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Environmental sustainability potentials of electric vehicles' batteries

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- Introduction & objective
- Innovations in Li-ion batteries (LIB)
- Potential environmental impacts of introducing such innovations
- Conclusions & outlook

Introduction & objective

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https://iopscience.iop.org/journal/1748-9326/page/Climate_Change_Air_Pollution
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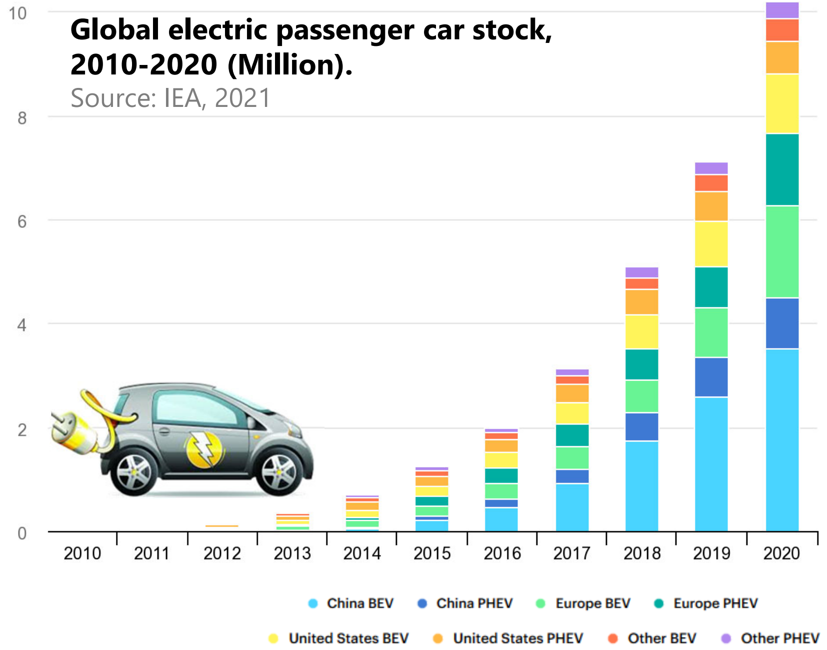
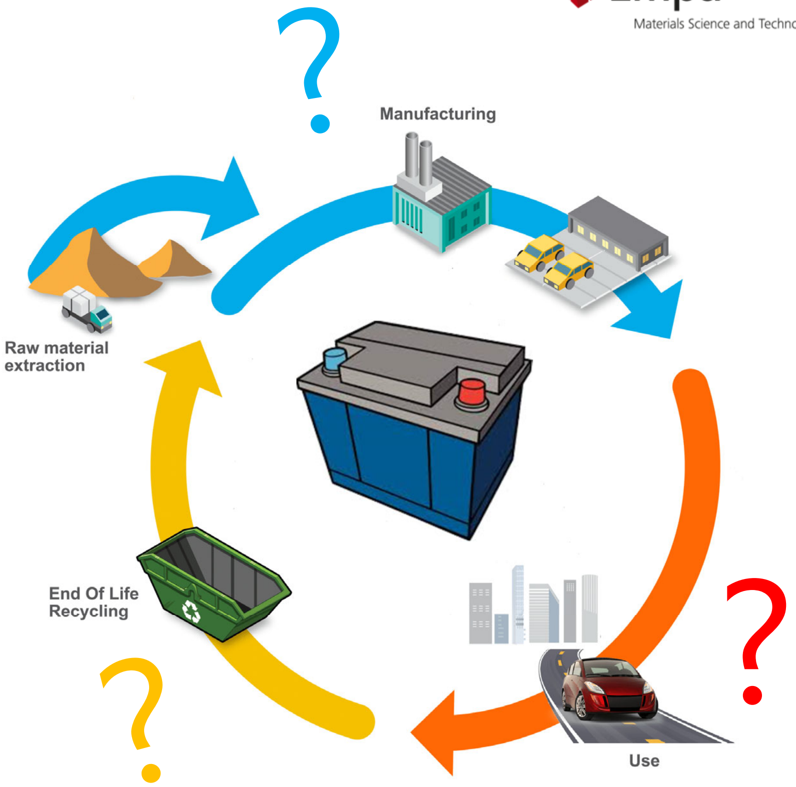


...However, the sustainability of batteries is still controversially discussed !

Objective

- To quantify the environmental impacts of new technological advancements (“**innovations**”) through life cycle assessment (LCA) and evaluate their **maximum potential** for the mobility sector for the near future



LCA adapted from www.worldautosteel.org

Innovations in Li-ion batteries

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1. **Chemical composition**: LFP vs NMC and NCA
   ⇨ LFP is chosen as promising chemistry for next generation batteries, because Co-free and already subject of interest in many companies (used in China, BYD is working on it…)

2. **Energy optimized process**: towards solvent-free electrodes
   ⇨ potentiality of reducing energy demand and emissions of toxic substances

3. **Use of electricity from renewable sources**: PV scenarios
   ⇨ potentiality of reducing emissions of GHG

1. Potential environmental impacts of LFP vs NMC and NCA battery cells

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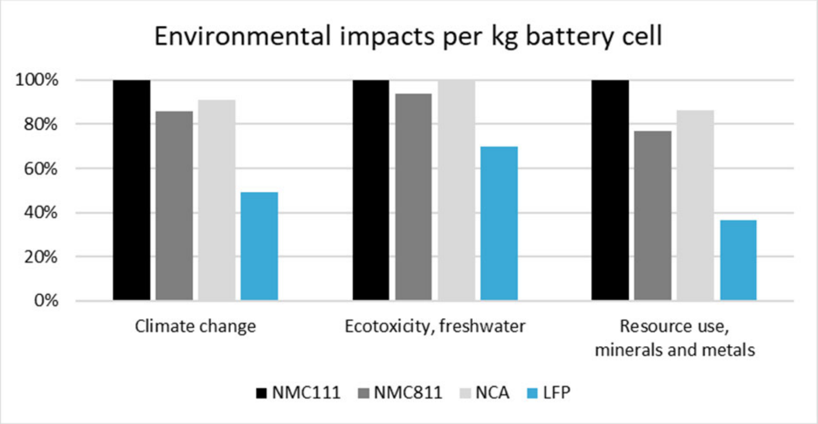
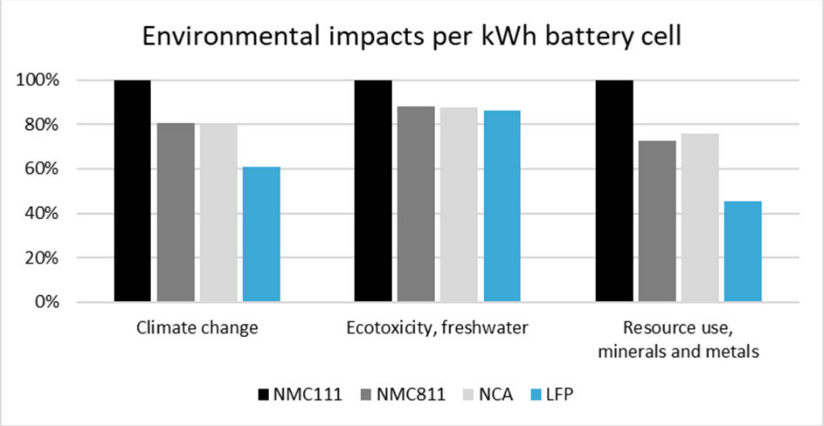
- Impact assessment method: EF v.3
- 3 selected impact categories based on their relevance
- Battery cells characteristics:

	NMC111	NMC811	NCA	LFP
kg cells/ pack	120	112	105	148
kWh/ kg cell	0.197	0.209	0.224	0.159





NMC111, NMC811 and NCA impact results are updated, compared to the results reported in Crenna et al. (2021): https://doi.org/10.1016/j.resconrec.2021.105619

1. Potential environmental impacts of LFP vs NMC and NCA battery packs

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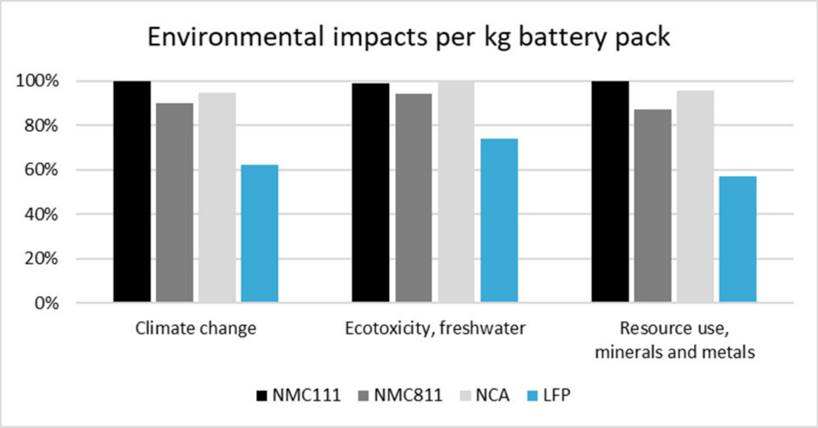
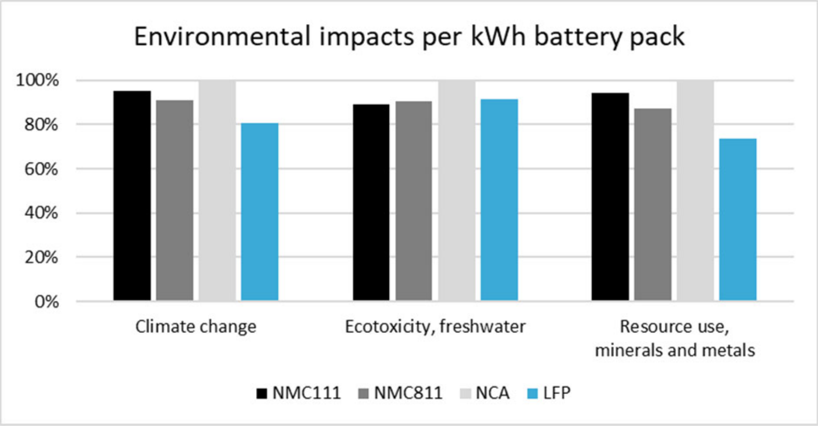
- Impact assessment method: EF v.3
- 3 selected impact categories based on their relevance
- Battery pack characteristics:

	NMC111	NMC811	NCA	LFP
kg pack	165	158	143	203
kWh/ kg pack	0.143	0.149	0.159	0.1159





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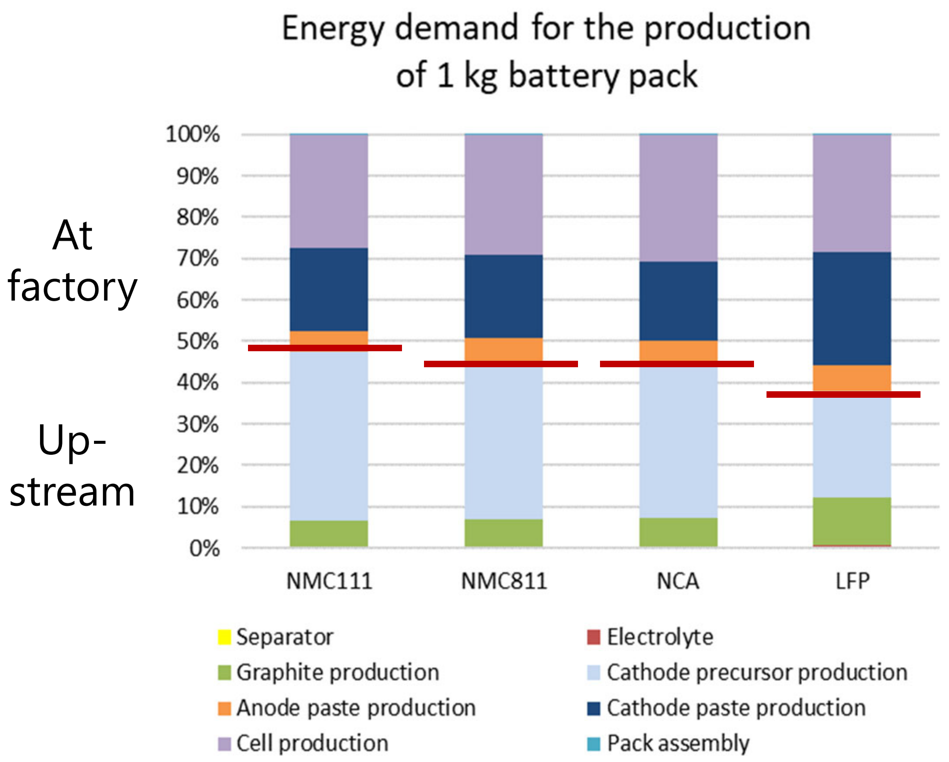
Upstream vs at factory energy demand for LIB

- Definitions:
  - **Upstream production** = production of raw materials & chemicals, e.g. graphite, cathode active material, and others which are bought by the company and used to assemble the battery cell (*from mine to factory*)
  - **At factory production** = production of electrodes, assembly of cells and battery pack within the same factory (*from factory to cell*)

- This is relevant to give an idea of <u>at which point of the value chain to intervene</u> for introducing technological innovations.

Upstream vs at factory energy demand for LIB



LFP battery pack	kWh/kg battery pack
Pack assembly	0.00028
Cell production	2.74
Cathode paste production	2.61
Anode paste production	0.58
Cathode precursor production	2.49
Graphite production	1.10
Electrolyte	0.07
Separator	0.00002

Energy “at factory” is 1.63 times the “upstream”

2. Energy optimized processes

- Two main innovative options to produce electrodes:
  - **Water-based process:** use of water as the solvent eliminates the release of volatile organic compounds (VOCs), while there is still need of thermal energy for evaporate the solvent.
  - **Dry process:** solvent-free technology with electrostatic spray deposition of the active material onto the current collector + hot rolling process. This eliminates the release of VOCs and reduces thermal energy consumption.

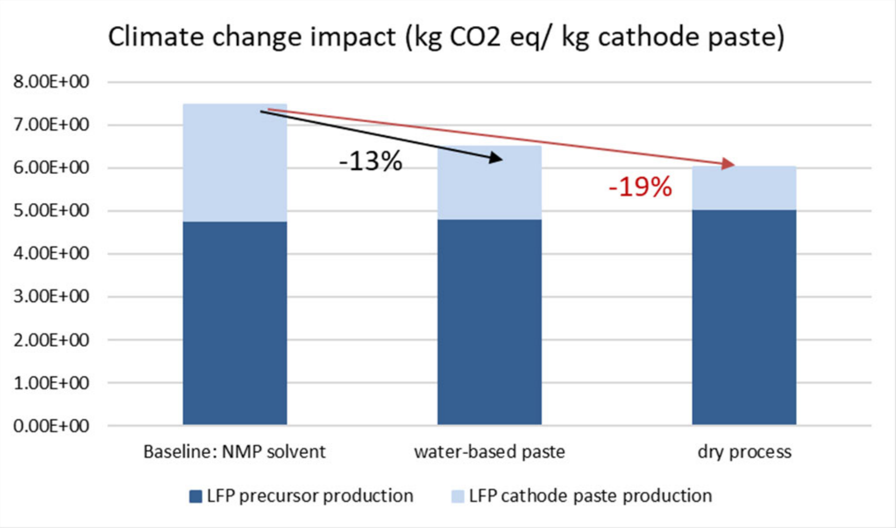
"**Extreme case**" modelling:

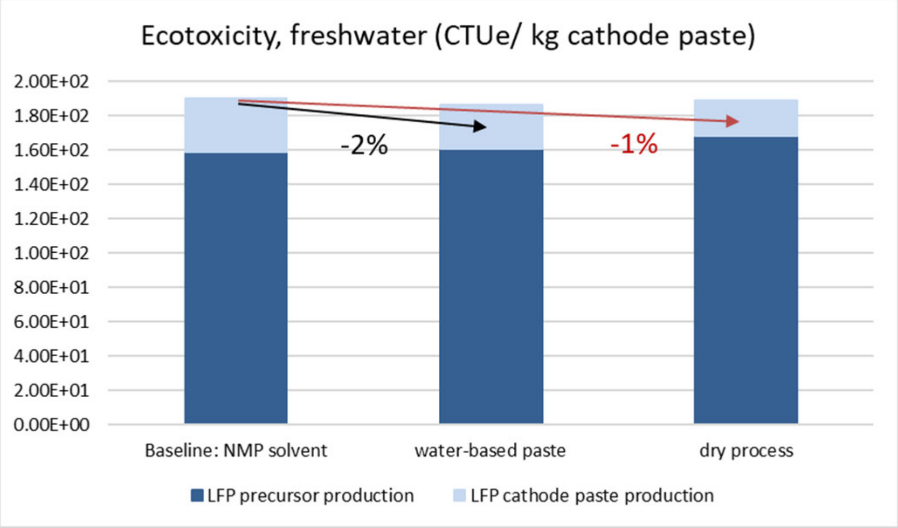
⇨ no thermal energy consumption in dry process

☝ A little amount of thermal energy might be needed for the hot rolling step; however we consider it negligible to assess maximum potential saving

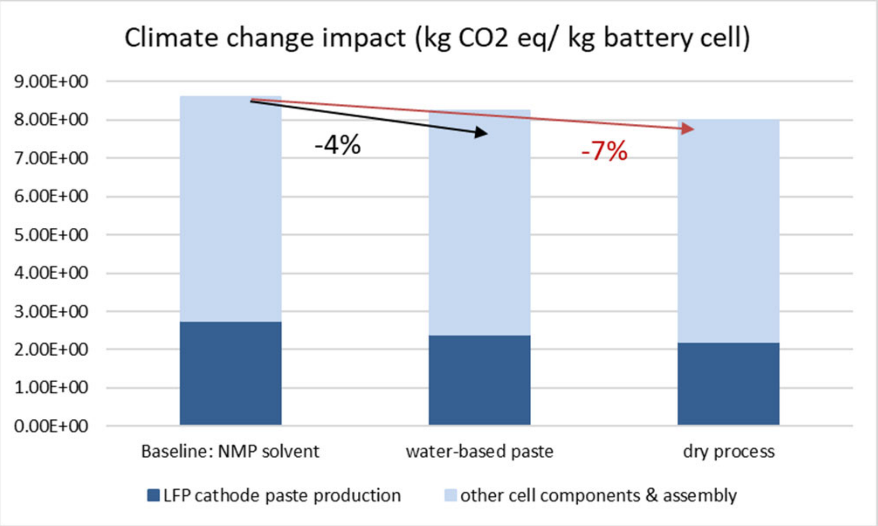
2. Potential environmental impact of energy optimized processes (cathode level)

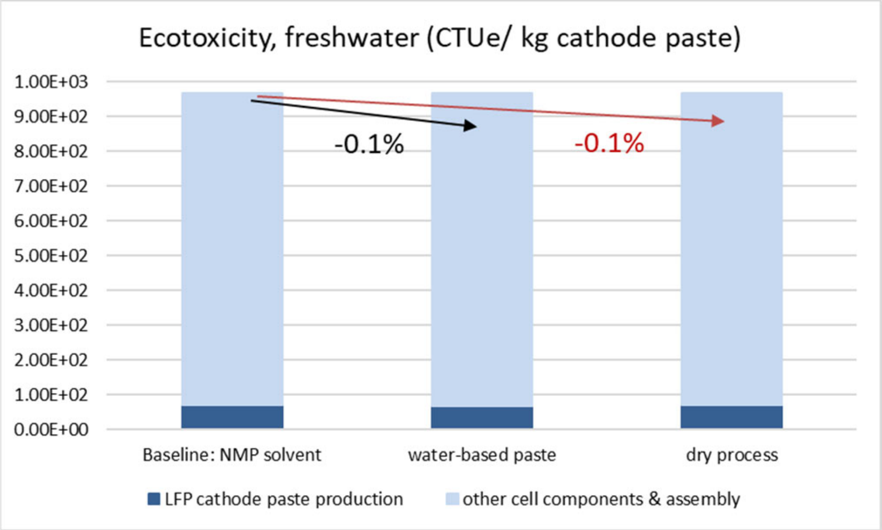
	LiFePO4	Binder	CB	solvent
Cathode, LFP (baseline)	89%	PVDF: 5%	6%	NMP
Cathode, LFP (water-based slurry)	90%	CMC: 2%, SBR: 3%	5%	water
Cathode, LFP (dry process)	94%	PVDF: 3%	3%	n.a.





2. Potential environmental impact of energy optimized processes (cell level)





3. Potential environmental impacts of using renewable based electricity supply

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- Chosen scenarios :
  - Baseline: Chinese (CN) electricity mix along the whole value chain
  - Average European (RER) electricity mix at factory for electrode production and final cell assembly
  - Electricity from photovoltaics (PV) from Guangdong & Jiangxi regions in China for electrode production and final cell assembly
  - Electricity from photovoltaics (PV) from Guangdong & Jiangxi regions in China for production of upstream chemicals, electrode production and final cell assembly

Increase use of renewables ↓

3. Potential environmental impacts of using renewable based electricity supply

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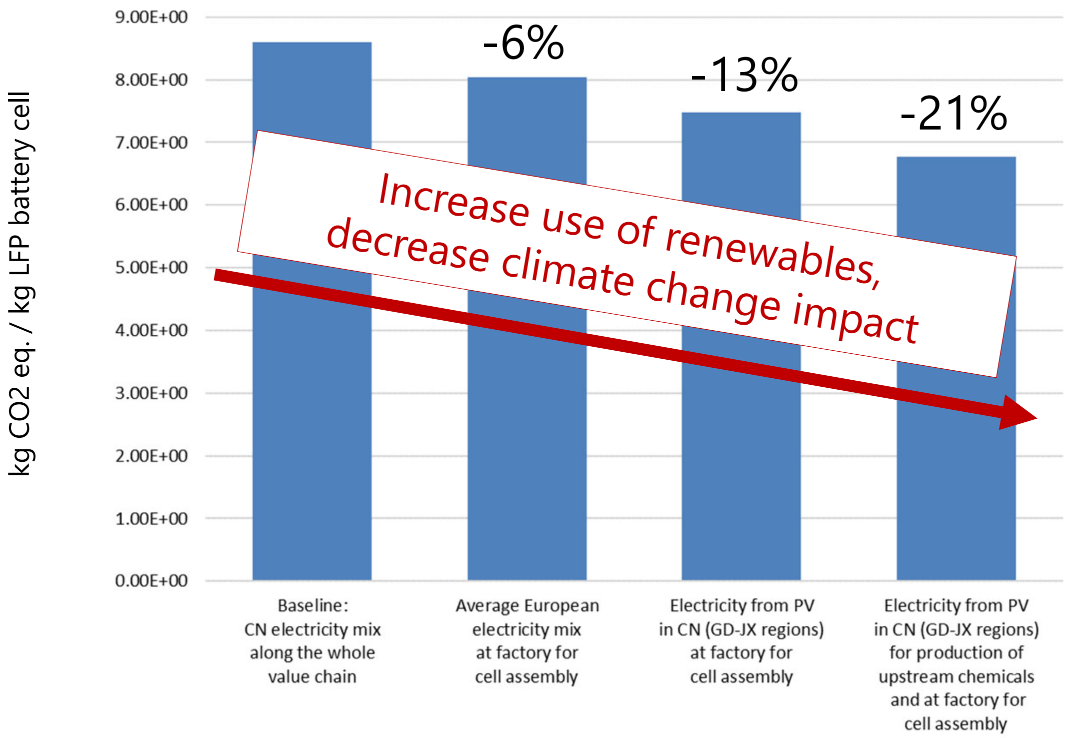

What if all innovations occur together?

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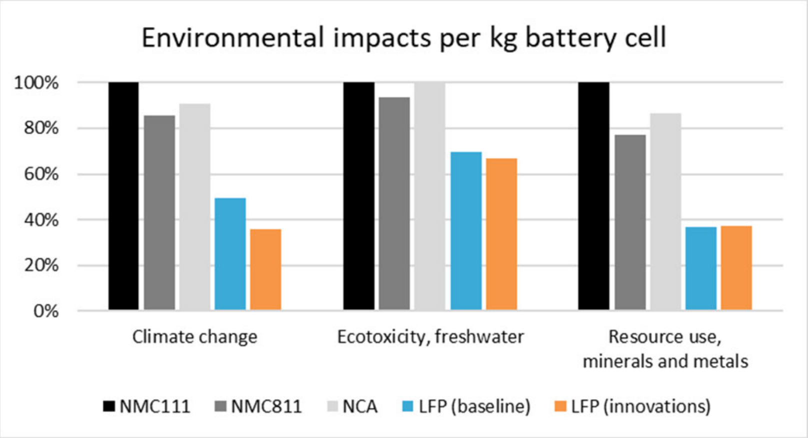
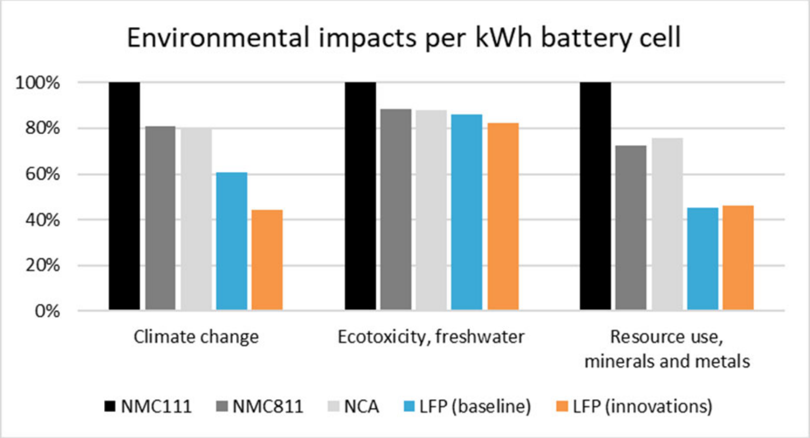
- Per kg battery cell:
  - up to max. potential 64% reduction in climate change impact compared to NMC111
  - up to max. potential 33% reduction in ecotoxicity impact compared to NMC111 and NCA
  - up to max. potential 63% reduction in resource depletion compared to NMC111





* PV as innovation, used for supplying energy to electrode production and cell assembly at factory

Conclusions & outlook

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- Do such innovations really matter for improving the environmental performance of LIB?

....YES, THEY DO! But...

- We have explored the **maximum potential for environmental impact reduction** based on the available numbers from studies, reports, our knowledge, etc.... Further progress is to be expected. We are open to inputs and suggestions to make this inventory even more realistic and up-to-date.

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Thank you for your attention!

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