Enabling a Greener Environment With Reduced Vehicle Lifecycle Costs and CO_2 Emissions

M. Rothbart

Today’s Presenter

Martin Rothbart
Senior Product Manager Energy & Sustainability

24 years of experience in
automotive industry

5 years responsible for business development
and lifecycle sustainability

Enabling a Greener Environment

About Us

AVL at a Glance

1948
Founded

75+
Years of Experience

26
Countries Represented

45
Global Tech and Engineering Centers

12,200
Employees Worldwide

68 %
Engineers and Scientists

10 %
Of Turnover Invested in Inhouse R&D

2,200
Granted Patents in Force

Today’s Agenda

1 **Challenges**

2 **Methods**

3 **Solutions**

4 **Examples**

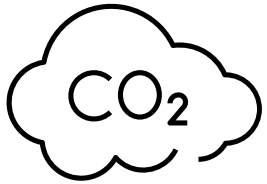
5 **Summary**

Enabling a Greener Environment

Challenges

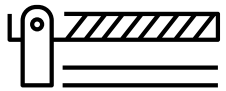
Legislation, Industry and Society Pushing for Decarbonization

Note: Not exhaustive and not all regulations might be relevant for all companies

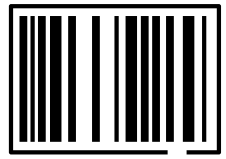


CO_2 tax/penalty

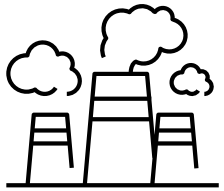
Reporting



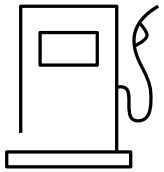
Cross-border adjustment measures



Emission trading scheme

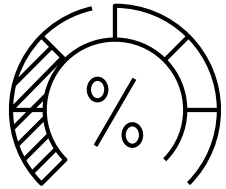


Other GHG emissions than CO_2

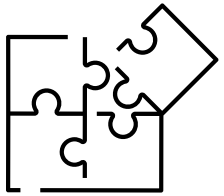


Alternative fuels

CO_2 fleet emissions

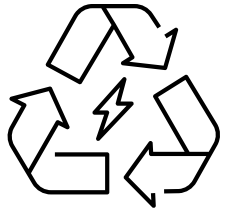


Clean truck and bus regulation



Life-cycle analyses

Battery regulation



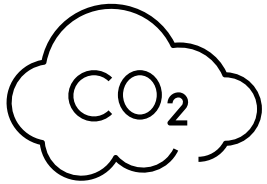
Circular economy

Corporate Sustainability Due Diligence Directive

Legislation, Industry and Society Pushing for Decarbonization

Today's topic

Note: Not exhaustive and not all regulations might be relevant for all companies



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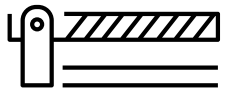

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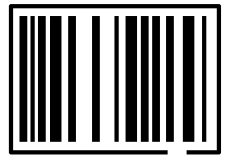

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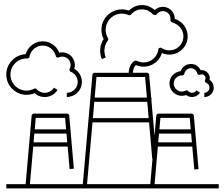
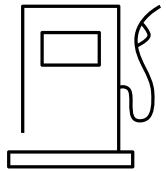


Other GHG emissions than CO_2



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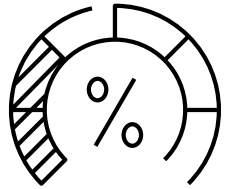

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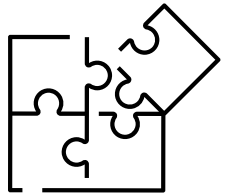

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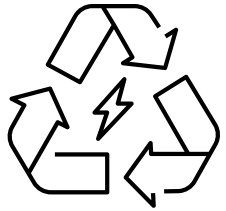
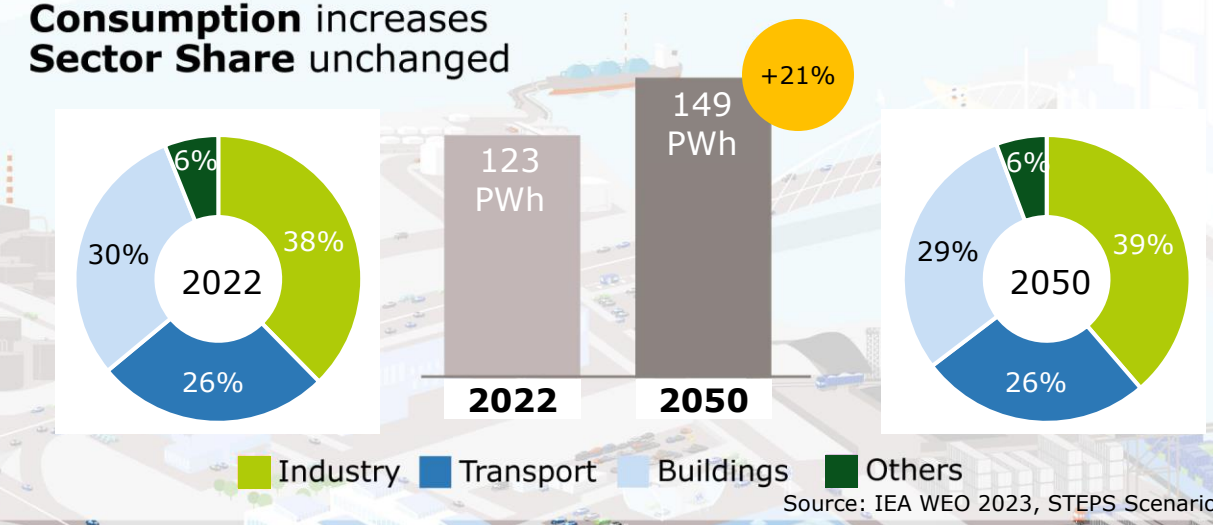
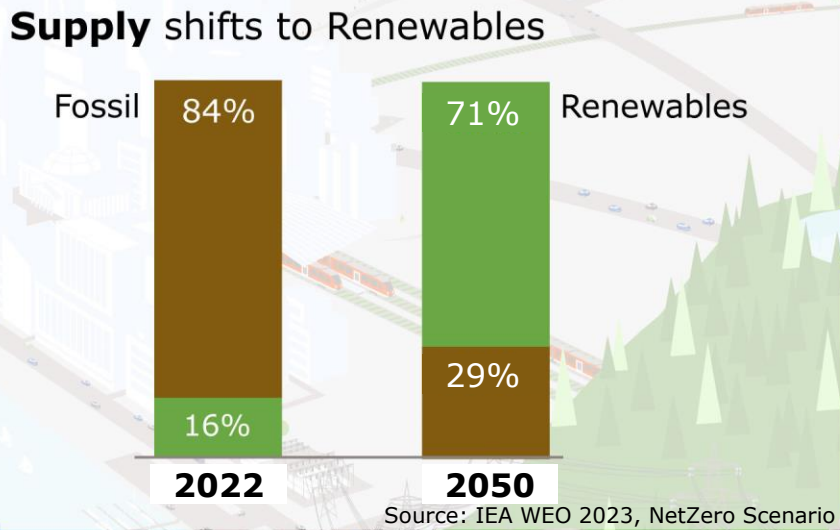


Circular economy

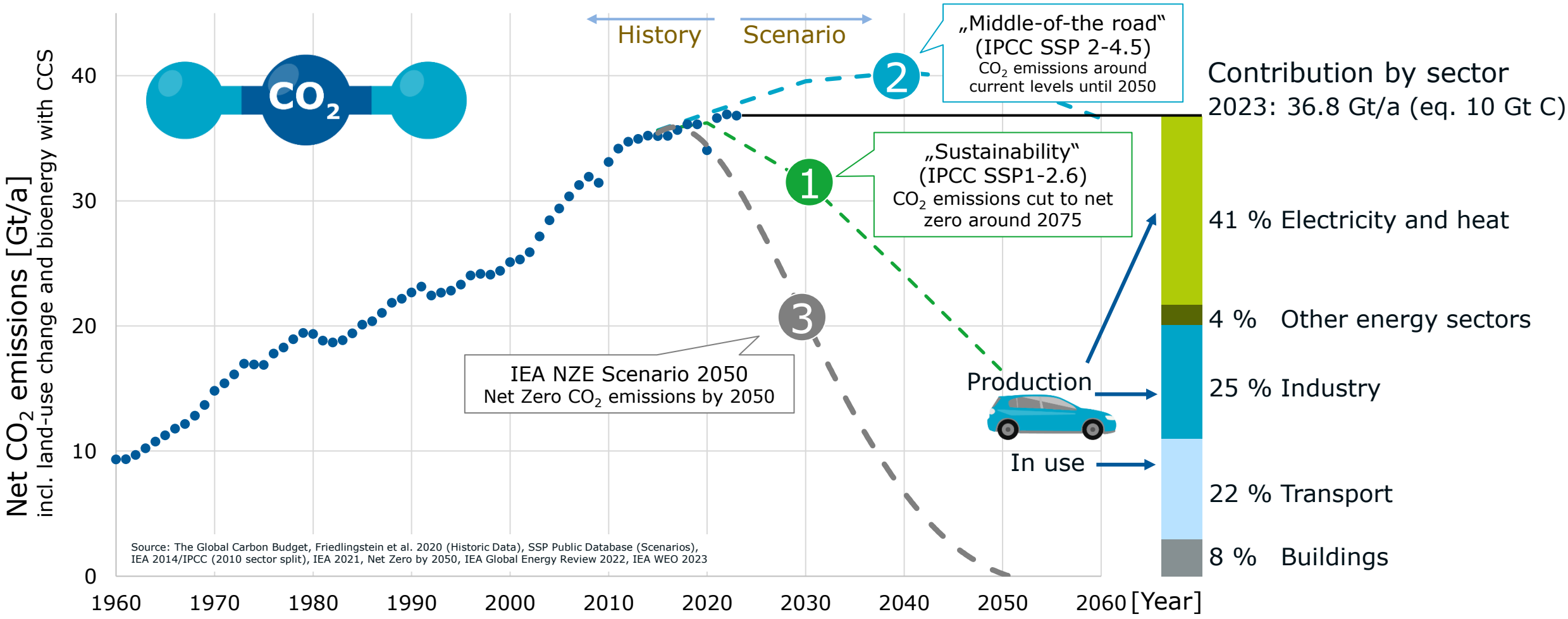
Corporate Sustainability Due Diligence Directive

Global Primary Energy Supply and Demand





History of Global Human-Made CO_2 Emissions



Growth of population and prosperity have been and still are the main drivers for GHG emissions.
Technology progress in all sectors needed for the entire lifecycle including production.

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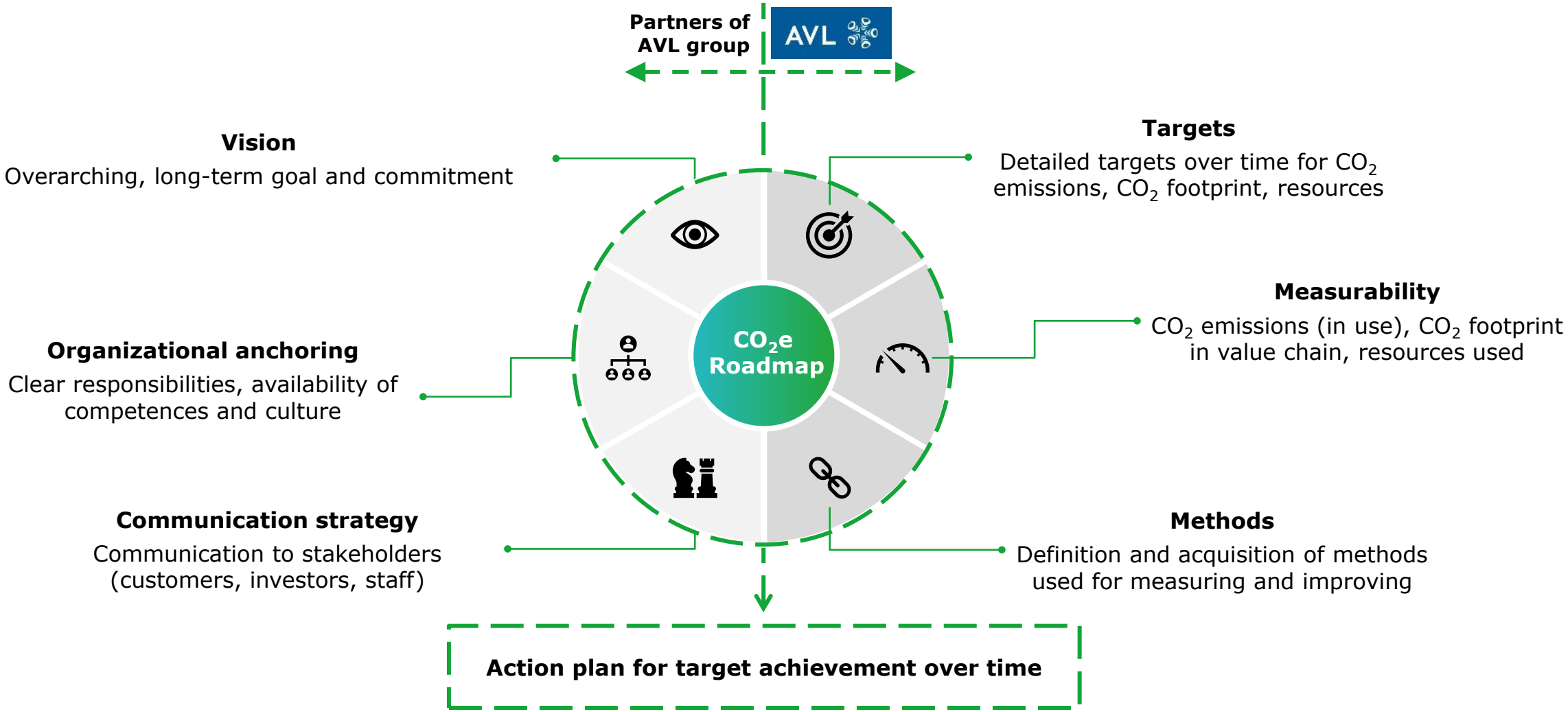
Methods

External Factors and Challenges
A Comprehensive CO_2 Strategy Should Address 6 Key Elements



Achieving CO_2e Targets
Corporate Level vs. Product Level

Corporate Level

Scope 1, 2, 3 emissions
Strategic actions to become carbon neutral

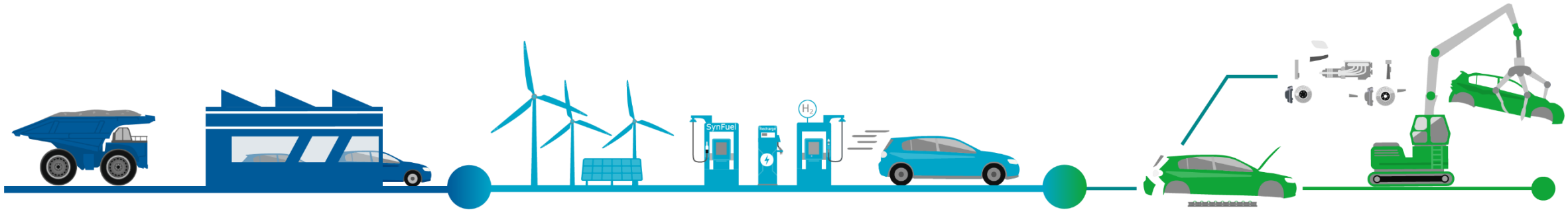
Product Level

Environmental footprint for components, drivetrains and vehicles

CO_2e … Carbon dioxide equivalent; metric measure, converting amounts of other gases to the equivalent amount of carbon dioxide with the same global warming potential

On Product Level: Lifecycle View is Essential

PRODUCTION	USE	END OF LIFE



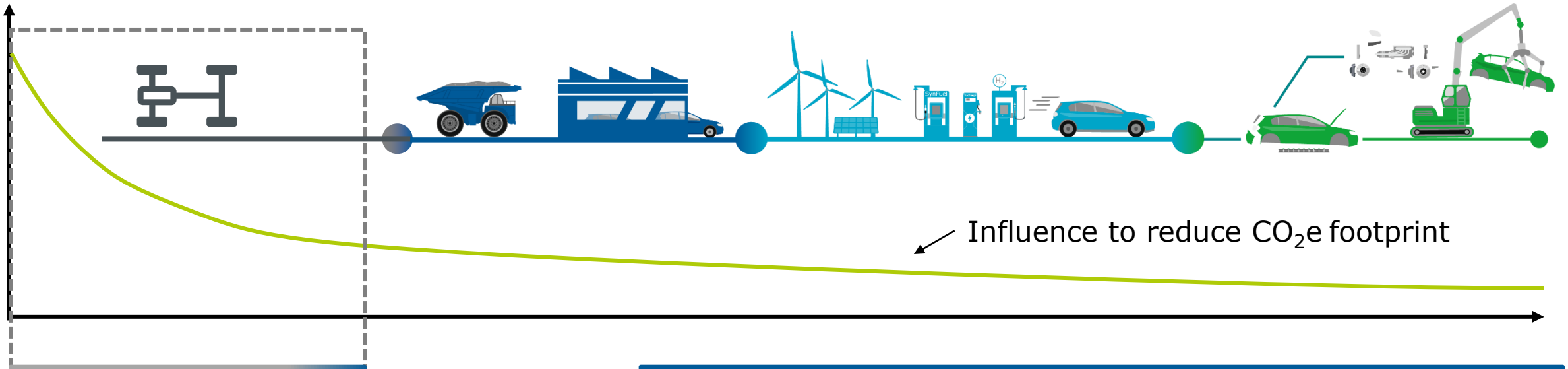
Raw Material | Manufacturing | Energy Generation | Fuels | Driving | Recycling

Design products for CO_2e – Design products for multi lifecycle

Sustainability in the Drivetrain

Early Development Phase Has Biggest Impact on Lifecycle GHG Emissions

DEVELOPMENT | PRODUCTION | USE | END OF LIFE



Design & DOE optimization:

Biggest enabler to reduce CO_2e footprint

Balancing objectives

Sustainability

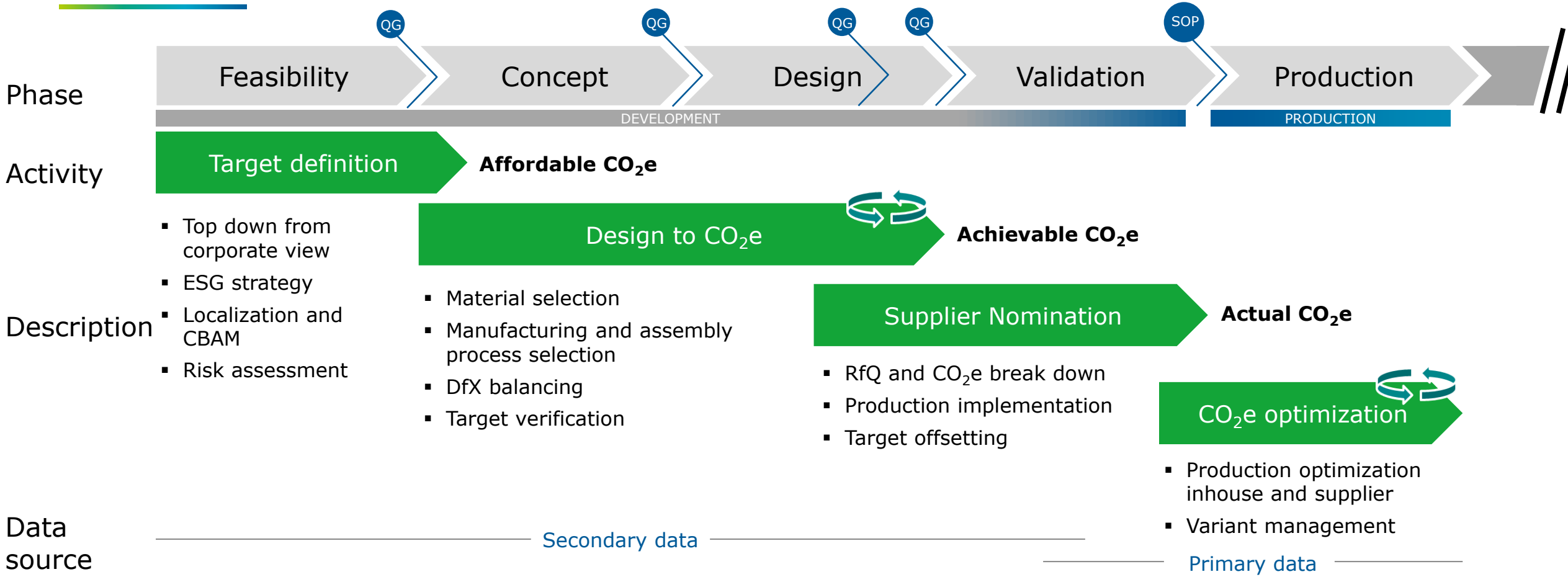
Material availability

Product costs

Driving efficiency

AVL's Method

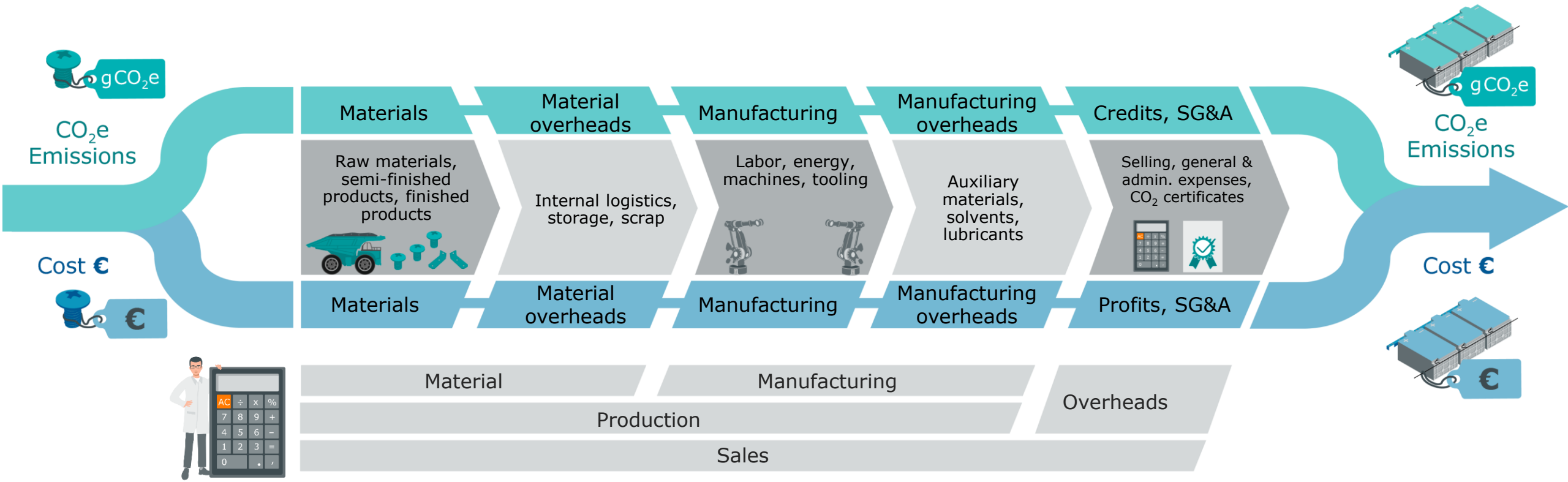
Design to CO_2e in Product Development Anticipating All Life Cycle Phases



It is important to consider CO_2e as a parameter in the early phase of development

QG… Quality Gate; ESG… Environmental, Social, Governance; CBAM… Carbon Border Adjustment Mechanism; EHS… Environment, Health, Safety; PLM… Product Lifecycle Management, RfQ… Request for Quotation

AVL Method
Simultaneous Assessment of Production Cost and CO_2e



Bottom-up calculation for optimized cost and CO_2e balancing in production.
Usage of same methods create the basis for finding the sweet spot for each product.

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Solutions

Up to 30 % Improvement
Of the CO_2e Performance of Your Product

Adjustment of material compositions and quantities

AVL Vehicle Benchmark

Over 20 experts in 3 excellence centers

AVL Know-how

Public Databases

Raw material CO_2e emissions

Primary Data

Manufacturing CO_2e emissions

Digital Twin Manu-facturing Process

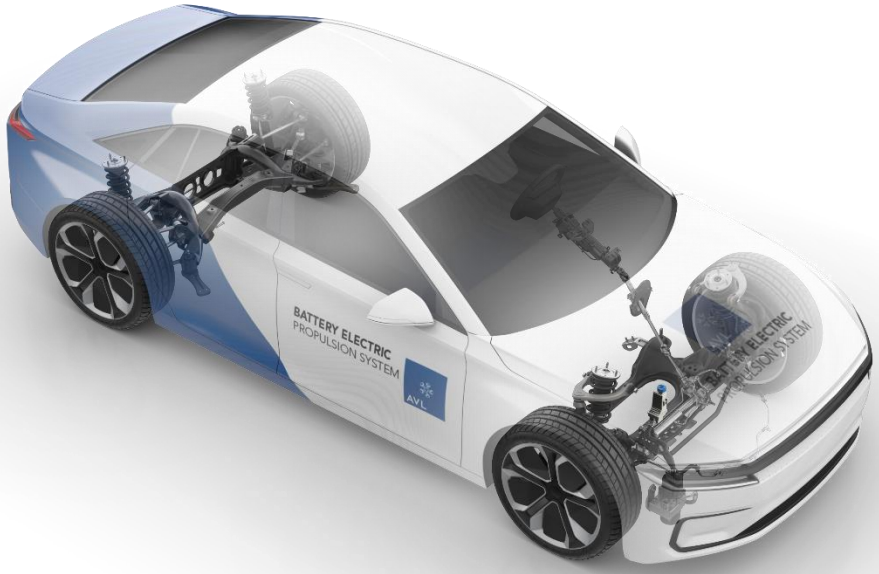
Energy-based control & scheduling of production

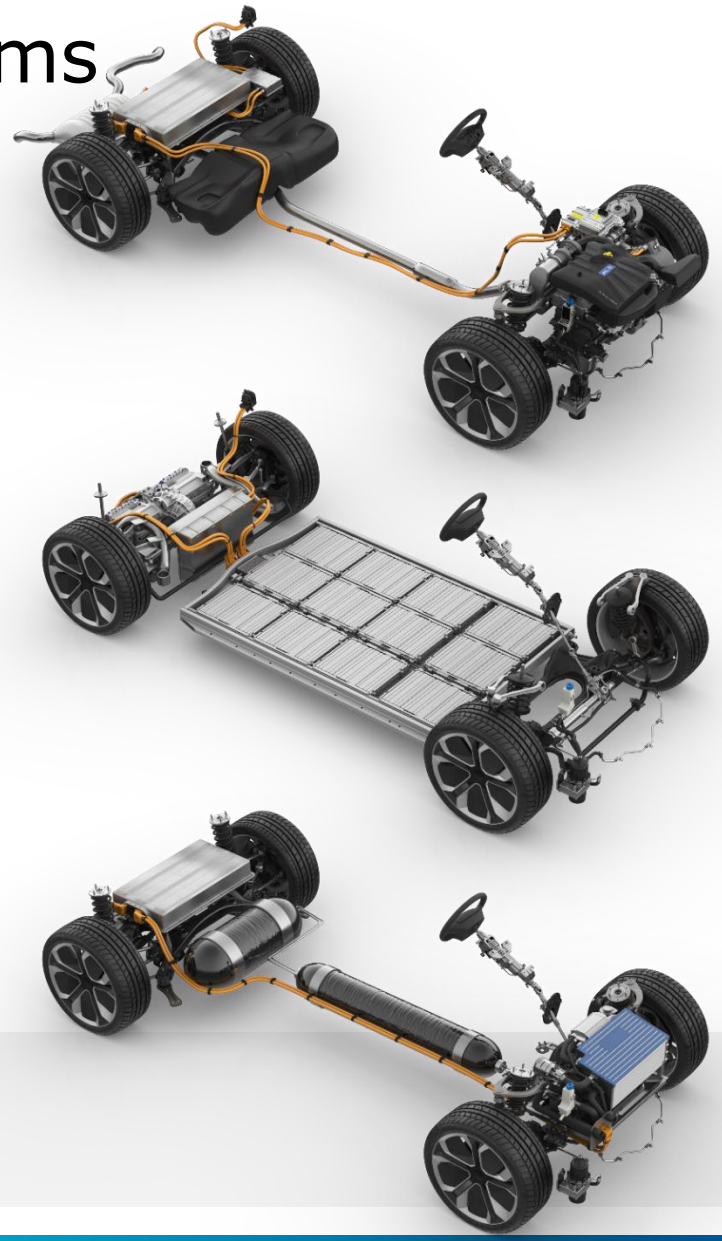
Assessment:
Find the base

Reduction:
Change materials, adapt processes

Eco Design:
Optimize CO_2e by design

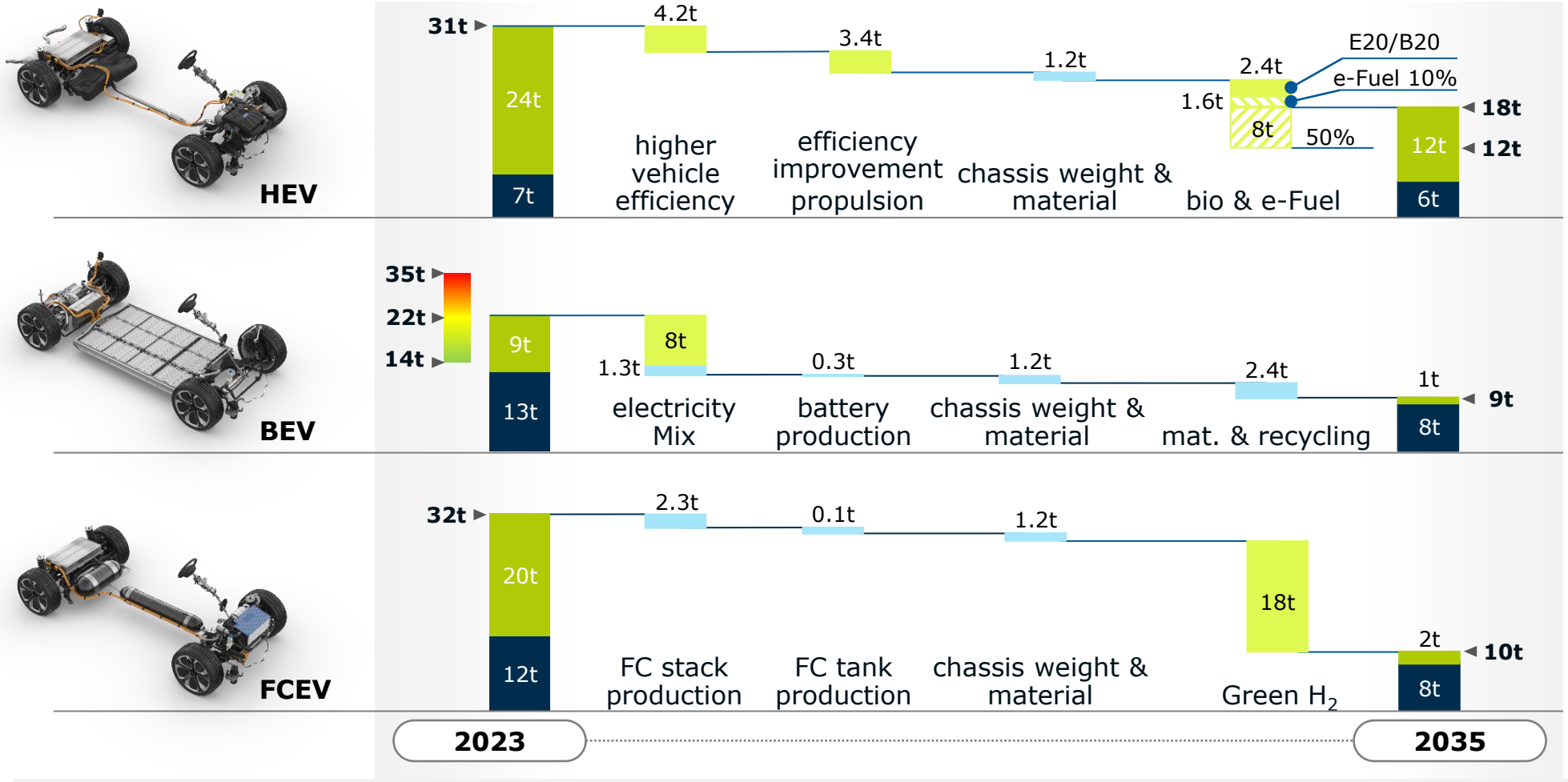
CO_2e Reduction for All Propulsion Systems





Finding the right composition of propulsion, body in white, chassis system and E/E architecture

Life Cycle CO_2e of Propulsion System Options



C-Segment Vehicles

Hybrid Electric Vehicle (HEV)
Propulsion 110 kW / Fossil Gasoline

Battery Electric Vehicle (BEV)
Propulsion 150 kW / Battery 60 kWh /330 km range

Fuel Cell Electric Vehicle (FCEV)
Propulsion 110 kW / Fossil Hydrogen

Sources: AVL, EU EEA, IEA WEO 2021, Fraunhofer ISI, ifeu

MTZ 09/22
Sams et al.,
Design-to-CO_2 Using the Example of Traction Battery Development

ATZ 02-03/24
Schmid et al.,
Design to CO_2e – The Reality Check

CO_2 Life Cycle Emission (180 tkm)

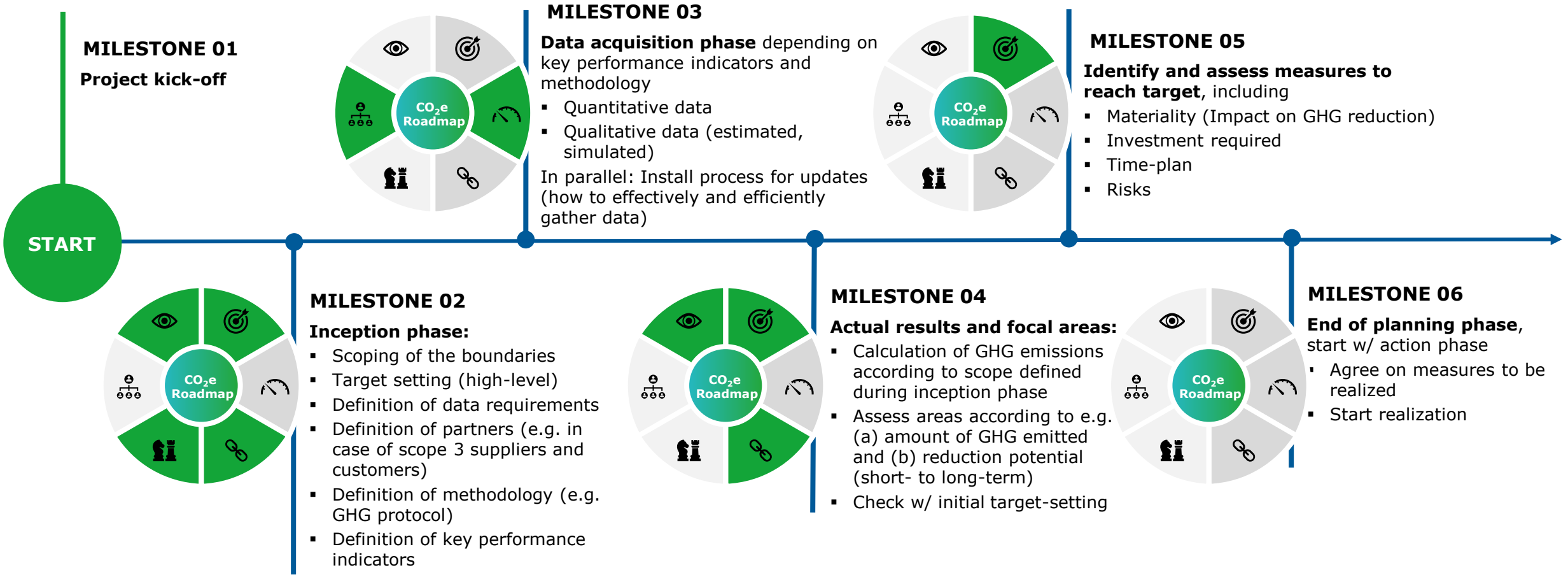
Production

In-use

Similar range of Life Cycle CO_2e emissions for all powertrains utilizing all options.
High dependency on energy mix, especially for BEV. Hydrogen and ICE fuel need to shift to renewable energy.

AVL Offerings
What Could a Project Approach Look Like?

Depending on accuracy requirements for MILESTONE 03, such an approach can take 6 to 12 months



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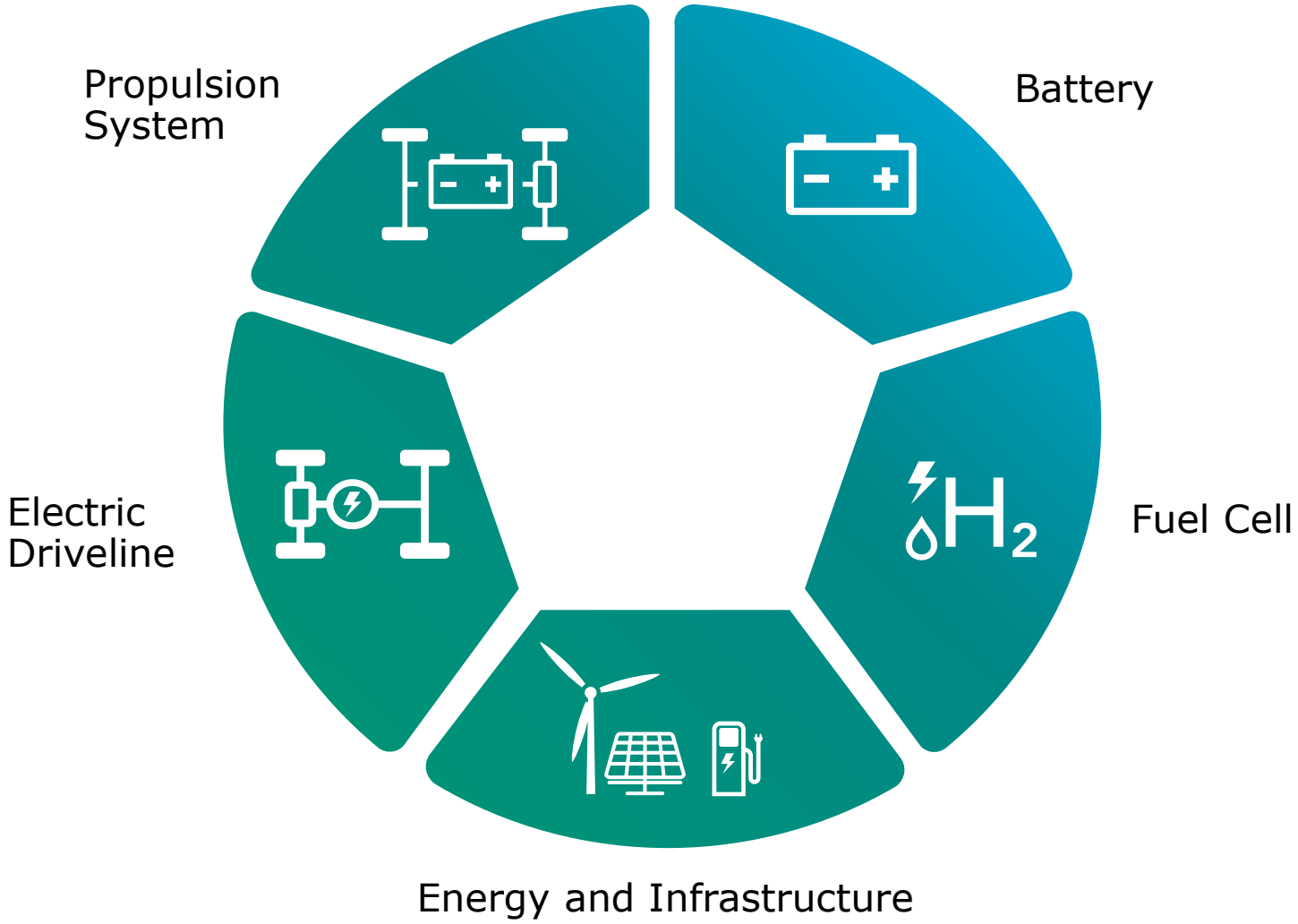
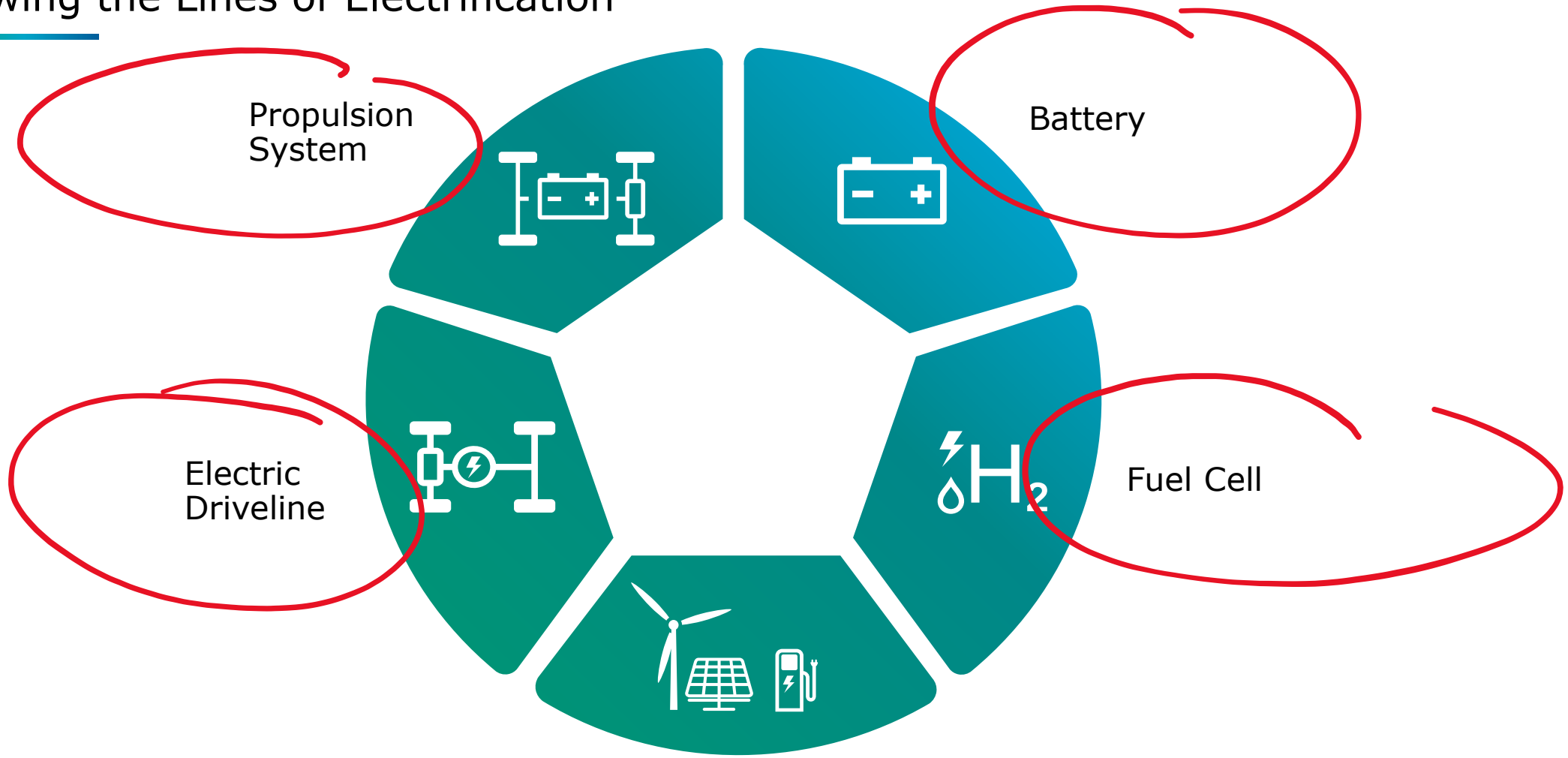
Examples

E-Mobility
Redrawing the Lines of Electrification



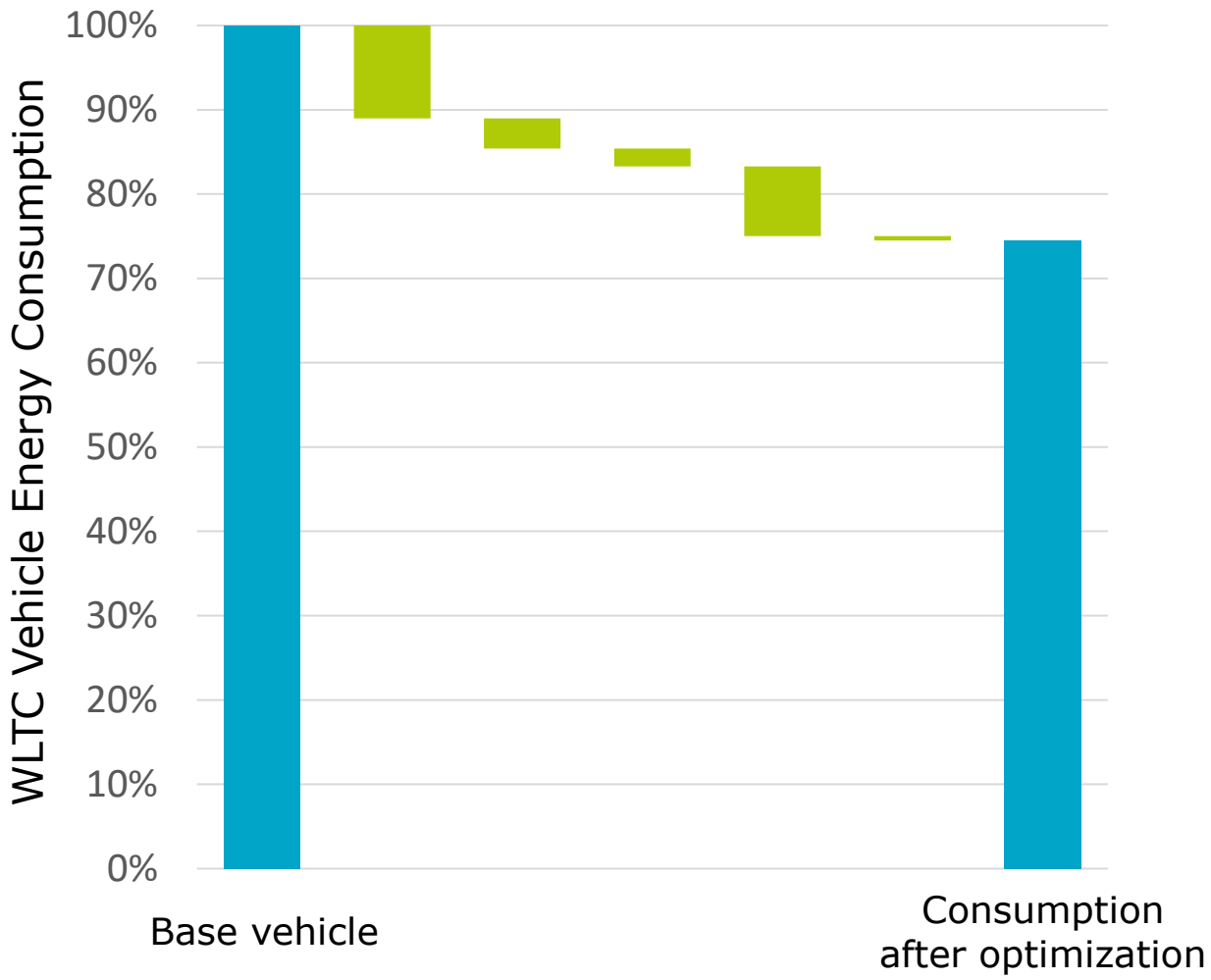
E-Mobility

Redrawing the Lines of Electrification



System Efficiency Concept

Efficiency Increase of up to 25 %*



*Based on current C-segment vehicle with 60 kWh battery

Starting point

- Standard C-segment vehicle with a 60 kWh battery

Conclusion

- A 25 % increase in efficiency is possible by using a highly efficient e-axle with optimized traction inverter, electric motor, and transmission

AVL Service Offering

- Powertrain system design optimization

Benefit

- Efficiency increase of up to 25 % through improved component application

EDU System Comparison
Speed Increase Saves 10 % CO_2e

Starting point

- PMSM with best power density & efficiency
- IM, EESM, SynRM use no rare earth → focus on EESM
- Other trade-offs not considered (e. g. supply chain)

Conclusion

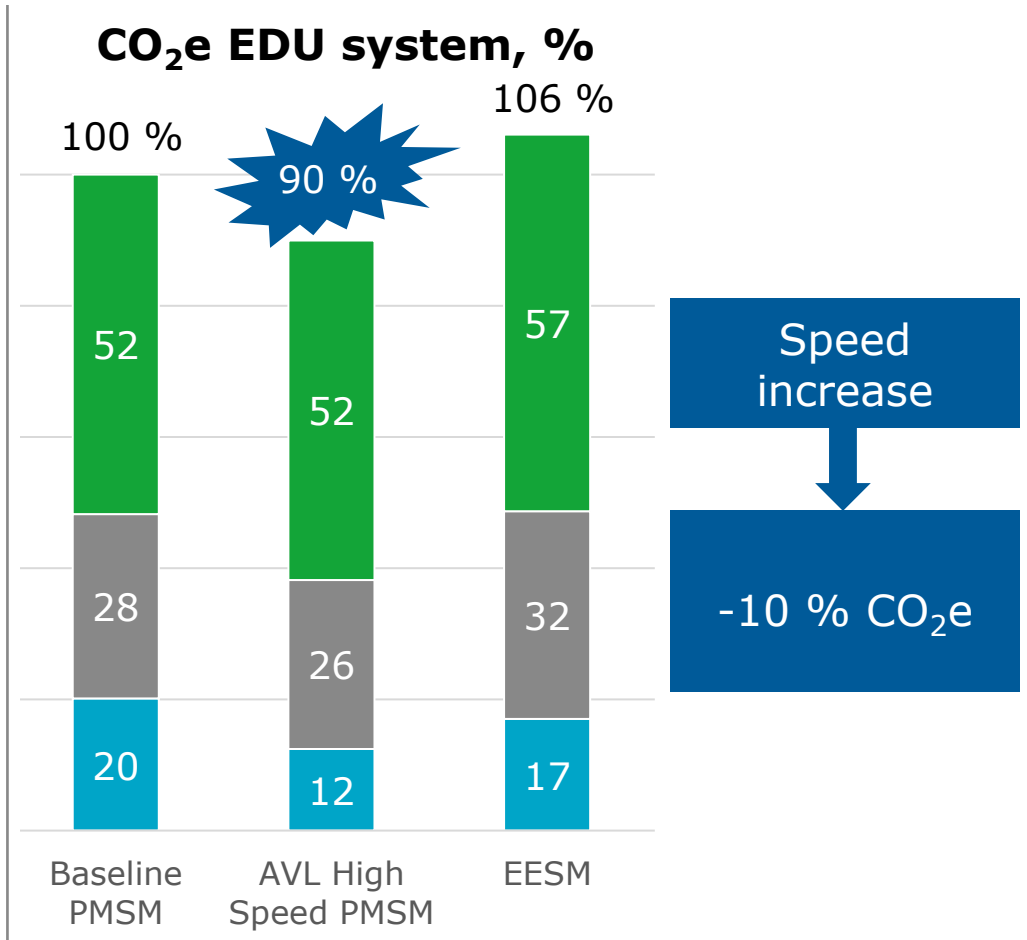
- Speed increase saves 10 % CO_2e

AVL Service Offering

- CO_2 assessment and Design to CO_2

Benefit

- Reduction of CO_2 footprints by design measures.



Add. components for EESM rotor excitation incl. in power inverter
Gearbox including EDU housing & rotor shaft incl. bearings
All scaled to same peak power of 160 kW

Source: A. Angermaier et.al., Electric drive units with high power density & sustainability, Vienna Motor Symposium 2024

Traction Battery Cover
Over 20 % CO_2e Saving Potential for Steel and SMC

Variant	Cost [€]	CF [kg CO_{2e}]	Weight [kg]
Steel	70	66	18
Aluminum	117	85	7
SMC*	147	67	10

rounded to the nearest whole number

Starting point

- Variation of battery cover material
- Variation of the production location

Conclusion

- With the view on lifecycle, beyond costs additional parameter need to be balanced.
- Over 20 % CO_2e saving potential for steel and SMC

AVL Service Offering

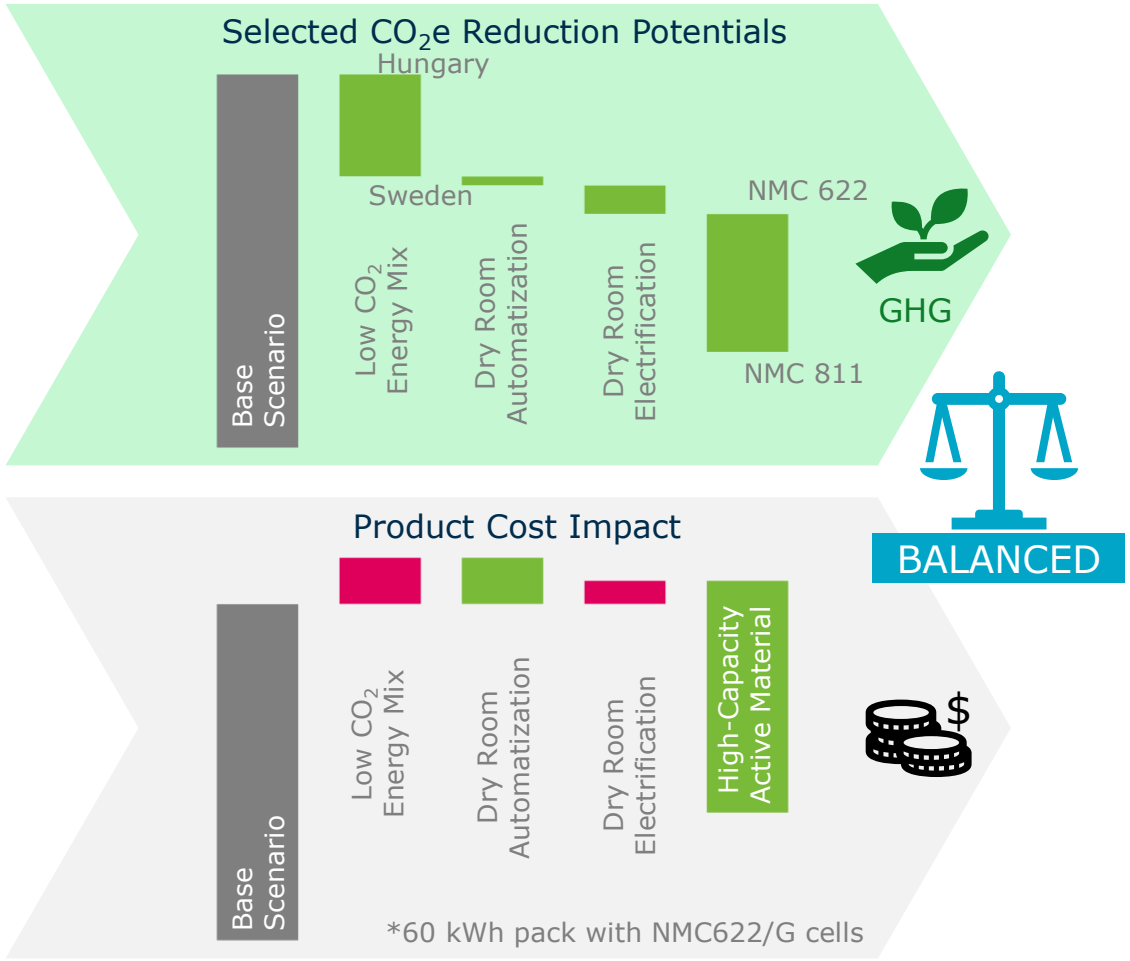
- CO_2 assessment and Design to CO_2

Benefit

- Reduction of CO_2 footprints by design measures

**SMC … Sheet Moulding Compound*

Traction Battery Cell
Simultaneous Cost and CO_2e Assessment for Battery Production



Starting point

- Standard NMC622 cells
- Adaption of manufacturing process

Conclusion

- Increase of CO_2e performance by change of production location and cathode material change
- CO_2e reduction might come at higher costs

AVL Service Offering

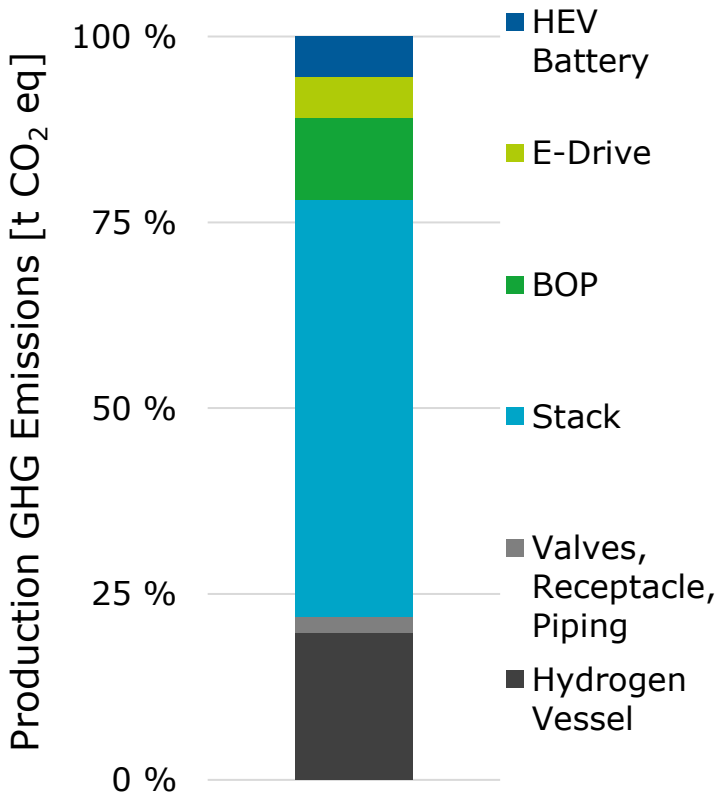
- CO_2 assessment and Design to CO_2 (in manufacturing)

Benefit

- Reduction of CO_2 footprints by process improvements

CO_2e Assessment of Fuel Cell Propulsion System

Based on Toyota Mirai 1 & 2, Hyundai Nexo, AVL fuel cell demo truck



Fuel Cell System Reference: 100 kW, Hydrogen Storage Capacity Reference: 5 kg

Starting point

- State of the art fuel cell stack system
- Consider scale-up measures and material variation

Conclusion

- Fuel cell stack and hydrogen storage production make up for over 70 % of CO_2e footprint
- Production efficiency & electricity mix improvement potential of 30 %

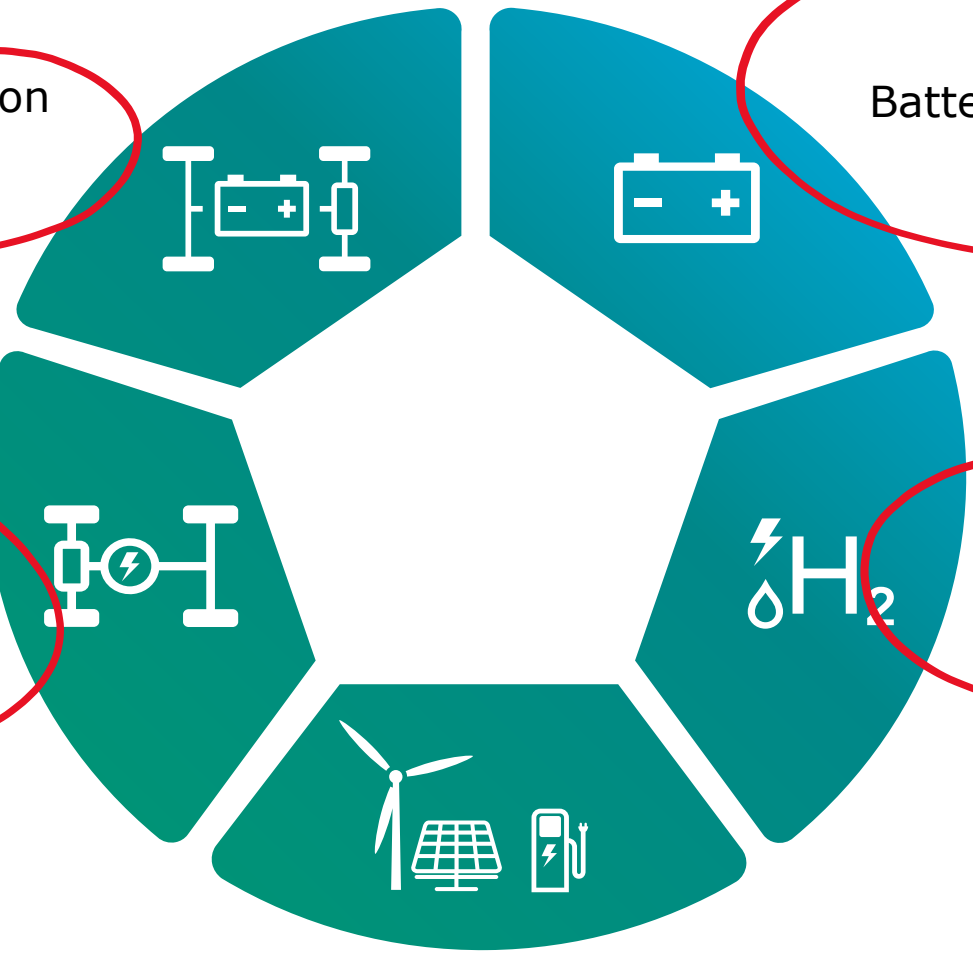
AVL Service Offering

- CO_2 assessment and Design to CO_2

Benefit

- Reduction of CO_2 footprint by design measures & process improvements

E-Mobility
Redrawing the Lines of Electrification



Propulsion System

Efficiency increase of up to 25 %

Battery

Over 20 % CO_2e savings for steel and SMC

Electric Driveline

Speed increase saves 10 % CO_2e

Fuel Cell

Production efficiency & electricity mix improvement potential of 30 %

Energy and Infrastructure

Summary

CO_2e reduction in energy supply is essential in all stages of the life-cycle.

The design and development has the highest impact on the CO_2e of the subsequent phases.

Design-to-CO_2e will become an integral part of future RFQs.

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Q&A

Contact

LOCATION

AVL List GmbH
Hans-List-Platz 1
8020 Graz
Austria

PHONE

(+43) 316 787 4169

EMAIL

martin.rothbart@avl.com

WEBSITE

www.avl.com

LINKEDIN

martinfromaustria

Thank you

www.avl.com