of these on infrastructure.

Source: G. Georges, E. Cabukoglu, L. Küng, G. Pareschi, K. Boulouchos (2017). Battery electric propulsion: an option for heavy-duty vehicles? Results from a Swiss case-study. Submitted to Transport Research Part C: Emerging Technologies

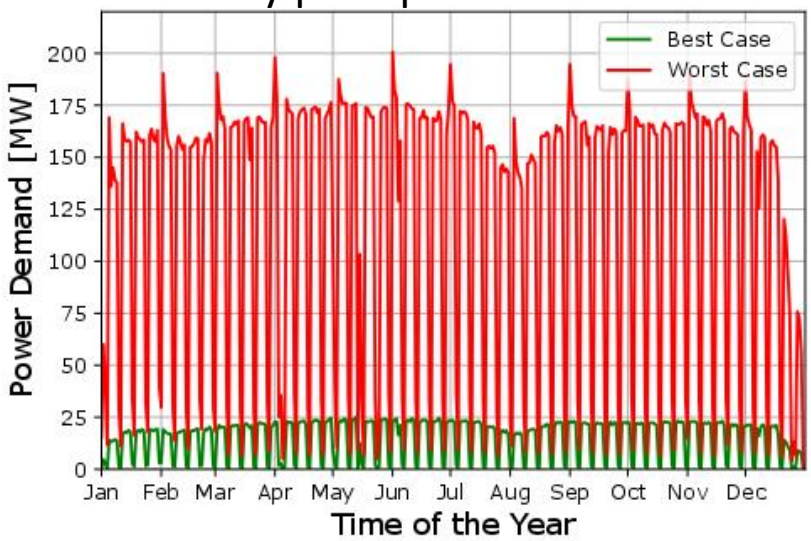
Results

Today (Status-quo)

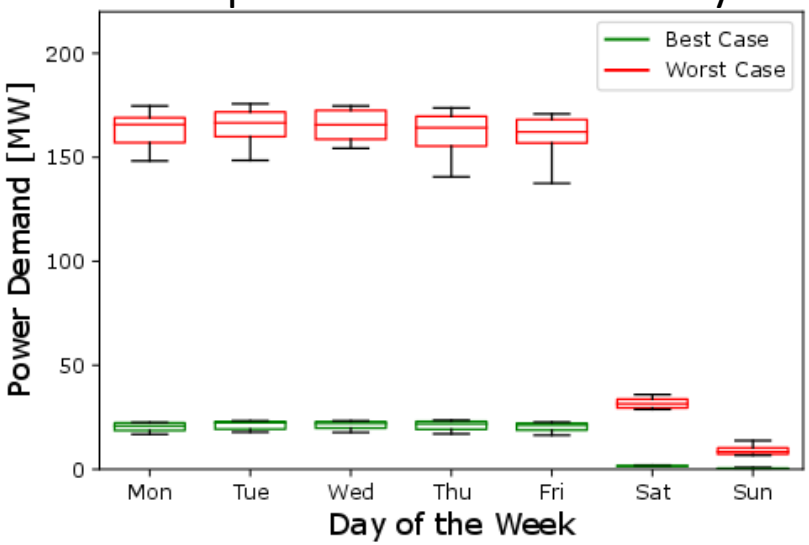
Today's technology ➡
- Battery Cell Density: 240 Wh/kg
- Charging: 50 kW x 12 hours
- No swaps

Resulting in ➡
- 12% of vehicles and only 1.4% of total performance (tkm) electrifiable

Daily peak power demand



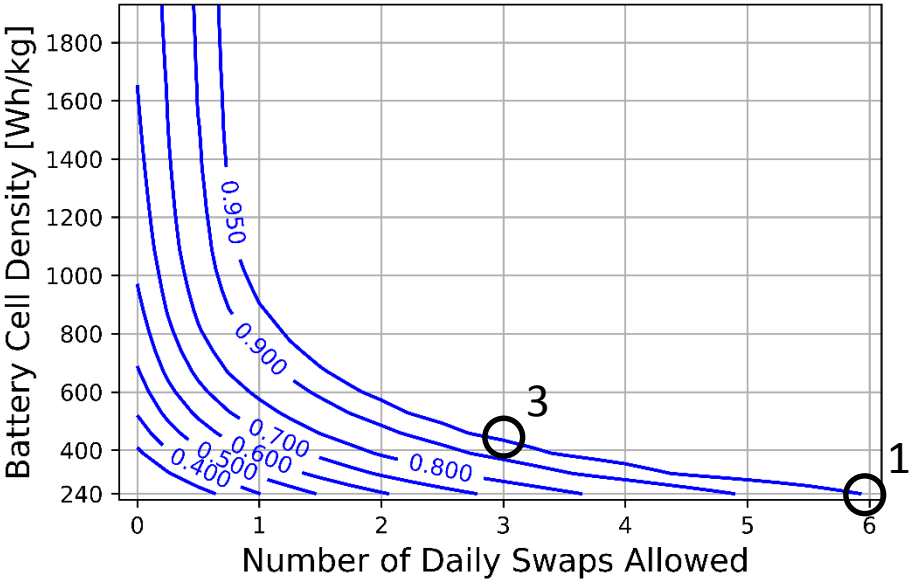
Peak power demand - weekdays



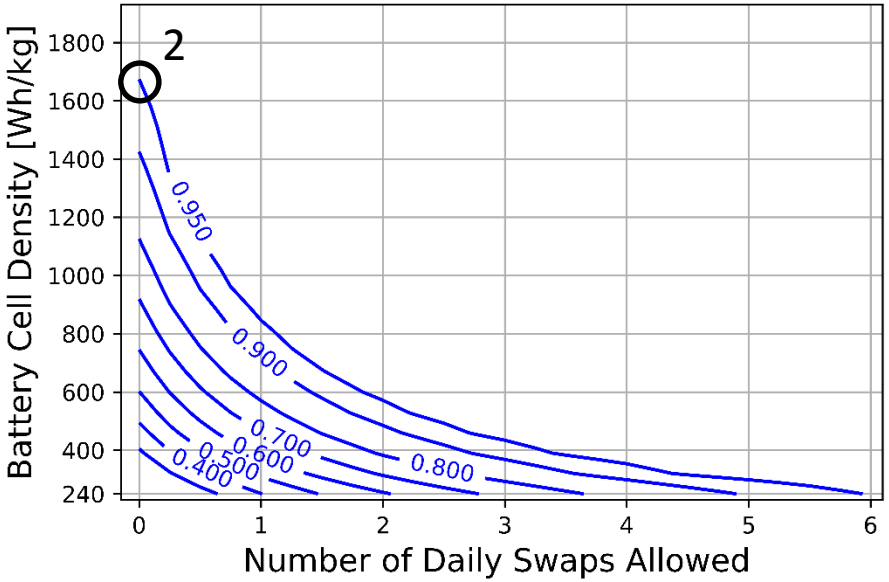
What if the technology improves…

Iso-curves for the share of electrified vehicles

Charging Power: 50 kW



Charging Power: 200 kW



Three scenarios for electrification

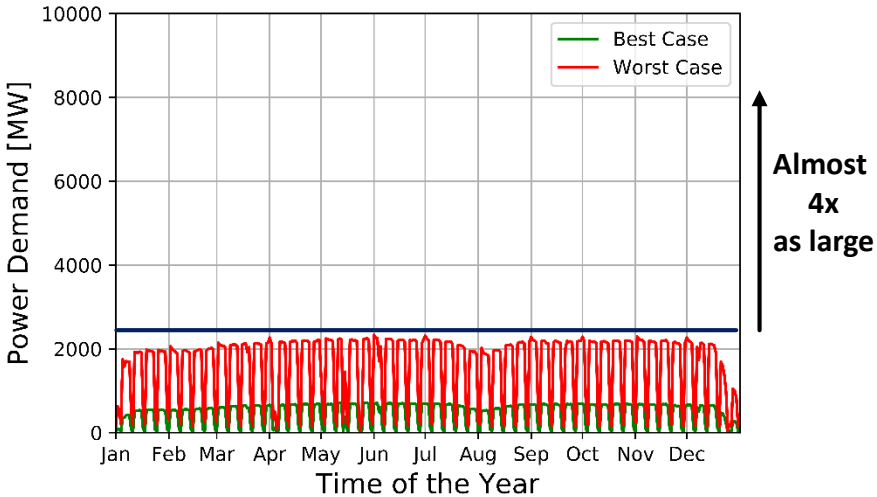
	Scenario	Battery Cell Density [Wh/kg]	Charging Power [kW]	Daily Swaps Allowed
1	Battery Swaps	240	50	6
2	Better Batteries + Very Fast Charging	1’650	200	0
3	Battery Swaps + Better Batteries	415	50	3

For all scenarios:

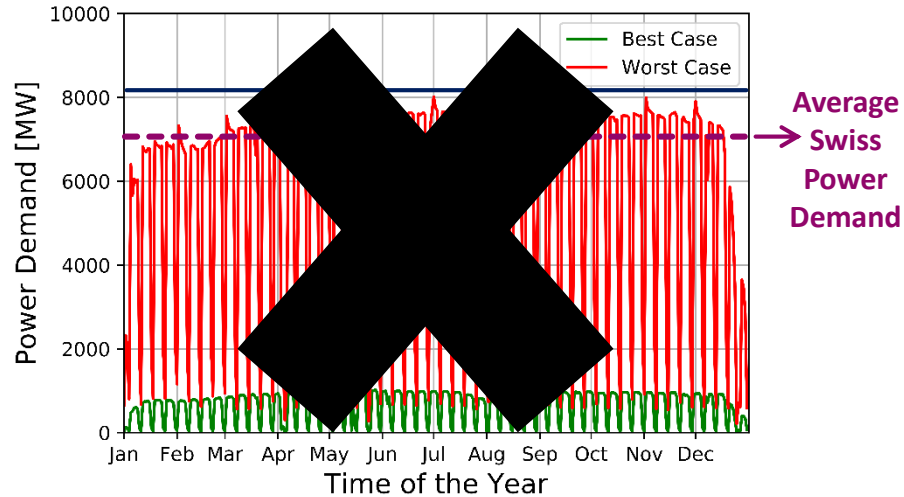
- 95% of vehicles electrified
- Around 90% of transport/vehicle performance (tkm/km) electrified

Peak power demand

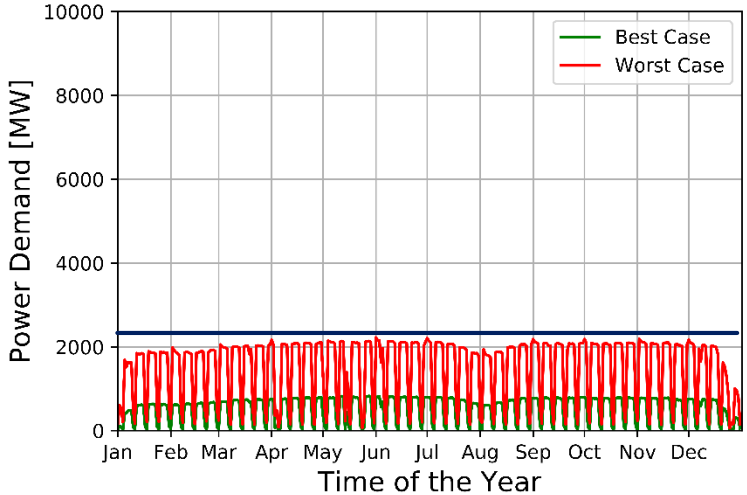
Scenario 1: Today's batteries, 6 Swaps, 50 kW



Scenario 2: Much better batteries, No Swaps, 200 kW

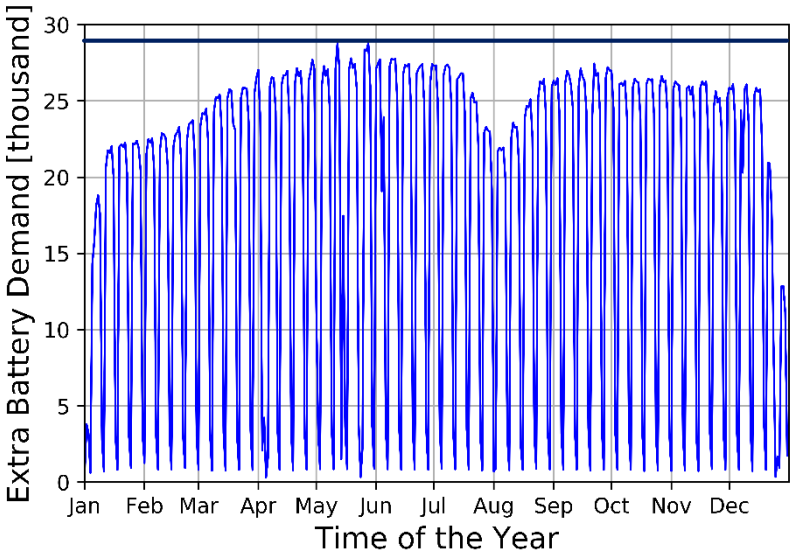


Scenario 3: Better batteries, 3 Swaps, 50 kW

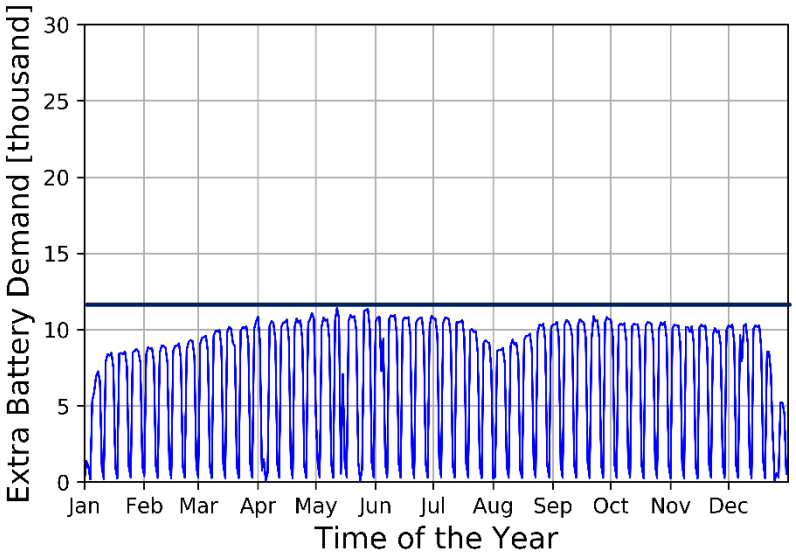


Extra Battery Demand for Swaps

Scenario 1: Today's batteries, 6 Swaps, 50 kW



Scenario 3: Better batteries, 3 Swaps, 50 kW



Vehicles using better batteries need less swaps and this decreases the demand for extra batteries.

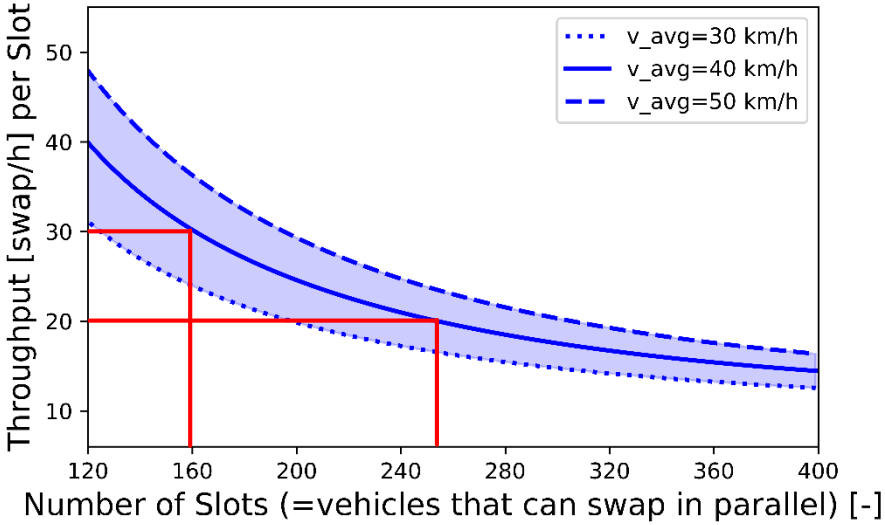
Battery Swapping Stations

- → A multi-agent, discrete event simulation is used
- → Each vehicle travels during the day at a constant average speed
- → Continues driving until reaching the destination or the battery is empty
- → Swapping stations work on a first-come, first-served basis
- → Swapping occurs in t_{swap} minutes
- → If there is no empty swapping slot and a vehicle needs a swap, it waits in the queue
- → We use the maximum time a vehicle spends daily as an indicator

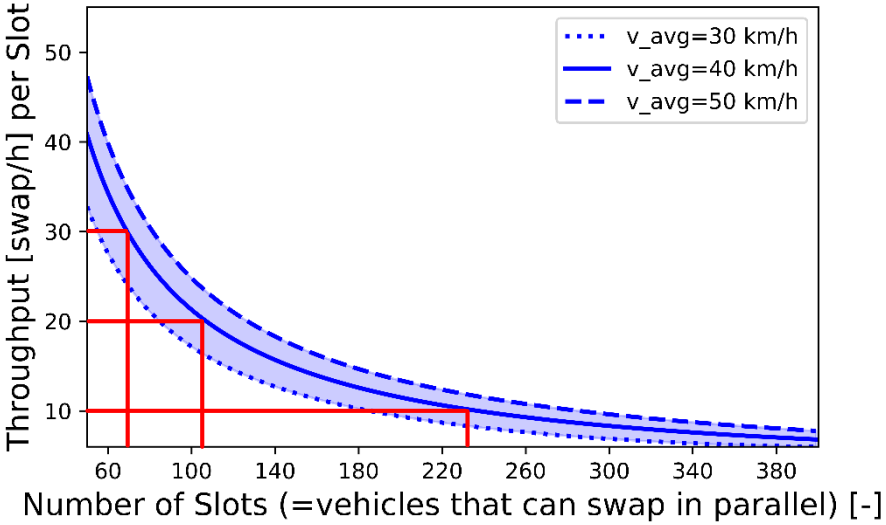
Congestion in battery swapping stations

Waiting for max. 30 minutes per day

Scenario 1: Today's batteries, 6 Swaps, 50 kW



Scenario 3: Better batteries, 3 Swaps, 50 kW



All Scenarios Compared

	Scenario	Battery Cell Density [Wh/kg]	Charging Power [kW]	Daily Swaps Allowed
1	Battery Swaps	240	50	6
2	Better Batteries + Very Fast Charging	1’650	200	0
3	Battery Swaps + Better Batteries	415	50	3

	Scenario 1	Scenario 2	Scenario 3
Peak Power Demand (Best Case) [MW]	715	1’018	827
Peak Power Demand (Worst Case) [MW]	2’405	8’391	2’296
Annual Electricity Demand [GWh]	2’773	2’740	2’783
Maximum Extra Battery Demand	28’796	-	11’422
Swapping Stations Needed (3 min/swap)	250	-	105

Conclusions and Outlook

→ Truck electrification is extremely hard compared to passenger cars, but still possible.

→ The level of demand on infrastructure depends heavily on the way electrification is achieved.

→ To make electrification possible from the infrastructure perspective, battery technologies should develop together with battery swapping technologies.

→ The same study is also being performed for fuel cell or plug-in hybrid vehicles (the next publication).

→ Model will be further developed to include the spatial component (future work).

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Thank you for your attention