A Blueprint for Eco-Friendly Battery Design and Recycling Excellence

Tom Horvat

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About me

Tom Horvat

Product Manager, Battery

Six years of experience in the field.

I specialize in product leadership, business strategy, and the development of battery technologies.

Agenda

1. **About AVL**
   Fact and Figuers
2. **Drivers for Sustainable Solutions**
3. **Challenges for OEMs**
4. **AVL Approach to Recycling**
5. **Examples and References**
6. **Conclusion, Q&A**

About Us

At AVL, we are one of the world’s leading mobility technology companies for development, simulation and testing in the automotive industry, and in other sectors such as rail, marine, and energy.

Based on extensive in-house research activities, we deliver concepts, technology solutions, methodologies, and development tools for a greener, safer, better world of mobility and beyond.

AVL at a Glance

1948
Founded

75+
Years of Experience

29
Countries Represented

50+
Global Tech and Engineering Centers

12,200
Employees Worldwide

68 %
Engineers and Scientists

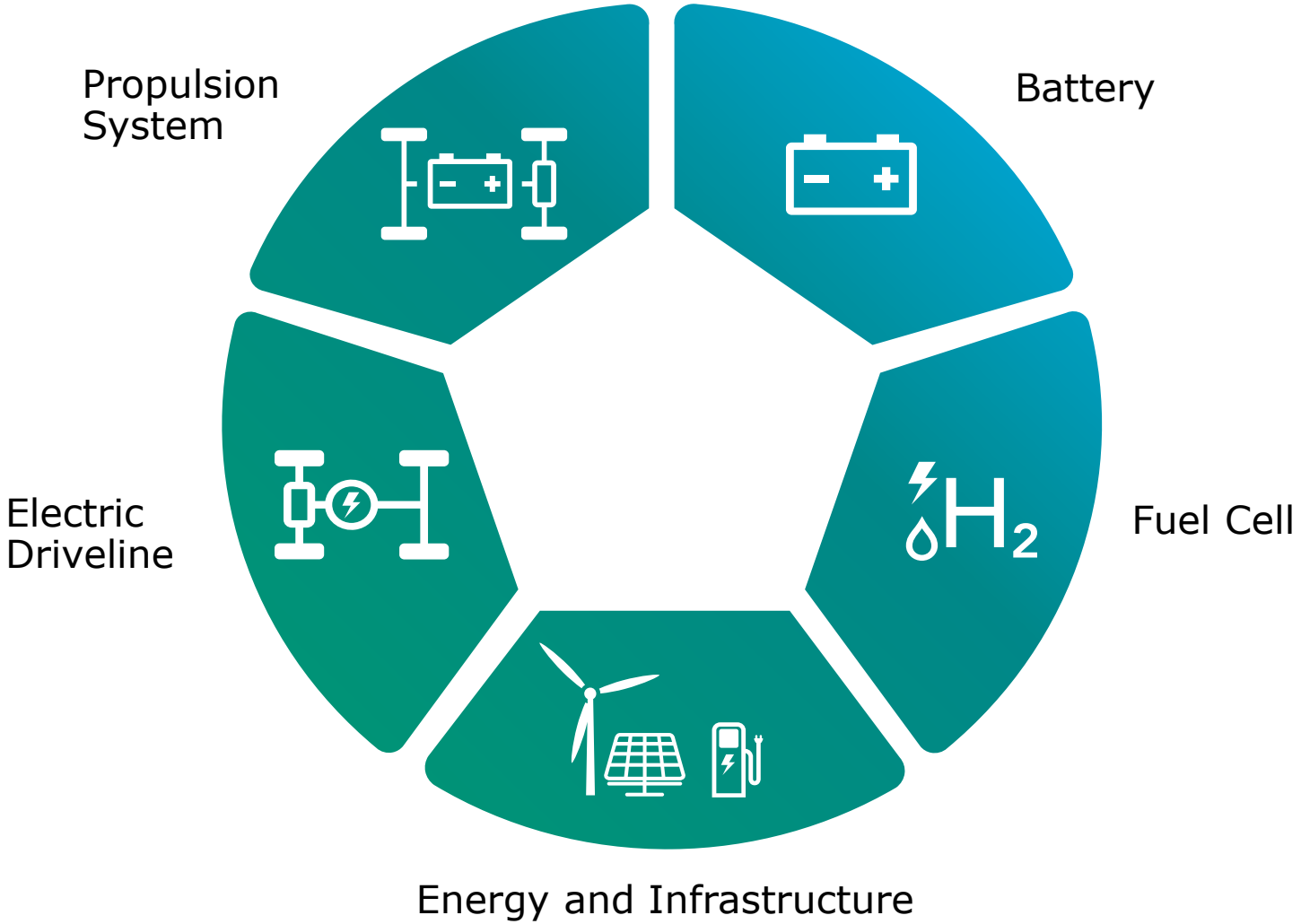
10 %
Of Turnover Invested in Inhouse R&D

2,200
Granted Patents in Force

Redrawing the Lines of Electrification

E-Mobility

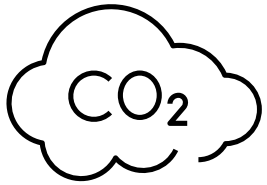
From battery to fuel cell technologies, we are paving the way for e-mobility by driving innovative, affordable and sustainable solutions.



Legislation, Customer Demand etc.

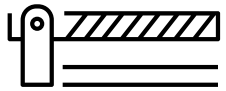
Drivers for Sustainable Solutions

Legislation, Industry and Society Pushing for Decarbonization

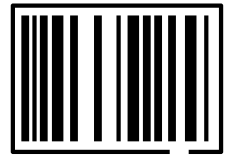


CO_2 tax/penalty

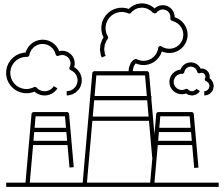
Reporting



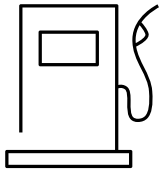
Cross-border adjustment measures



Emission trading scheme

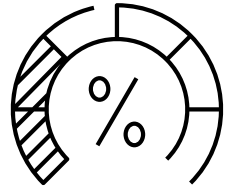


Other GHG emissions than CO_2

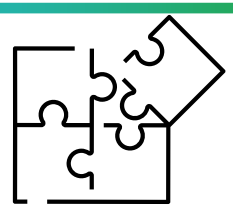


Alternative fuels

CO_2 fleet emissions

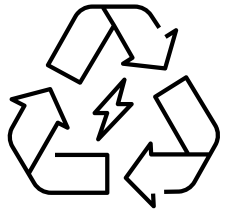


Clean truck and bus regulation



Life-cycle analyses

Battery regulation



Circular economy

Corporate Sustainability Due Diligence Directive

Preparing for Sustainability

The Driving Forces Behind Battery Recycling Initiatives and Renewable Solutions

Environmental
- Prevent release of harmful substances
- Circularity of critical raw materials
- CO_2 savings compared to production from primary resources

Economical
- Recovery of valuable metals
- Competitive advantage

Strategic
- European raw material supply
- Independence of foreign supply chains

Legislative
- Fulfill demanded recycling rates (Battery regulation)
- Supply Chain Law (EU Due Diligence)

Design for CO_2 and Recycling
Market Demands

Volvo to issue world's first EV battery passport ahead of EU rules

"It's really important for us to be a pioneer and a leader"

- Vanessa Butani, Volvo's head of global sustainability

Challenge: CO_2 performance

Battery supply-chain development in Western countries faces short-term headwinds

"Physical regionalization lengthens the global supply chain"

- Kevin Chan, US-based lithium producer Albemarle's

Challenge: Circularity

France says 'non' to EVs made in China

"We will no longer be subsidizing car production that emits too much CO_2"

- Bruno Le Maire, French Finance Minister

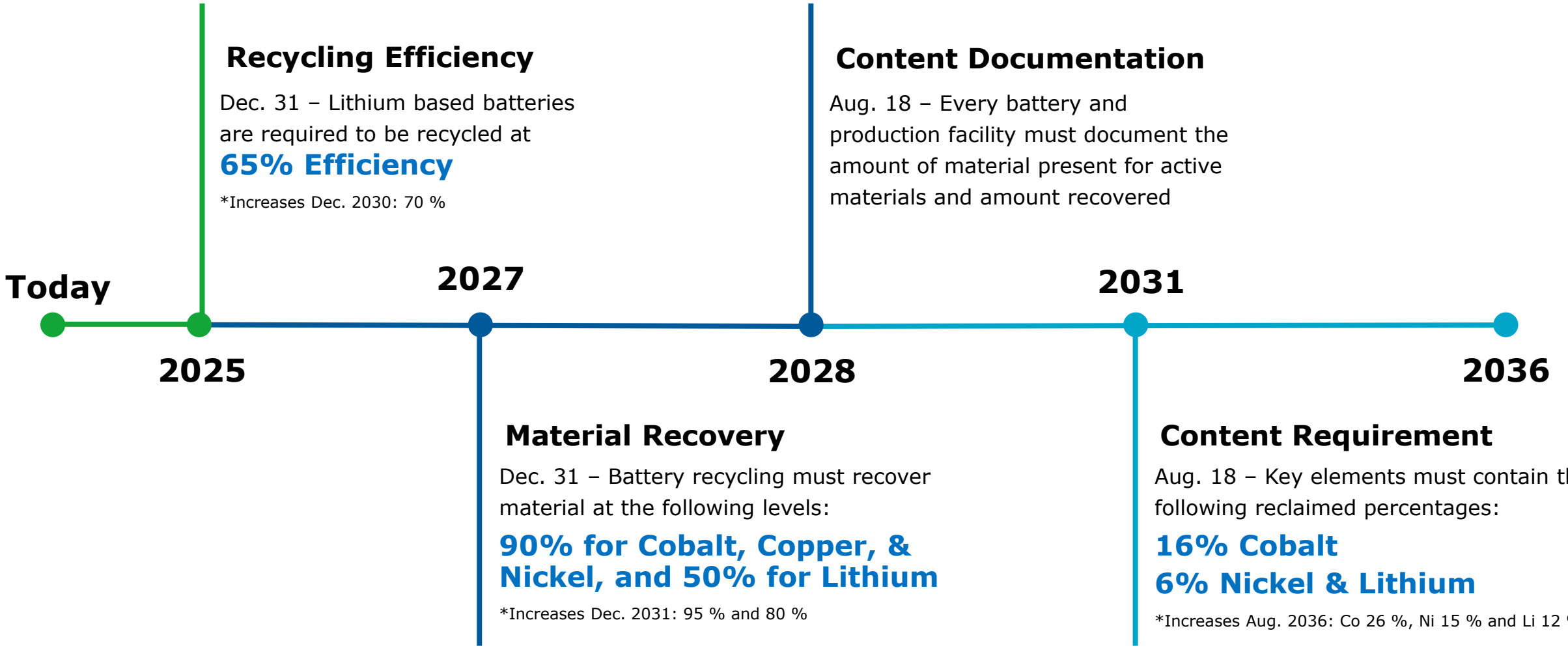
Chinese EV makers set sights on European production

SAIC LEAPMOTOR GEELY BYD CHERY

Challenge: CO_2 performance

Key Milestones for Battery Recycling Regulations in Europe

Articles 8 and 71 of the 2023/1542



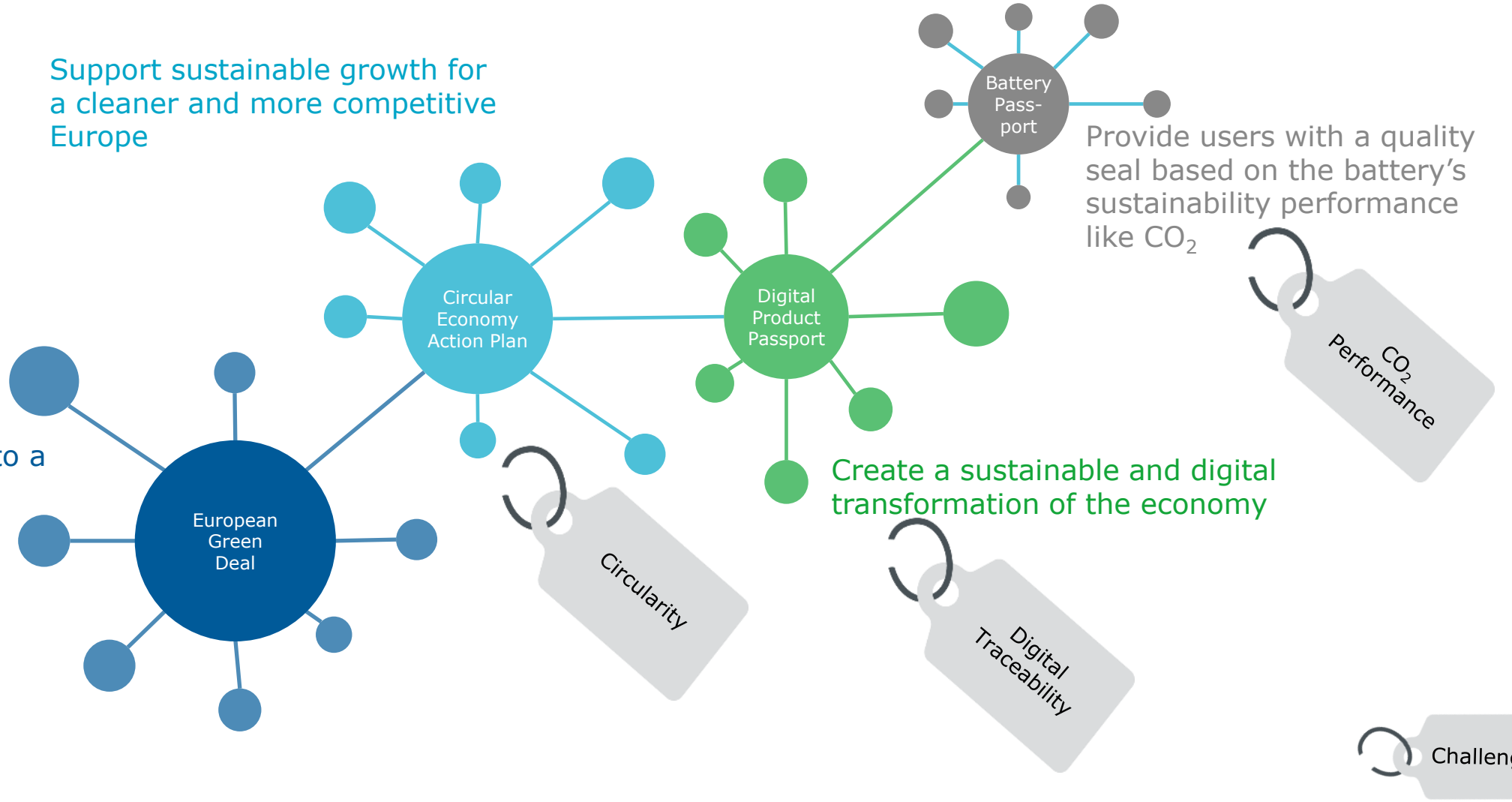
Design-for-Recycling

Challenges

Challenge
Sustainable batteries in context of the European Green Deal

Support sustainable growth for a cleaner and more competitive Europe

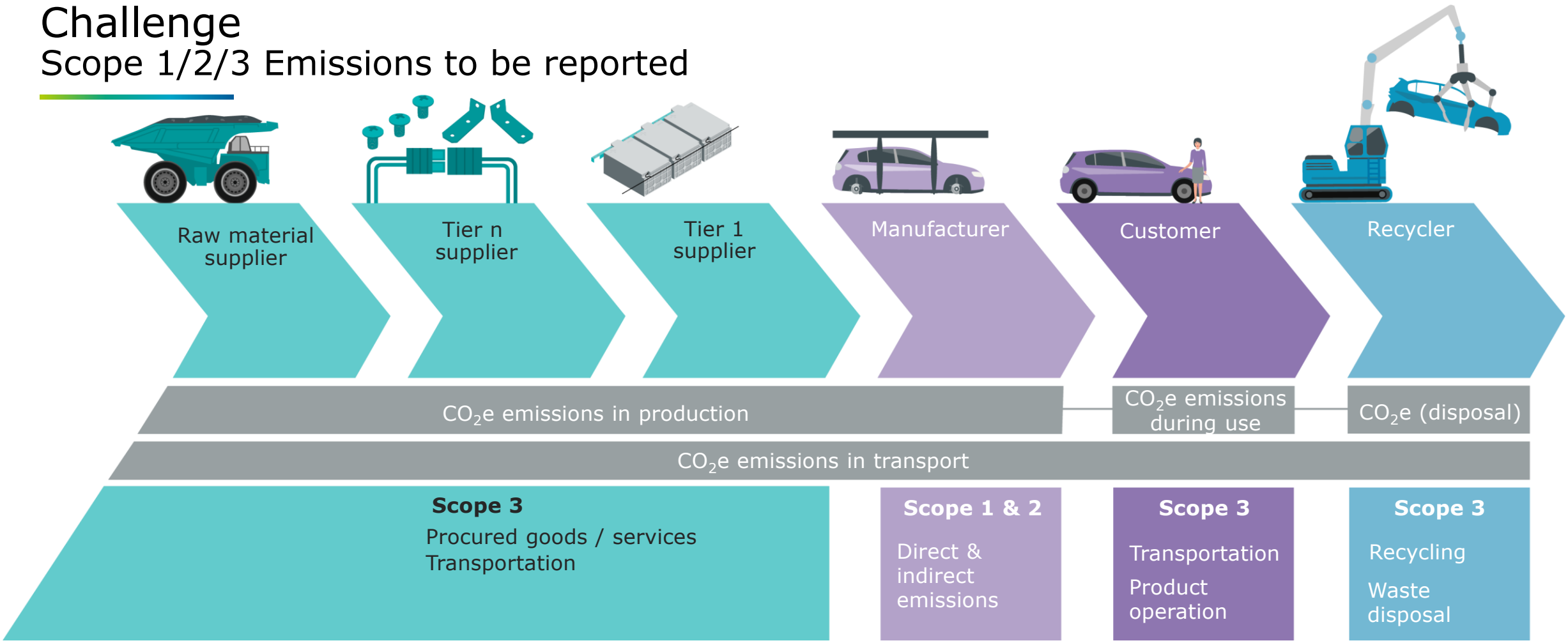
Set the EU on the path to a green transition



Provide users with a quality seal based on the battery's sustainability performance like CO_2

Create a sustainable and digital transformation of the economy

Challenge
Scope 1/2/3 Emissions to be reported



By far the largest share of emissions are assigned to Scope 3 and includes all upstream and downstream activities of a legal entity

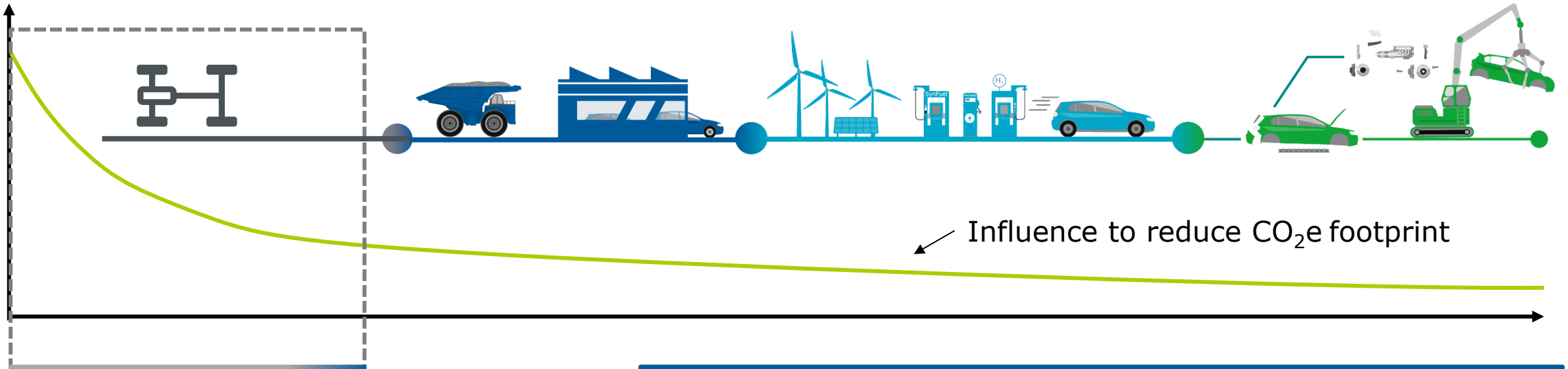
Design to CO_2, Battery Passport, Design for Recycling

Our Approach

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

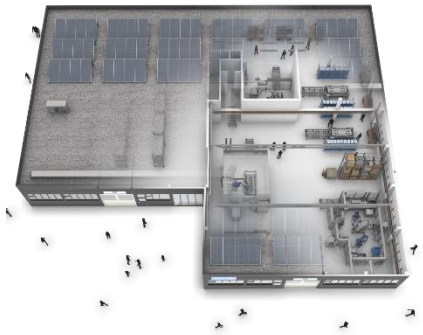
Driving efficiency

AVL Examples

Design-to-CO_2

Material variation for battery cover using steel, aluminum or SMC.

Over 20 % CO_2e saving potential for steel and SMC*

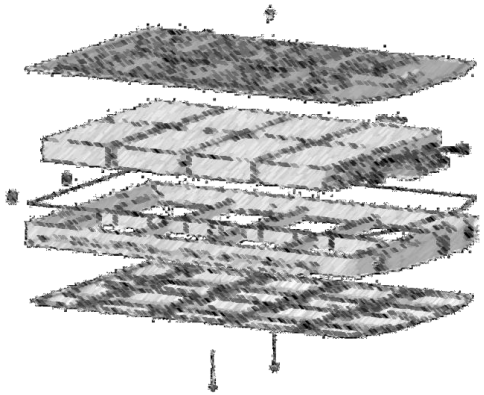


Digital Battery Passport

Battery Passport @ AVL Battery Innovation Center (BIC)

Implementation 2021–2023

Save up to 12 months in the battery passport implementation



Design-for-Recycling

Gain understanding of the total cost of recyclability to identify areas of improvements

40 % reduction in operating costs, up to 50 % CO_2 savings in recycling

*Sheet moulding compound

Design for Recycling – Methodology Comparison

State of the Art

Shredding

- Focused solely on energy density and production costs
- C2P or C2C approach
- Often using adhesive bonding
- Chemical or physical methods required for disassembly
- Not reusable due to destruction of shape and functionality

Recyclability / Reusability / Serviceability

Recyclable

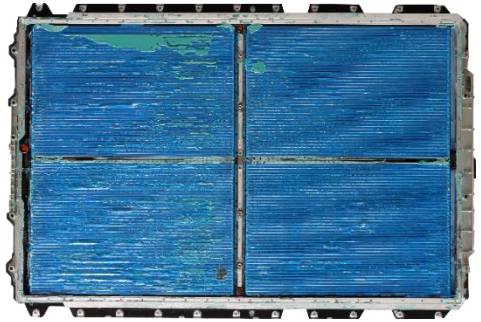
Disassembly

- Total cost mindset, including reused/recycled material value
- Automated disassembly consideration in design
- Serviceability of modules and potentially even cells
- DfR and serviceable approach boosts marketing & customer acceptance

AVL's DfR Methodology Balances Energy Density and Recyclability!

Disassembly: Comparison Cell2Pack vs. Module2Pack

C2P



Top cover sealing	✗
Top cover removal	✗
HV path removal	✗
Module removal feasible	✗
Cell disassembly	✗
E/E unit removal	✓

M2P

Top cover sealing	✓
Top cover removal	✓
HV path removal	✓
Module removal feasible	✓
Cell disassembly	✗
E/E unit removal	✓

Source: AVL Benchmark program

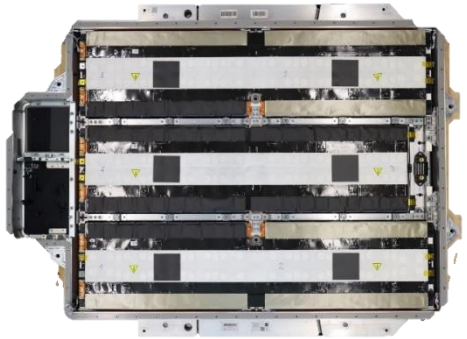
Benchmarking Battery Design

Are Today's Batteries Aligned to Regulation and Efficient Sustainability?

C2P – Cell to Pack

Nio ET 7 (75kWh Prismatic LFP & NMC)

- Cells are retained by bottom plate bonding
- Serviceability is limited or destructive
- Recycling via shredding or labor-intensive process

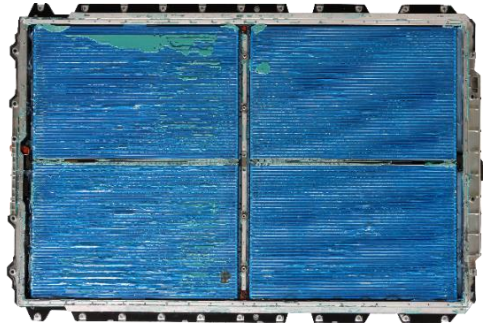


Max. Service Level:
Module Controller

C2P – Cell to Pack

BYD Seal (82,5kWH Prismatic LFP)

- Cells are retained by bottom plate and top cover bonding
- Recycling likely only possible via full pack shredding



Max. Service Level:
Service Lid EE System Only

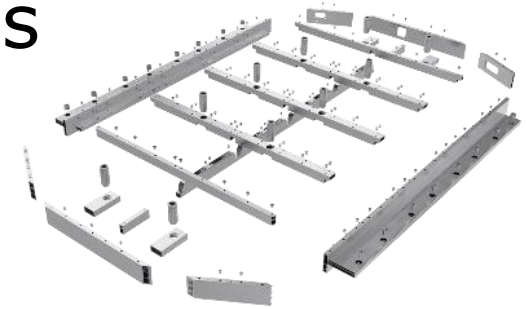
C2M – Cell to Module

VW ID3 (58kWh Pouch NMC)

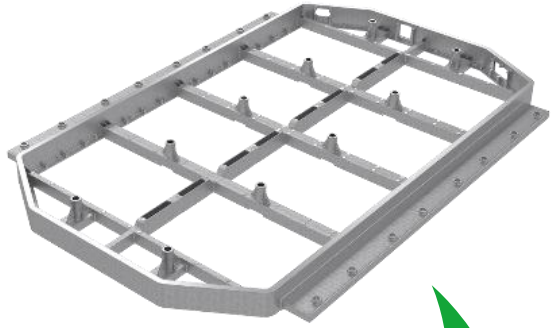
- Modules are serviceable with thermal gap filler to the bottom plate
- Modules or potentially even cells directly input to the recycling process

Max. Service Level:
Cell-Modules

Design for Recycling Solutions
Considering Aluminum and Design



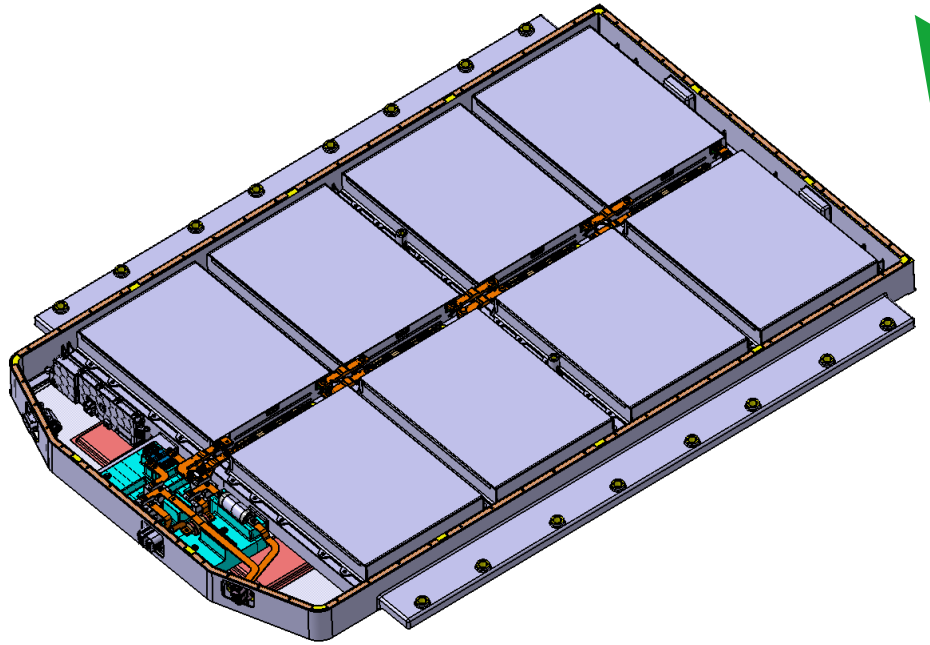
Extrusion
(state of the art)



HPDC
(High Pressure Diecast)

Recycling Targets and Design Considerations for Aluminum Components:

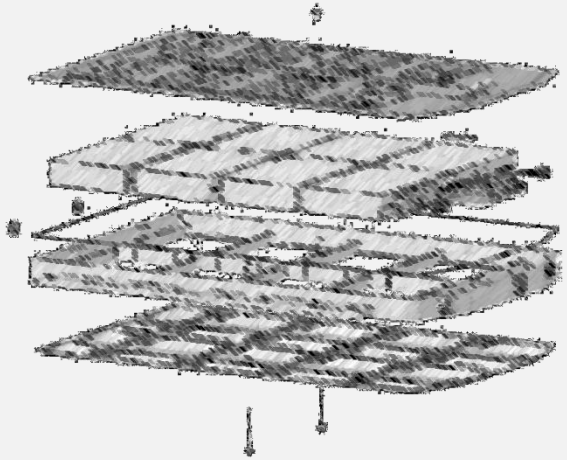
- Reduce amount of different aluminum alloys
- Minimize impurities like iron, copper, and titanium
- Ensure no mixture of cast and wrought aluminum or welding filler material
- Avoid (coated) steel inserts
- Enable easy disassembly and removal of components like covers, modules, and high-voltage parts
- Use silicone-free thermal paste or pads and standardize bolt head types for fasteners



High Pressure Die Casting Enables Improved Recyclability Compared to Extrusion Profiles

Design for Recycling Solutions

Design Evaluation for Tailormade Recycling Concept



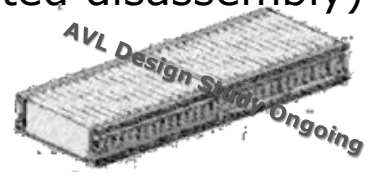
- E/E Unit removal ✓
- HV path removal ✓
- Module removal ✓

Housing Design

Sealing Solution (serviceability of cover)

Module Design (serviceability of cell, automated disassembly)

Target: serviceability of cell, automated disassembly
Benchmarking: Only a few EVs where
cells can be removed (mostly destructive – busbars)



Thermal System

Challenge
Battery regulation

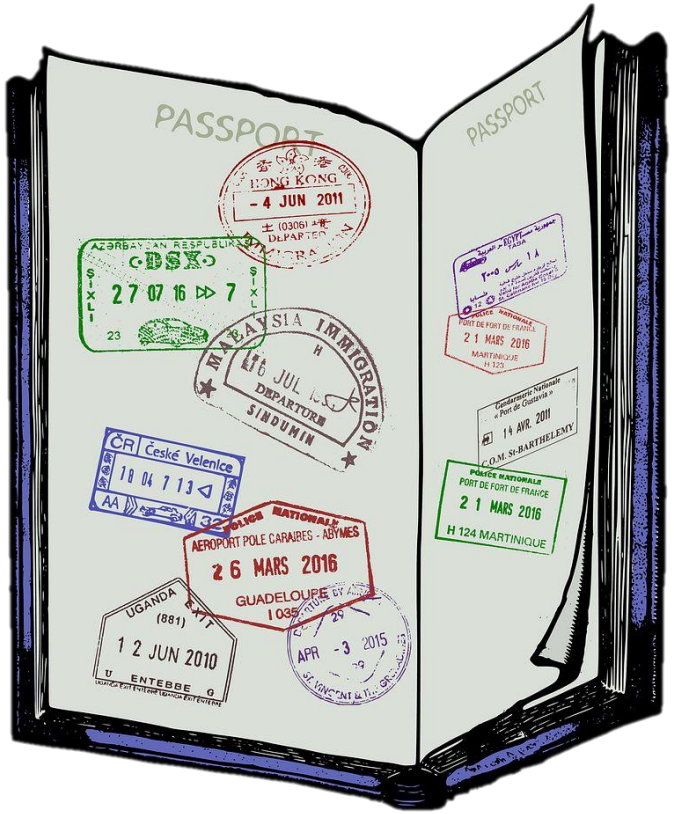
Why act now?

2027

Timeline

Differentiation

Consequences



What Is a “Digital Battery Passport” ?

Legal requirements

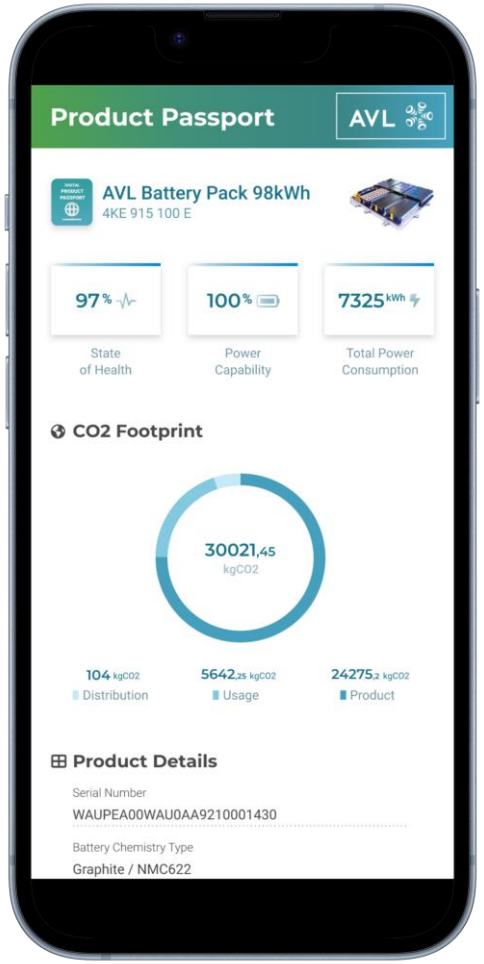
Derived from the new EU Battery Regulation.

Meant to increase transparency and data availability

Definition

Stores relevant battery data through the entire battery lifecycle

All stakeholders need to collect and share relevant data



Content

Identification via secure unique serial number

Information on production date, type and model, chemical composition and CO_2 footprint.

Statistics on performance and durability

From Product to Vehicle Passport

BATTERY PASSPORT → PRODUCT PASSPORT → VEHICLE PASSPORT

Various countries are in early stages of defining and implementing similar product passport regulations

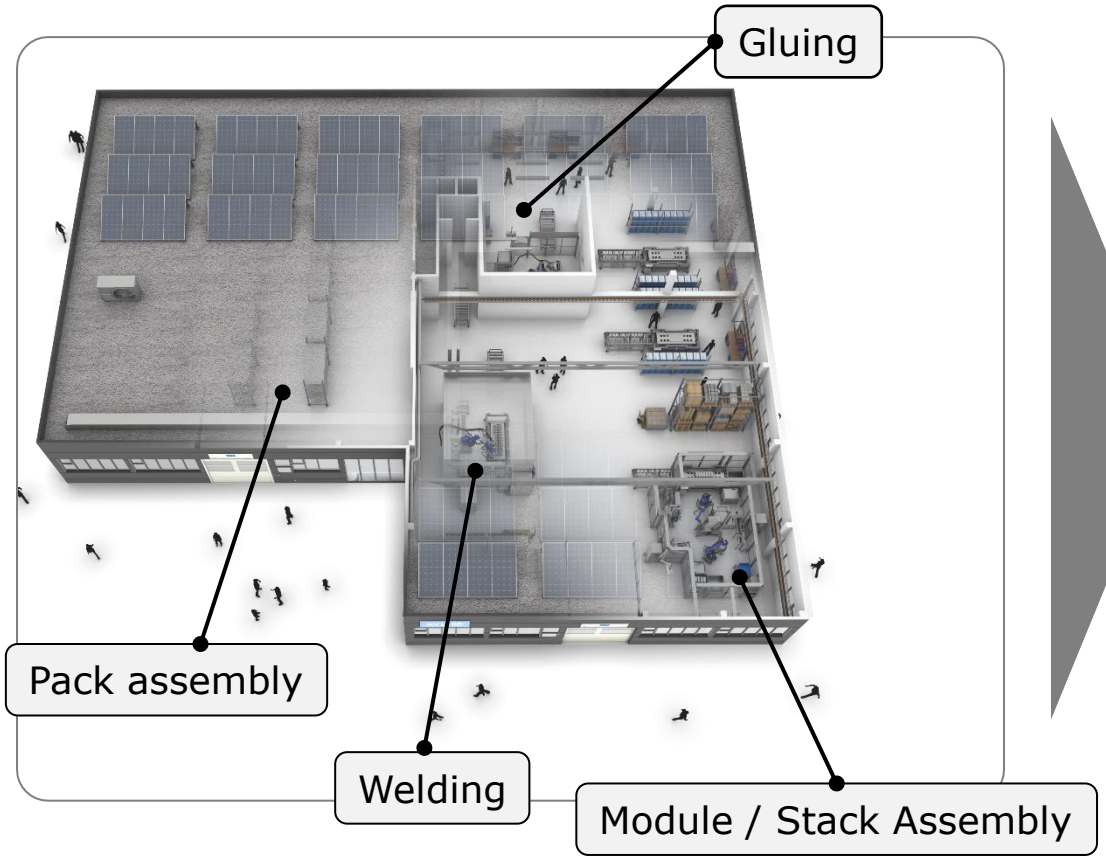
Discussion state	
Considering adoption	
Concept proposed	
Opportunity on digital value chain	
Move to sustainable battery lifecycle	
Plans for battery production disclosure	

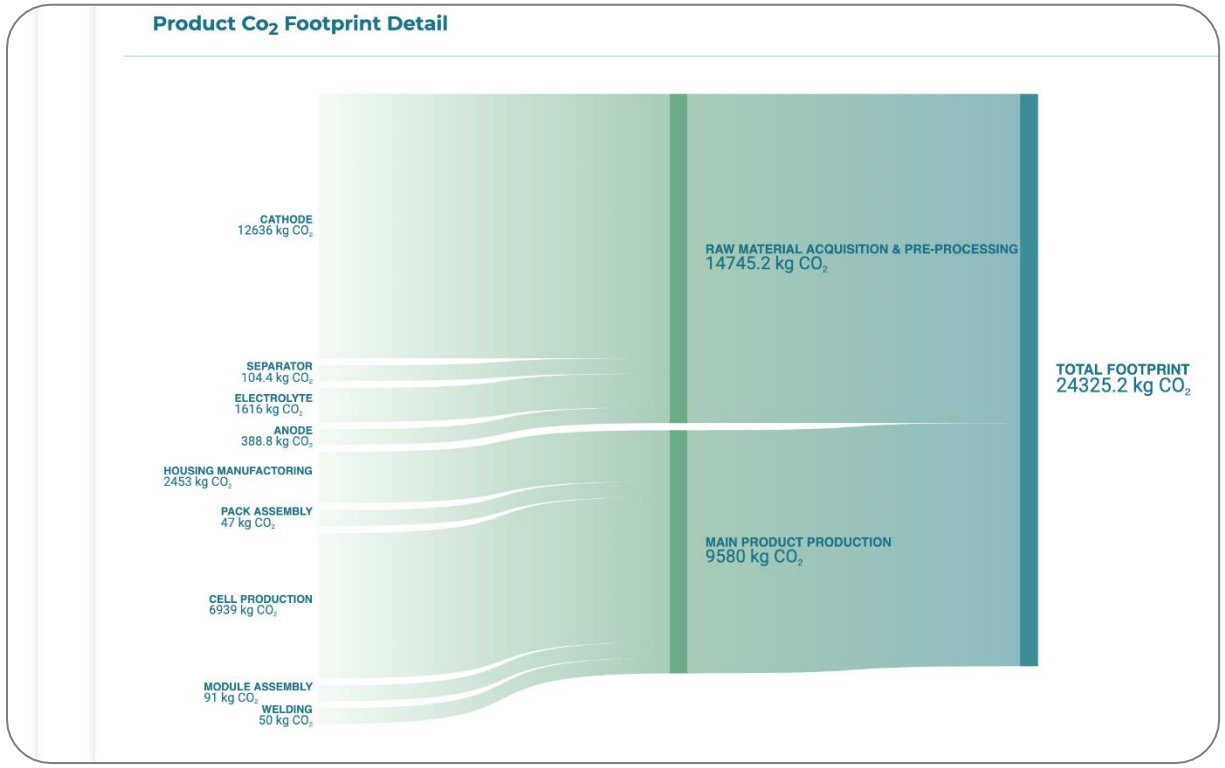
EURO 7: An Environmental Vehicle Passport (EVP) will be made available for each vehicle

- Emission limits
- CO_2 emissions
- Fuel/electric energy consumption
- Electric range
- Battery durability
- Data availability via QR-code

Source: EU, 12/2023, Link to EU parliament news

Battery Passport @ AVL Battery Innovation Center (BIC) Implementation 2021 - 2023





- Integration of measured values in CO_2 modeling
- Digital-twin for energy- based control & scheduling of production

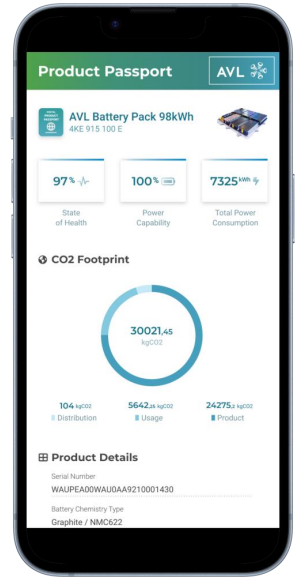
- Direct link of time-based measured values to the battery passport
- Application of manufacturing CO_2 to the total footprint value

Digital Battery Passport Implementation @ AVL Battery Innovation Center (BIC)

Digital Battery Passport

AVL has the only fully operational digital battery passport in a productive environment.

https://www.avl.com/batterypassport



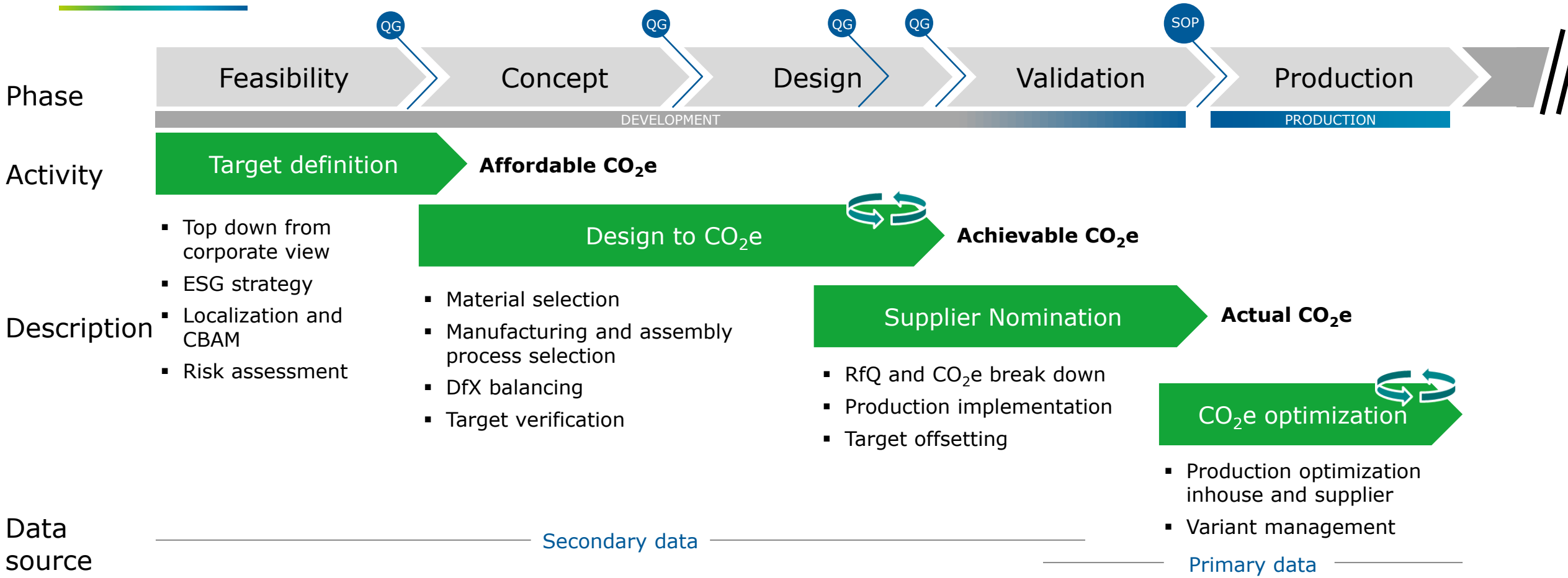
The passport in your pocket

AVL has the only fully operational digital battery passport in a productive environment.

We help you to save up to 12 months in the battery passport implementation in your processes and facilities.

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 Cost and CO_2e Engineering

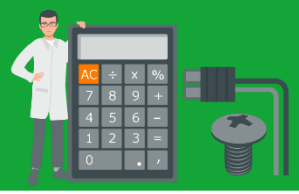
MANUFACTURER´S VIEW

Target CO_2e

Target Pricing

- Sales planning
- Cost planning
- Investment & financing planning
- Profit & loss statement
- Cash flow statement

Bottom-up CO_2e



Bottom-up Costing

- Sales price
- Overheads & profit
- Production cost
- Manufacturing cost
- Material cost

USER'S VIEW

End-of-life Costs
- Disposal
- Recycling
- Resale value

Operation Costs
- Energy
- Consumables
- Service & maintenance
- Financing

Acquisition Costs
- Purchase
- Infrastructure
- Application and start-up

Total cost of ownership

Recycling/ reuse CO_2e

Tank-to-wheel and servicing CO_2e

Acquisition/ production CO_2e

Source: Sams C, von Falck G, Sorger H (2020) Cost Engineering in Systems Engineering. In: Hick, Küpper, Sorger (eds) Systems Engineering for Automotive Powertrain Development. Springer

Conclusion

Conclusions

What Are the Benefits of Design for Recycling?

- Preparing for the upcoming recycling regulations while also achieving today's **e-mobility energy density demands** can only be done utilizing efficient DfR methodologies.
- With this approach, the recycling process can realize a **up to 40 % reduction in operating cost and ~50 % CO_2 emissions savings!**
- Operational savings includes the ability to achieve up to **20 % higher material revenues** compared to conventional methods due to higher purity product recovery and efficient recycling process.

As Recycling Regulations are Implemented, the Utilization of DfR will Reduce Total Product Cost by Enabling Efficient Recycling!

Q&A

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Thank you

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