VOLKSWAGEN

AKTIENGESELLSCHAFT

GROUP RESEARCH

AN LCA COMPARISON OF POWERTRAINS AND FUELS

TODAY AND 2030

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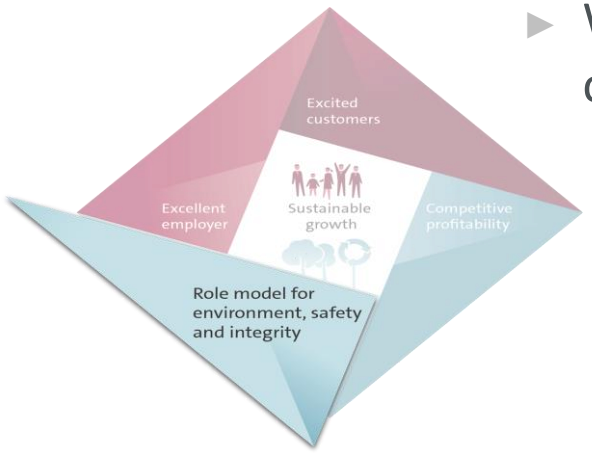
VOLKSWAGEN – CHALLENGES OF THE FUTURE AND OUR STRATEGY

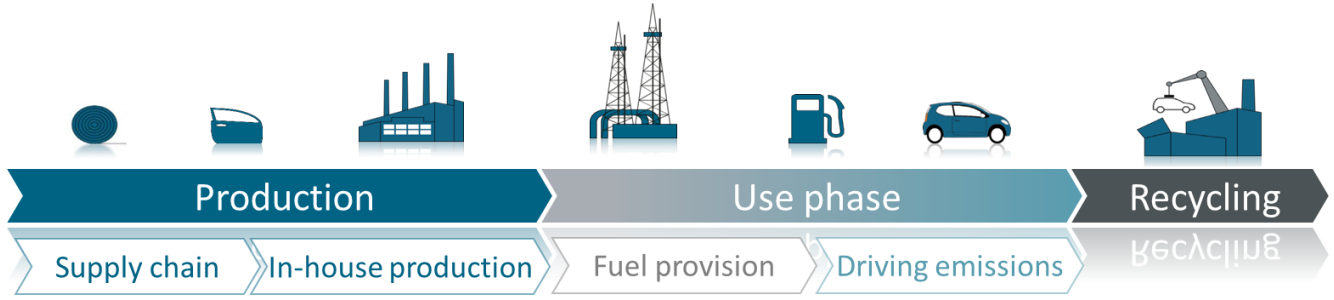
Challenges

- **Key factors of the future:** decarbonization, scarcity of resources, increasing legal requirements.
- Increasing expectations regarding the environmental performance by **policy, customers, NGOs** and **sustainability ratings**.
- **Resource efficiency** and **Life Cycle Strategy** are central elements.

Strategy Group Research Environment



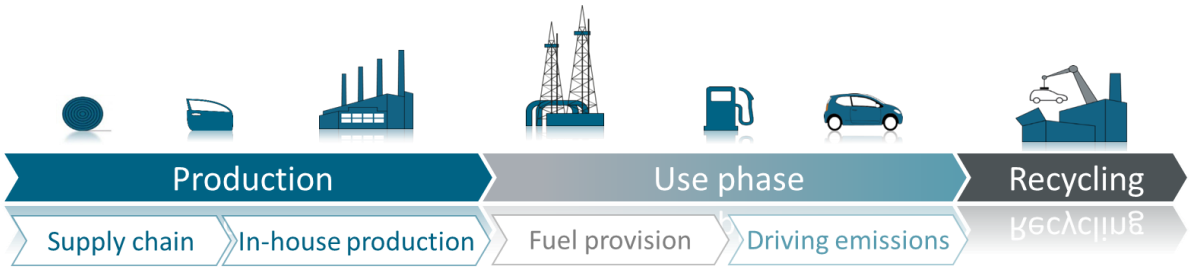
- We improve the environmental properties in all value-added steps, thus contributing to the Strategy 2025 „leading provider **of sustainable mobility**“



LCA COMPARISON OF DIFFERENT POWERTRAINS AND FUELS

RESEARCH QUESTIONS

- What is an appropriate basis of comparison when comparing CO_2 emissions over lifecycle for different powertrain technologies?
- What are the potentials for reducing future CO_2 emissions?
- What are the main drivers for unlocking those CO_2 reduction potentials?

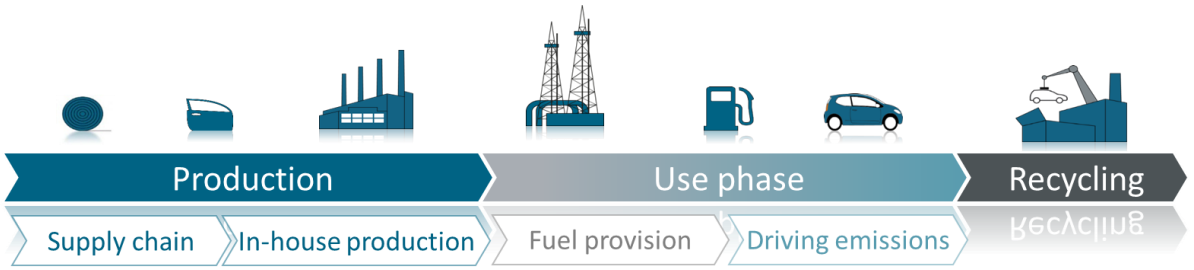


APPROACH

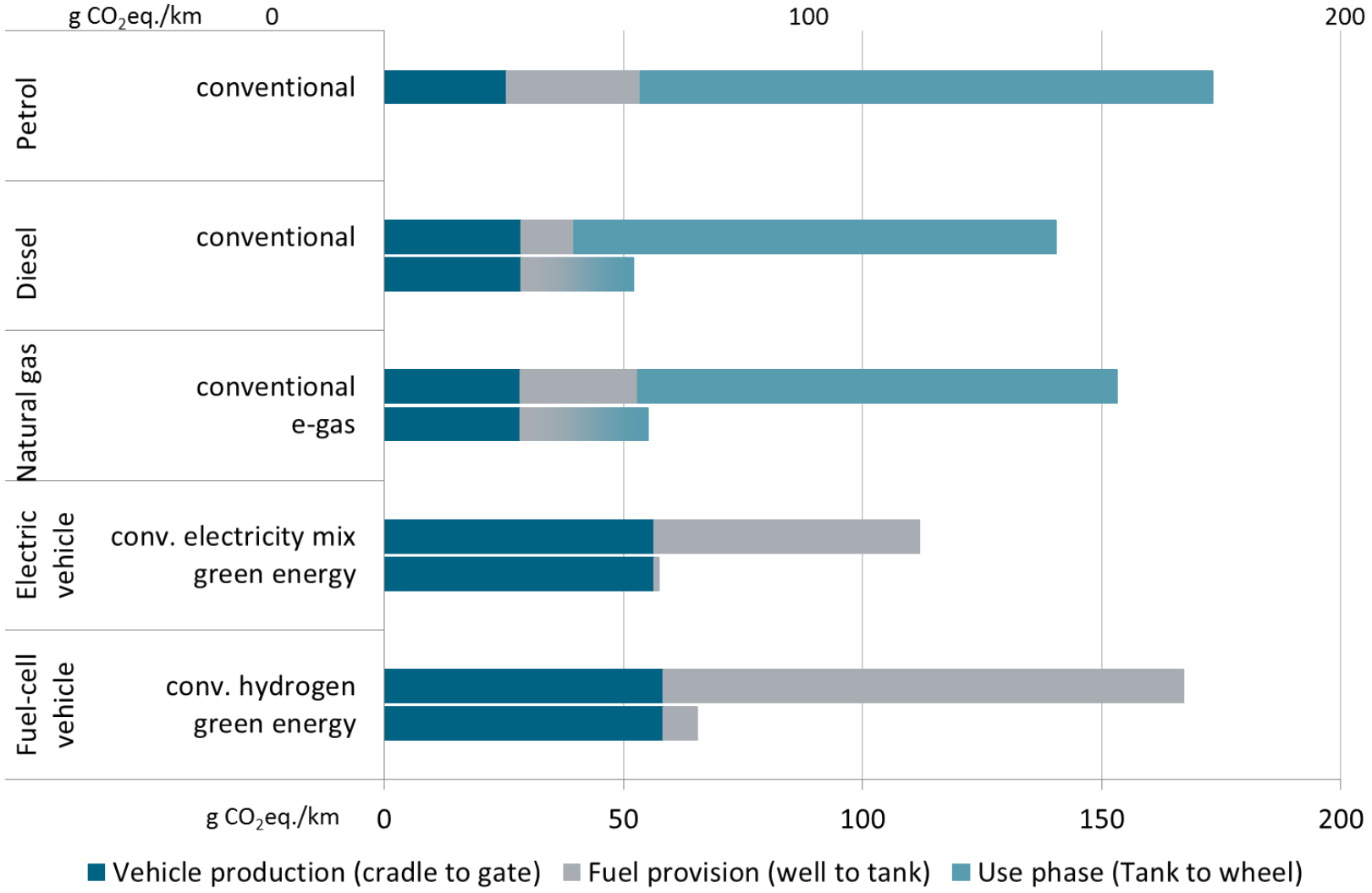
- New methodological approach for making different powertrain types comparable:
  Driving simulations based on similar Performance Feel Index (i.e. independently from the powertrain concept, the user's driving experience stays the same)

- Based on that, comparison of CO_2 emissions over lifecycle of conventional and electrified powertrains for today and 2030.

- Identify the main drivers for future CO_2 improvement over lifecycle.



CO_2 PROFILE OF POWERTRAINS AND FUELS – TODAY



Underlying assumptions

Vehicle base
Golf VII 2017; production, use (200,000 km, WLTC) and recycling in EU

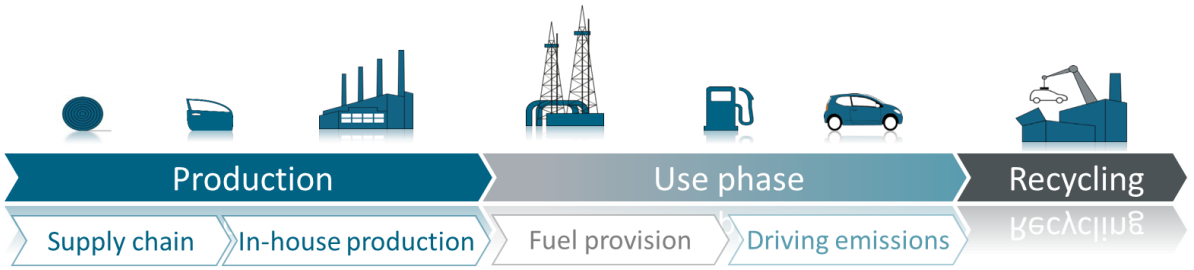
Compressed Natural Gas Vehicle (CNG)
Bivalent, CFK gas tanks

Battery-electric Vehicle (BEV)
Current lithium-ion battery, Range 300 km

Fuel-Cell Electric Vehicle (FCEV)
Fuel-cell stack: current research state

MAIN DRIVERS FOR EFFICIENCY IMPROVEMENT

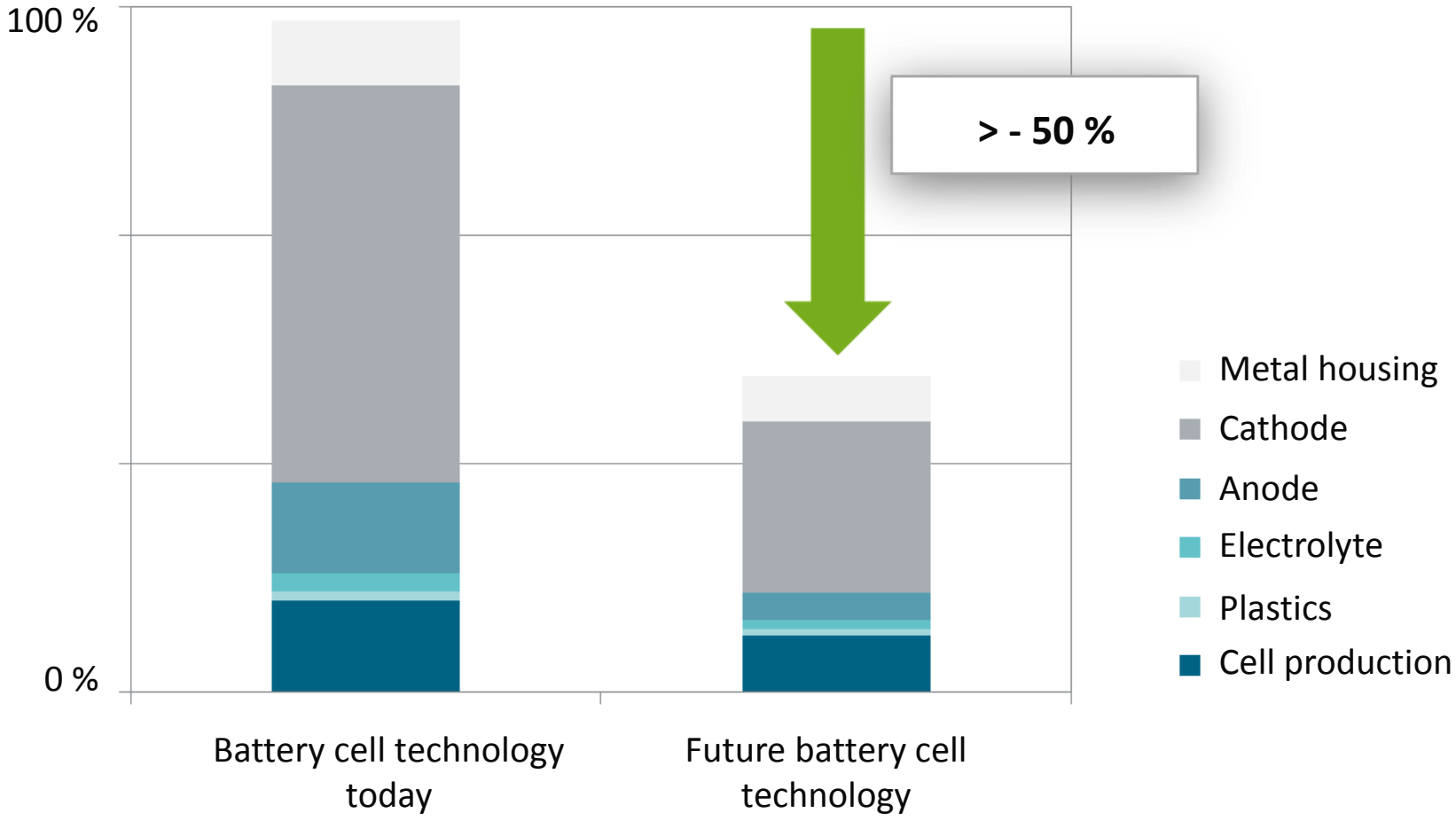
Production phase	▶ New battery technology (increased energy density)
Use Phase	▶ Improvements in powertrain efficiency and weight ▶ Mild hybridization of conventional powertrain systems
Fuel/Energy Provision	▶ Switch fuel provision to regenerative fuels/energy carriers



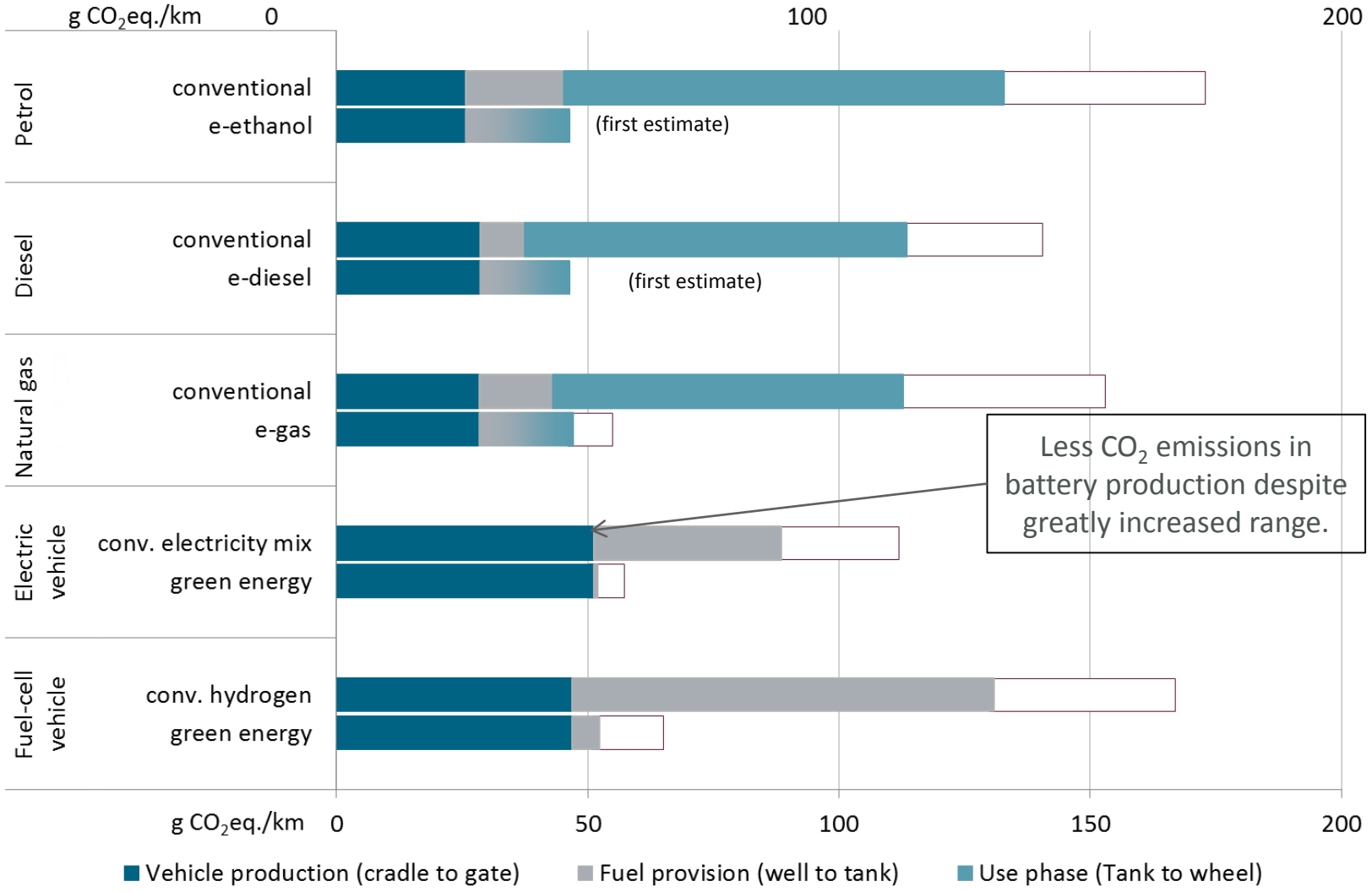
EXCURSION: CO_2 REDUCTION POTENTIALS E-MOBILITY

IMPACT OF NEW CELL TECHNOLOGY NMC 8-1-1

- Specific CO_2 emissions in battery production are expected to decrease by more than 50 % with future battery cell technology (NMC 8-1-1).
- Main driver: Substitution of cobalt by nickel, leading to a significant energy density increase.



CO_2 PROFILE OF POWERTRAINS AND FUELS – TECHNICAL POTENTIALS 2030



Underlying assumptions

Vehicle base
Golf VII 2017; production, use (200,000 km , WLTC) and recycling in EU

Compressed Natural Gas Vehicle (CNG)
Monovalent, CFK gas tanks

Battery-electric Vehicle (BEV)
Future lithium-ion battery technology;
Range 500 km

Fuel-Cell Electric Vehicle (FCEV)
Platinum-reduced fuel-cell stack

2017

CONCLUSION

- All powertrain systems still have potential for significant improvement.
- For all powertrain technologies, the use of green energy/fuels needs to be established.
- For electrified powertrains, CO_2 emissions shift to the production phase, making reduction efforts in this lifecycle phase especially important.

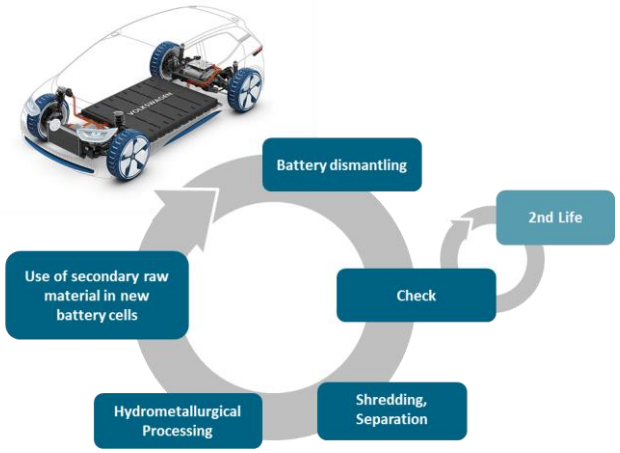
OUTLOOK

Main fields of action for Volkswagen:

- Further efficiency improvements for all powertrains.

- Support the shift to regenerative fuels/energy carriers (e.g. Audi e-fuels).

- For electrified powertrains, reduce CO_2 footprint in the production phase by:
  - Energy-efficient in-house production processes
  - Use of (raw) materials with an optimized carbon footprint
  - Closed-loop recycling of lithium-ion batteries
    (CO_2 reduction potential: approx. -20 % for battery production)



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