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Economic and environmental assessment of different battery technologies for different grid network applications

Prof. Dr. Tobias Schmidt, Energy Politics Group, ETH Zurich; 68th LCA Discussion Forum, April 15, 2018

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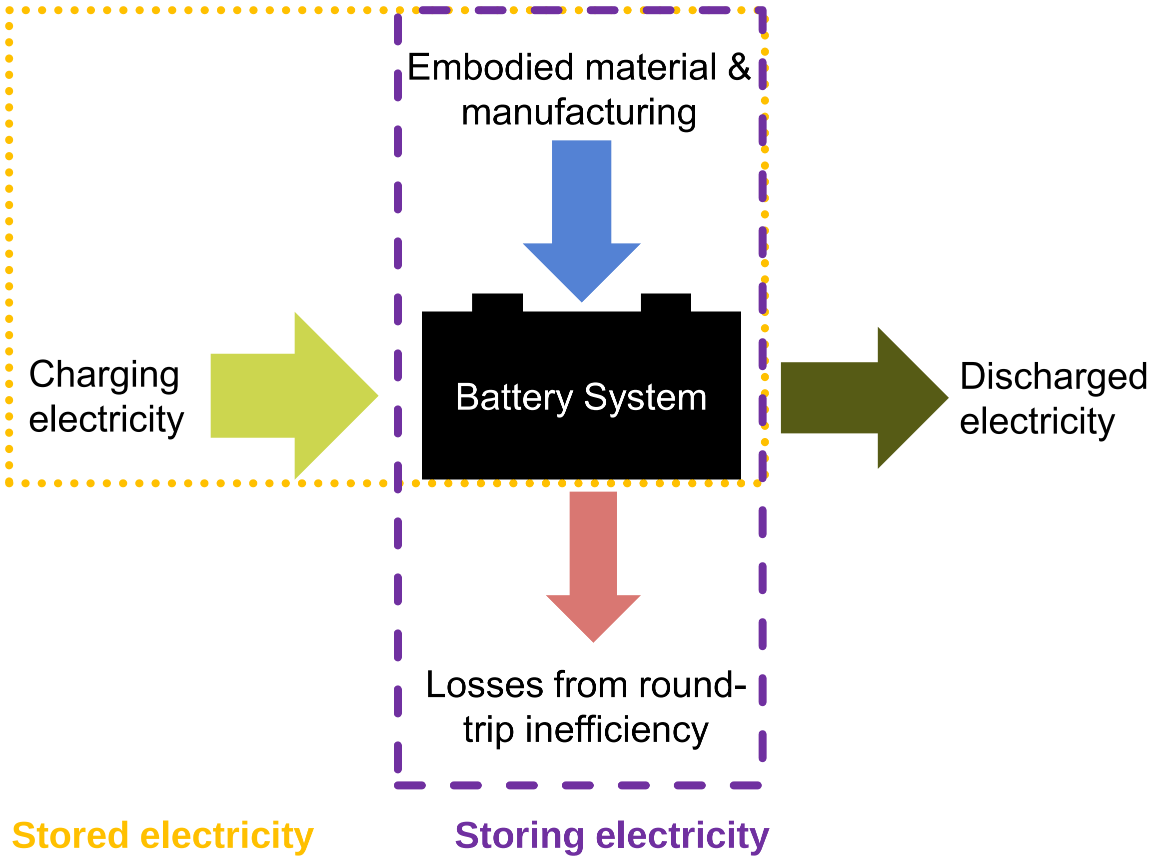
To which extent can stationary battery systems support the transition to a low-cost, decarbonized electricity sector?

- Stationary batteries as potential technological lever enabling high shares of intermittent RE
- But the ***additional*** use of batteries leads to ***additional*** **emissions** and **cost**
- There might be **potential trade-offs** between emissions and cost dimensions (e.g., between technologies)
- Very few studies have analyzed life-cycle emissions (LCE) and cost (LCC) consistently
- They analyze the cost of ***stored*** electricity, but we are interested in the ***additional*** LCE and LCC that stem from ***storing*** electricity in a battery storage system
- Effect of **geography** on LCE and LCC is also hardly analyzed
- **Comparisons** thus far rather arbitrary

RQ: How do the additional LCE and LCC of leading battery technologies compare that are caused by storing electricity in different grid applications and geographies?



We perform a consistent assessment of 6 battery technologies in 5 different applications and three geographies

Technologies:

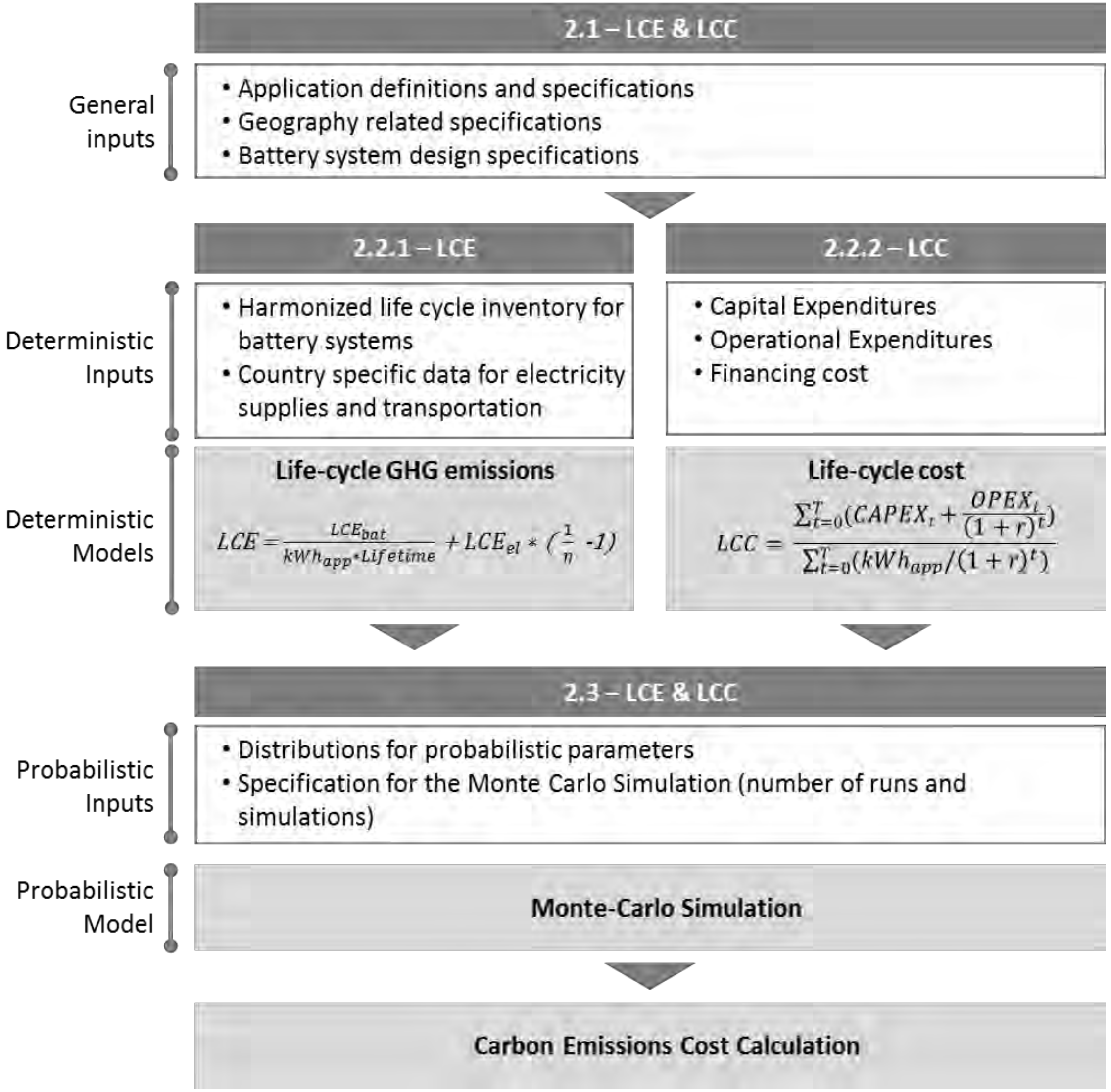
- Lithium-ion anode materials:
  - lithium iron phosphate (LFP)
  - lithium titanium oxide (LTO)
  - lithium nickel cobalt aluminum oxide (NCA)
  - lithium nickel manganese cobalt oxide (NMC)
- Vanadium Redox Flow (VRF)
- Lead-Acid (VRF/PB)

Applications:

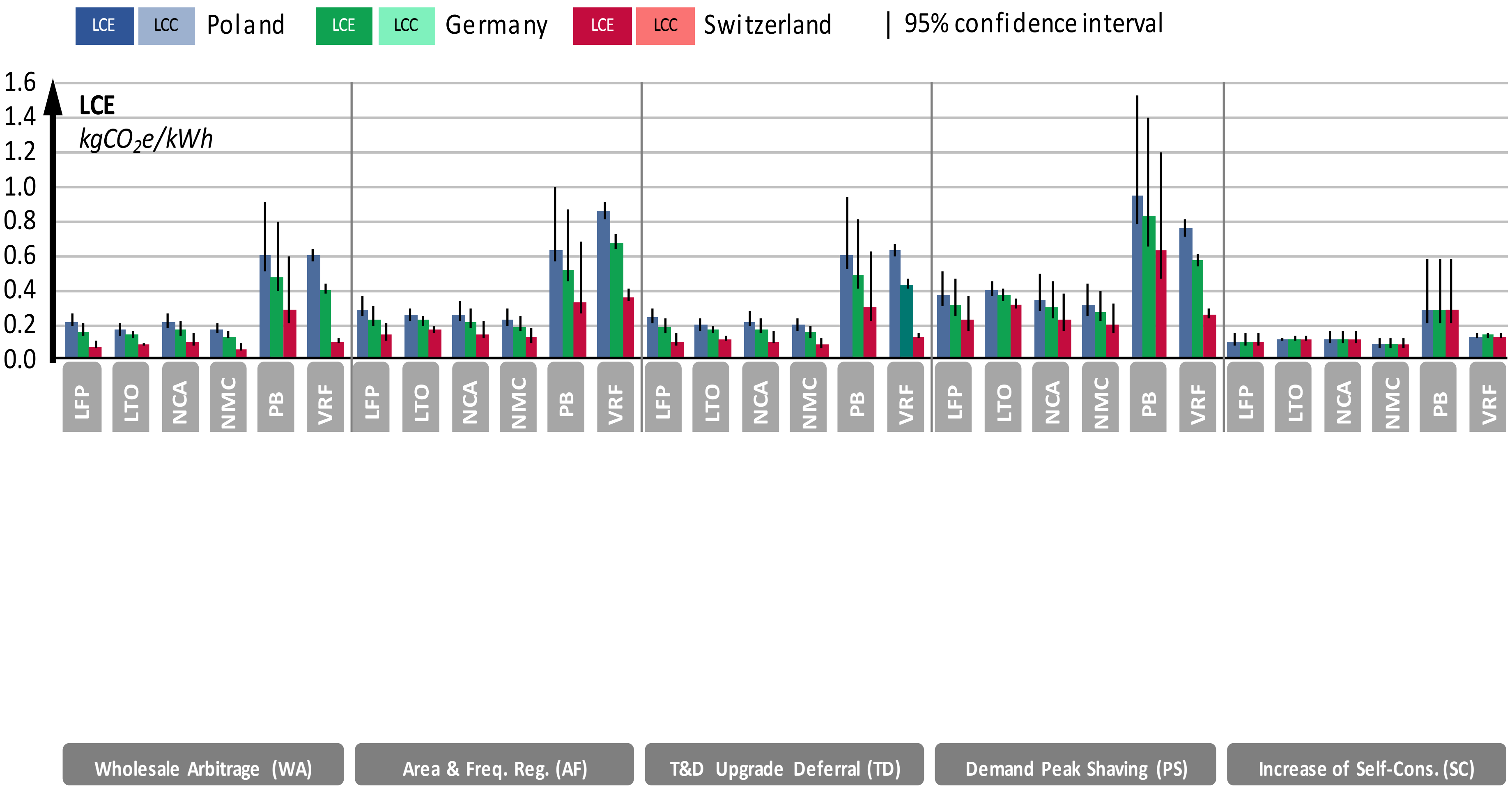
- Wholesale Arbitrage (WA)
- Area & Frequency Regulation (AF)
- Transmission & Distribution Grid Upgrade Deferral (TD)
- Demand Peak Shaving (PS)
- Increase of PV electricity Self-Consumption (SC)

Countries:

- Poland (high emissions, low cost of electricity)
- Switzerland (low emissions, high cost of electricity)
- Germany (in between)



Results 1: Life-cycle emissions (LCE) and cost (LCC) by battery technology and application



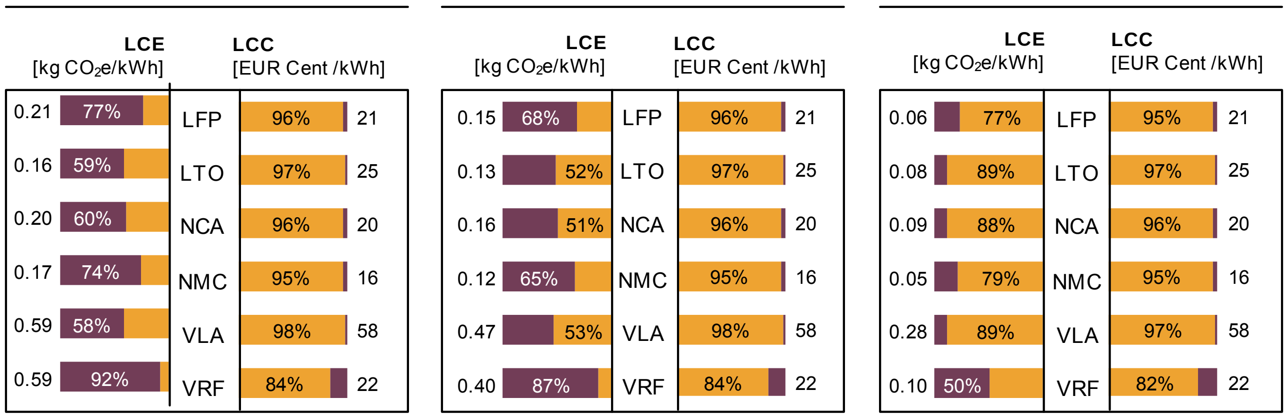
- Major between-application differences
- Major between-country differences regarding LCE
- Mostly between-technology differences regarding LCC

Results 1: Contributions of the manufacturing- and use-phase

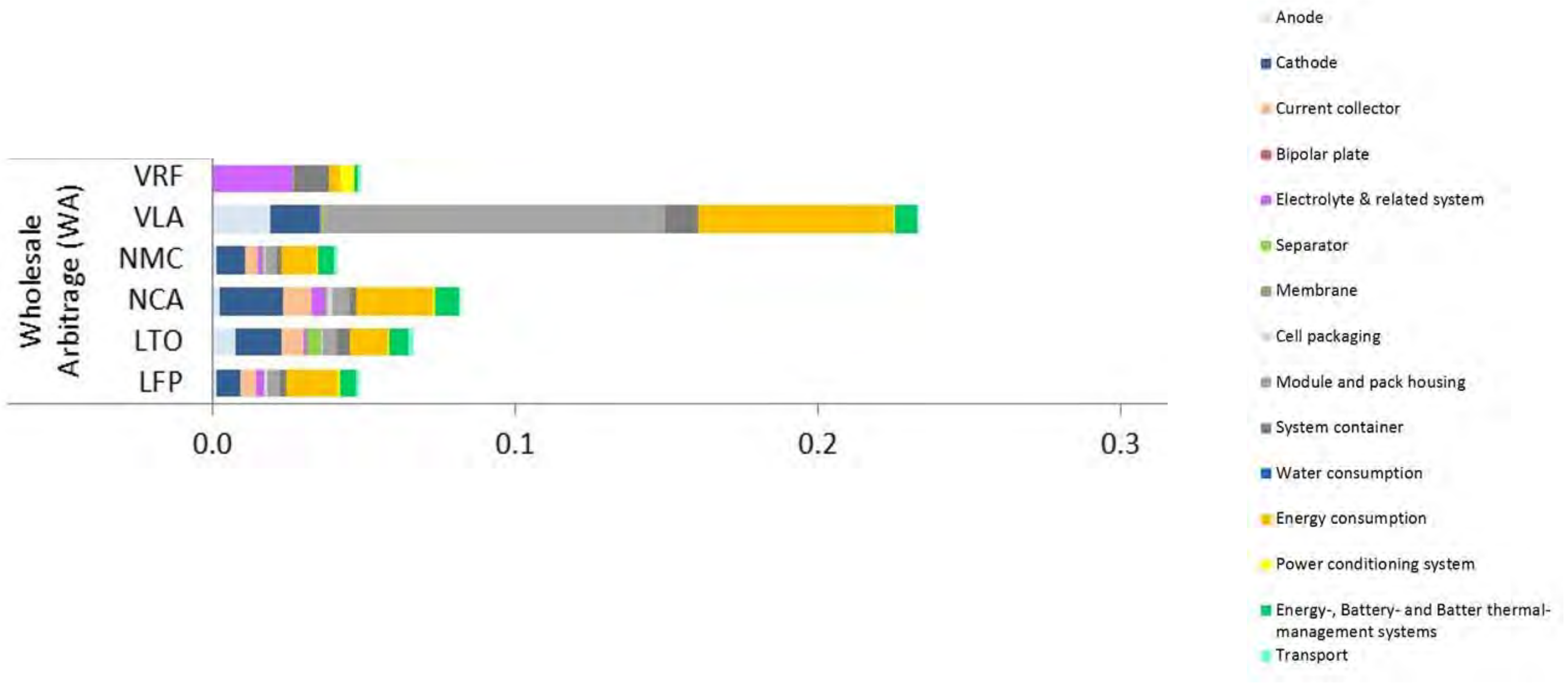
Pre-use phase (incl. Integration, logistics, replacement)

Use Phase

Wholesale Arbitrage (WA)



Results 3: Contribution of manufacturing-related emissions to LCE



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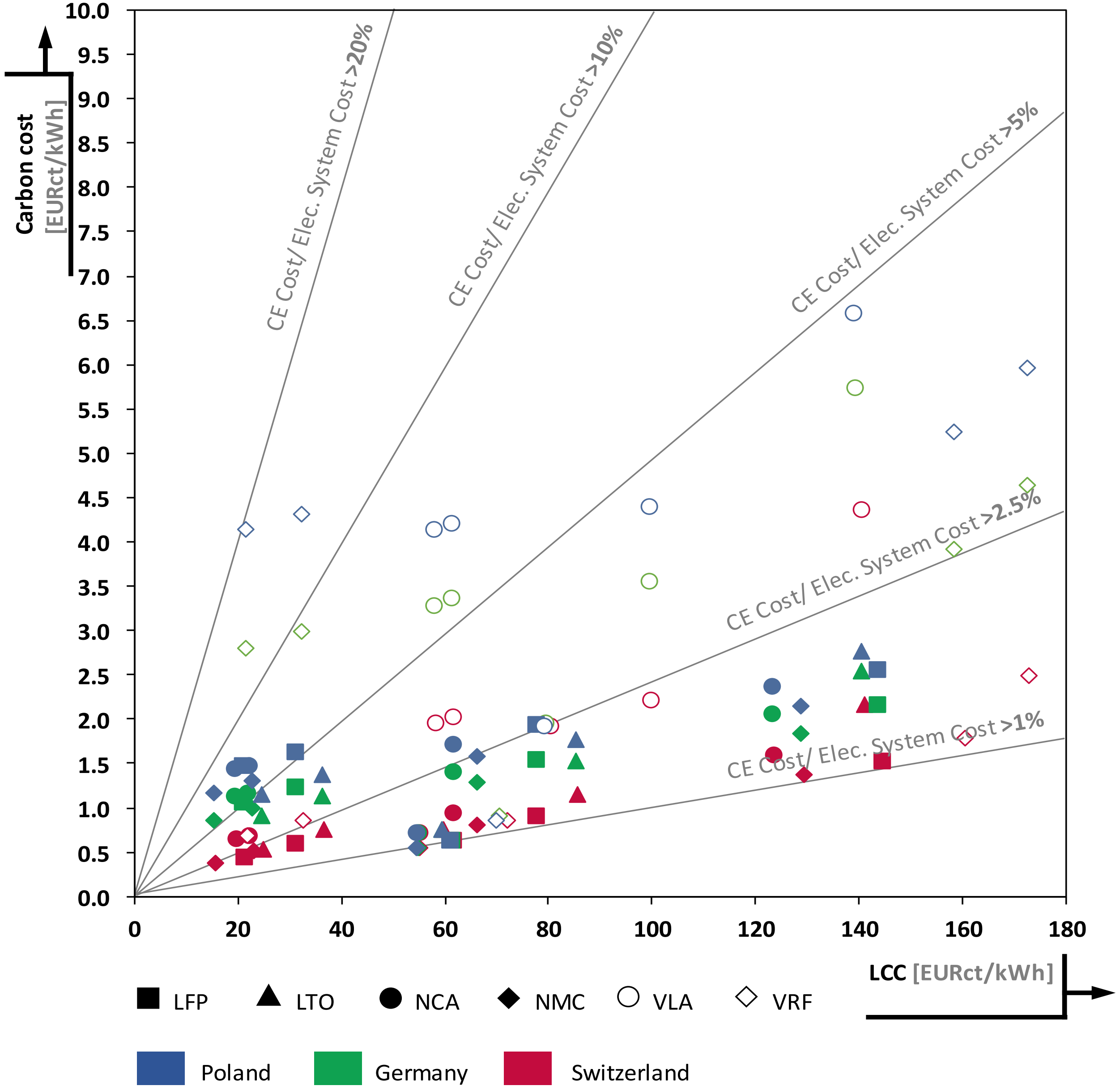
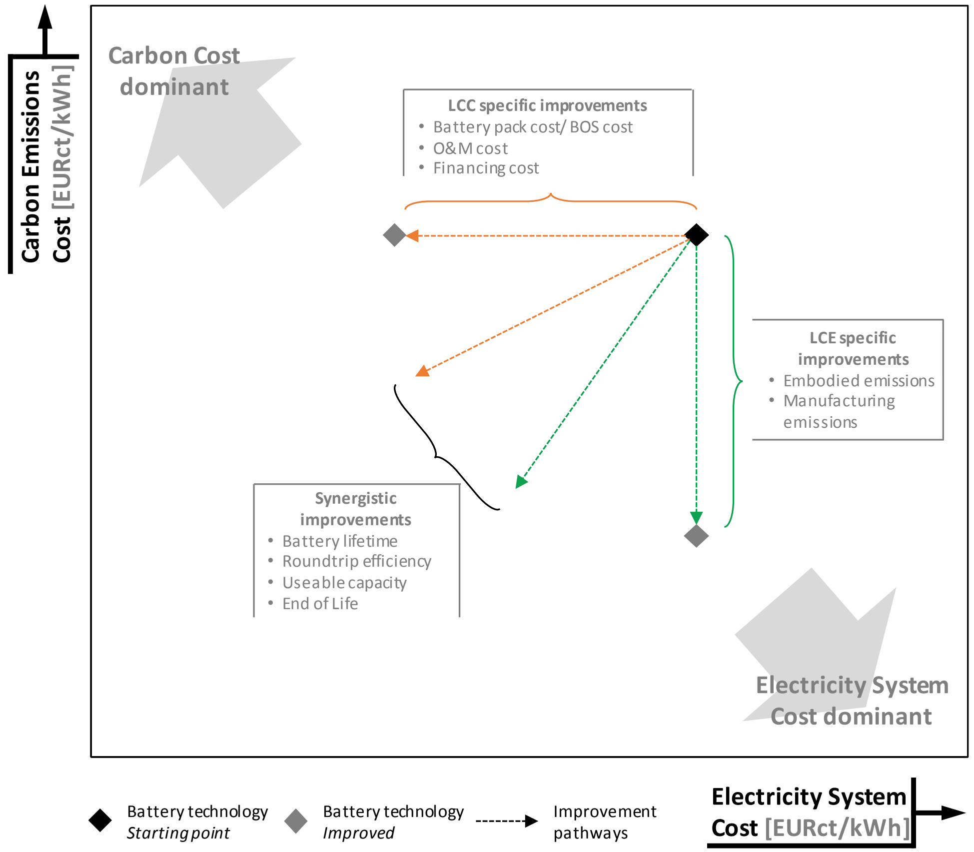
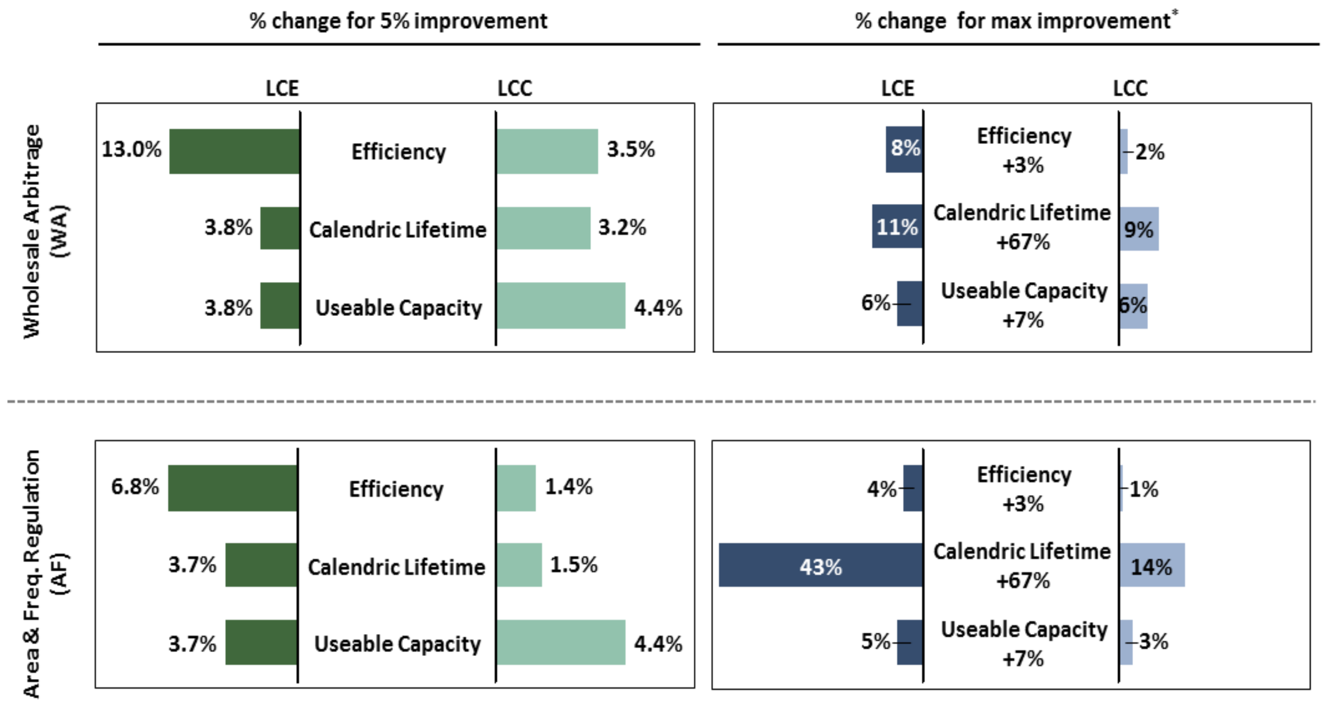
Results 4: Comparison of carbon and life-cycle cost of storing electricity in battery systems



Discussion: What are levers to further improvements be achieved along both dimension?





*Maximum of range described in the distribution per parameter

Thank you for your attention!

For more information please see
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Table 1 Common specification of battery applications which are assumed for our LCE and LCC analyses.

Abbr.	Application	Site	Power delivered per cycle [kW]	Energy delivered per cycle [kWh]	Energy-to-Power Ratio	Usage [#cycles p.a.]	Energy delivered [kWh p.a.]
WA	*Wholesale Arbitrage*	*Generation/ Grid site*	10,000	60,000	6	365	21,900,000
AF	*Area & Freq. Regulation*	*Generation/ Grid site*	10,000	5,000	0.5	176	880,000
TD	*T&D Upgrade Deferral*	*Grid site*	10,000	50,000	5	250	12,500,000
PS	*Demand Peak Shaving*	*C&I sites*	125	250	2	104	26,071
SC	*Increase of Self-Consumption*	*Residential end-consumer*	2.5	5	2	250	1,250

Abbr.	Item/ Application	Units	Poland	Germany	Switzerland
WA	*Wholesale Arbitrage*	kg CO_2e/kWh	1.043	0.673	0.094
		EUR cent/kWh	3	2.9	3.8
AF	*Area & Freq. Regulation*	kg CO_2e/kWh	1.043	0.673	0.094
		EUR cent/kWh	3	2.9	3.8
TD	*T&D Upgrade Deferral*	kg CO_2e/kWh	1.043	0.673	0.094
		EUR cent/kWh	3	2.9	3.8
PS	*Demand Peak Shaving*	kg CO_2e/kWh	1.043	0.673	0.094
		EUR cent/kWh	7.6	7.9	12.3
SC	*Increase of Self-Consumption*	kg CO_2e/kWh	0.091	0.101	0.095
		EUR cent/kWh	11	12	15