

FEV ONLINE SEMINAR

HYDROGEN POWERED FUTURE



KAI KRÜGER
MANAGER, FEV CONSULTING

Hydrogen Society & Impact on Transport Sector

23.03.2021

**FEV
ONLINE
SEMINAR**

SEMINAR OVERVIEW

**1st Session March 23:
Hydrogen Mobility
Strategies, Infrastructure & Powertrain Concepts**

2nd Session March 30:
Vehicle Integration of Hydrogen Fueled Powertrains

3rd Session April 13:
Fuel Cell Electric Propulsion

4th Session April 20: Hydrogen Internal
Combustion Engine

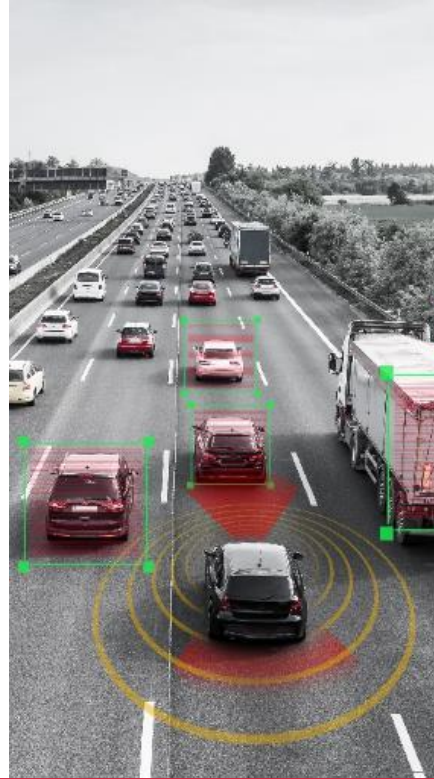
FEV Group – Your engineering and consulting partner for the development of mobility services and solutions tailored for your needs and requirements



Vehicle
Development



Powertrain
Development &
Electrification



Intelligent
Mobility & Software



Consulting

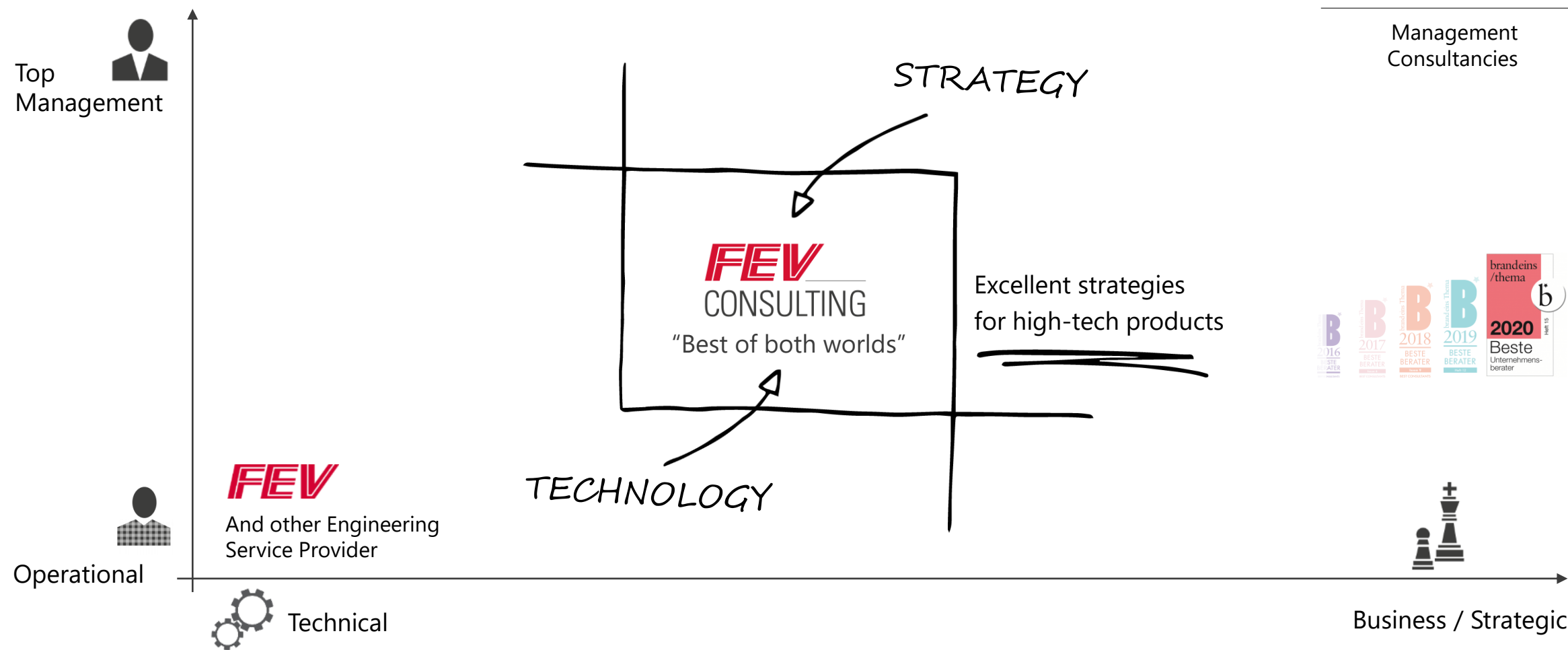


Software &
Testing Solutions

FEV Consulting offers solutions to top management issues in a technology-strategic environment paired with strong FEV engineering collaboration



POSITIONING OF FEV CONSULTING



FEV Consulting offers consulting and advisory services to the automotive and other high-tech driven industries across four key pillars



PORTFOLIO OF SERVICES



1 BUSINESS STRATEGIES

- Market & Customer Studies
- Growth Strategies
- New Product Opportunities
- (Digital) Transformation
- Due Diligence & M&A

2 ADVANCED TECHNOLOGIES

- Technology Roadmapping
- Powertrain & Vehicle Technologies
- Zero CO₂ Concepts
- Electrification and H₂ Strategies

3 SMART MOBILITY

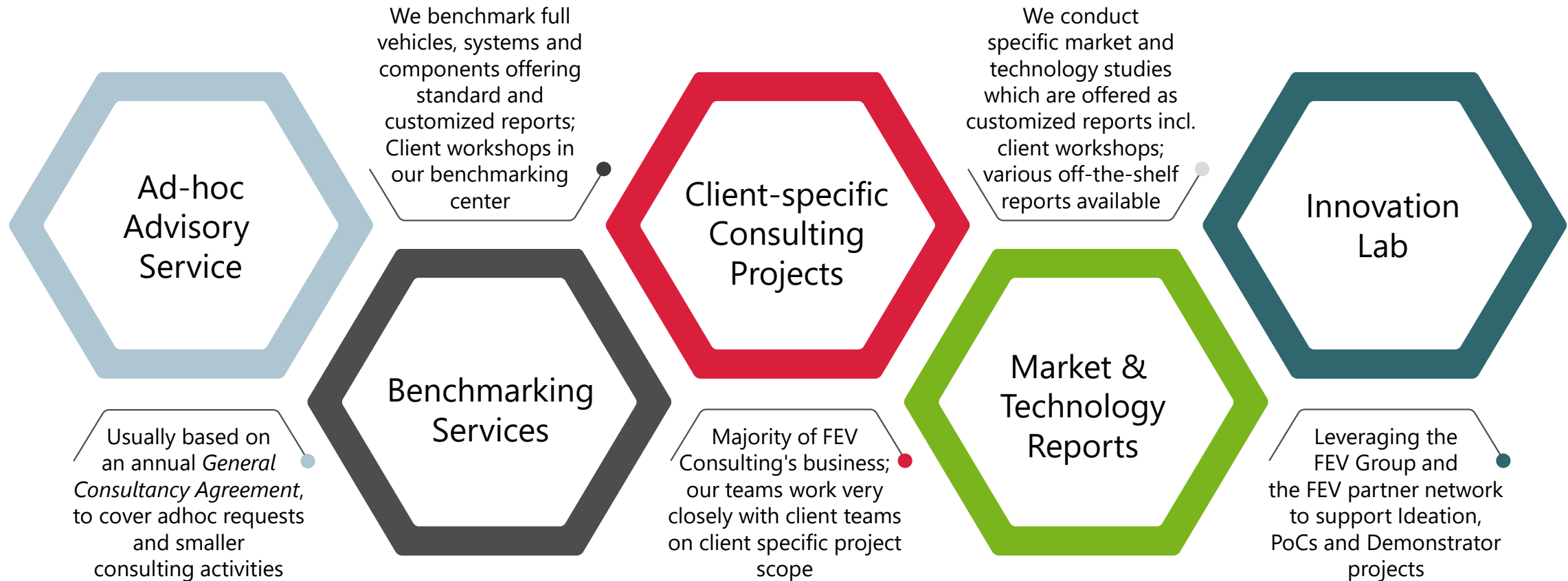
- Connected & Automated Vehicles
- Urban Air Mobility
- Smart City Concepts
- ITS & Cloud Services

4 COST ENGINEERING & OPERATIONS

- Cost Engineering
- Benchmarking
- Procurement & Supply Chain
- Process Optimization
- Production Planning

We support our clients through several types of consulting services

TYPES OF SERVICE



HYDROGEN SOCIETY

IMPACT ON TRANSPORT SECTOR



Many indicators for Hydrogen propulsion technology and fuel cell electric vehicles show increasing momentum

SELECT GLOBAL DRIVERS & MOMENTUM INDICATORS

 **4,000 H₂ STATIONS**
PLANNED TO BE IN OPERATION
IN EUROPE BY 2030

 **6 MEGATONS**
OF CLEAN HYDROGEN PRODUCTION
ANNOUNCED GLOBALLY UNTIL 2030

 **3-4 MINUTES REFUELING TIME**
A HYDROGEN FUEL CELL CAR NEEDS NEARLY THE SAME AMOUNT
OF TIME AS A CONVENTIONAL CAR TO REFUEL

 **10 million FUEL CELL VEHICLES**
EXPECTED BY 2040 WITHIN THE BASE SCENARIO IN PASSENGER CAR,
COMMERCIAL VEHICLE AND SELECTED NON-ROAD APPLICATIONS

 **0 EMISSIONS**
NO POLLUTANT AND CO₂ EMISSION
WITHOUT RANGE ANXIETY
FOR CUSTOMERS

 **11x MORE ENERGY THAN BEV**
HIGHER HYDROGEN GRAVIMETRIC ENERGY DENSITY COMPARED
TO BATTERY FITS BETTER FOR APPLICATIONS
WITH HIGH ENERGY DEMAND

Different private customer groups will have different purchase criteria for fuel cell powertrains

EXEMPLARY PRIVATE FUEL CELL CUSTOMER GROUPS



Always seeking for new technology

Vehicle availability



May not have sufficient access to electric charging points

Hydrogen cost & availability



Required flexible usage of vehicles for regularly long-driving distances

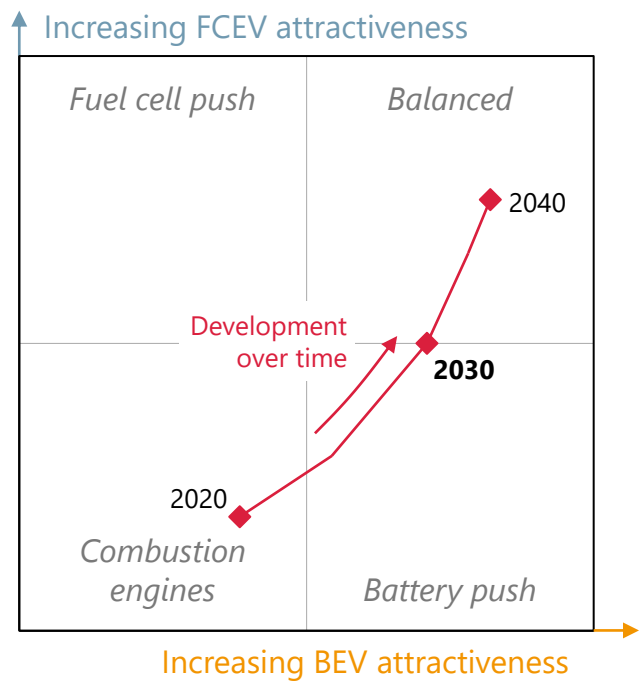
Hydrogen range & refueling time

After a phase of battery push in the early 2020, the momentum is expected to change towards fuel cell vehicles in 2030 leading to a balanced scenario

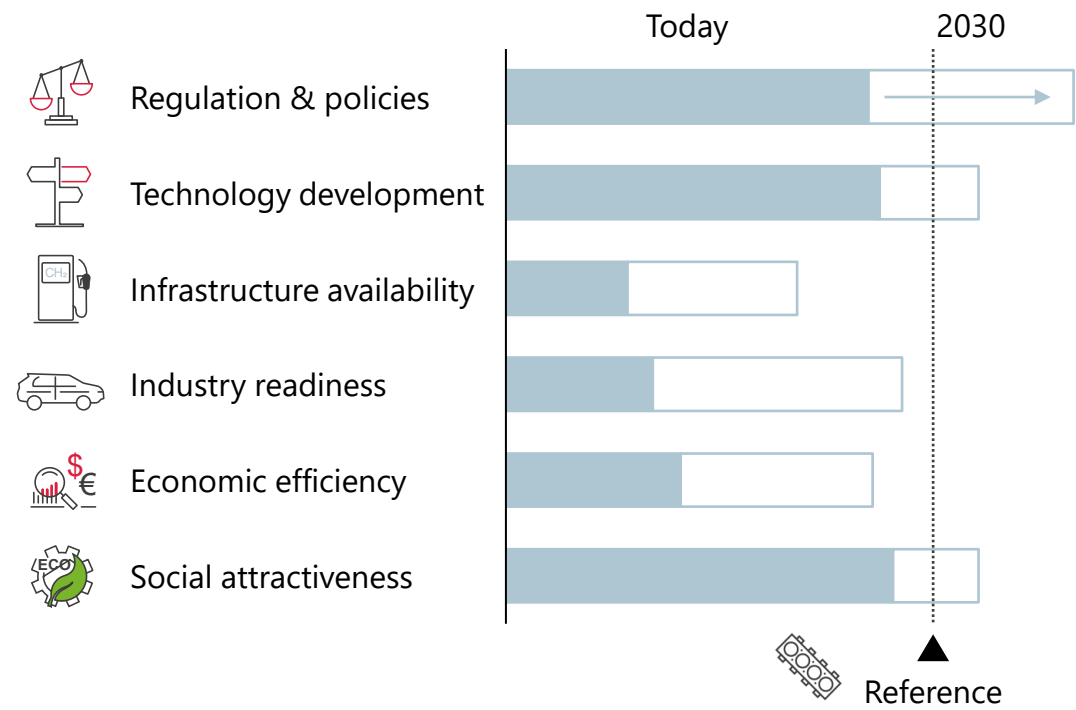


ZEV INDEX DEVELOPMENT

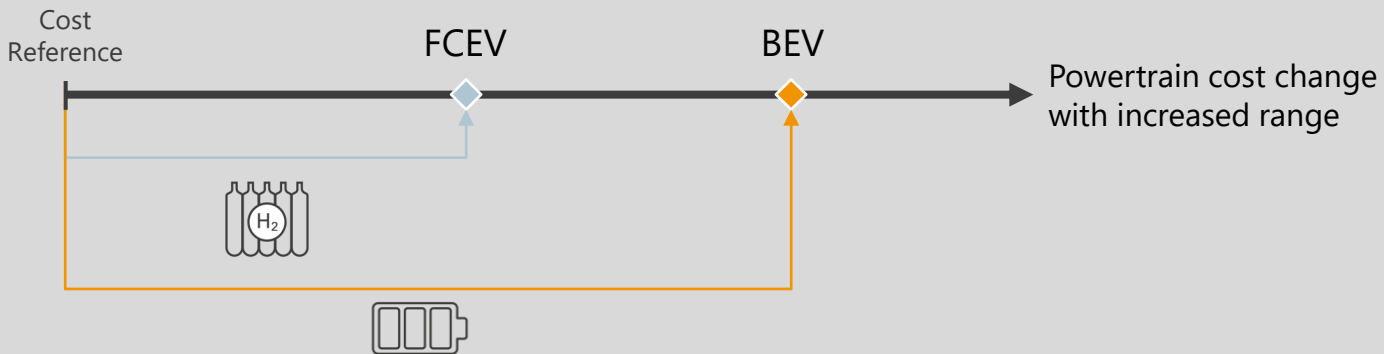
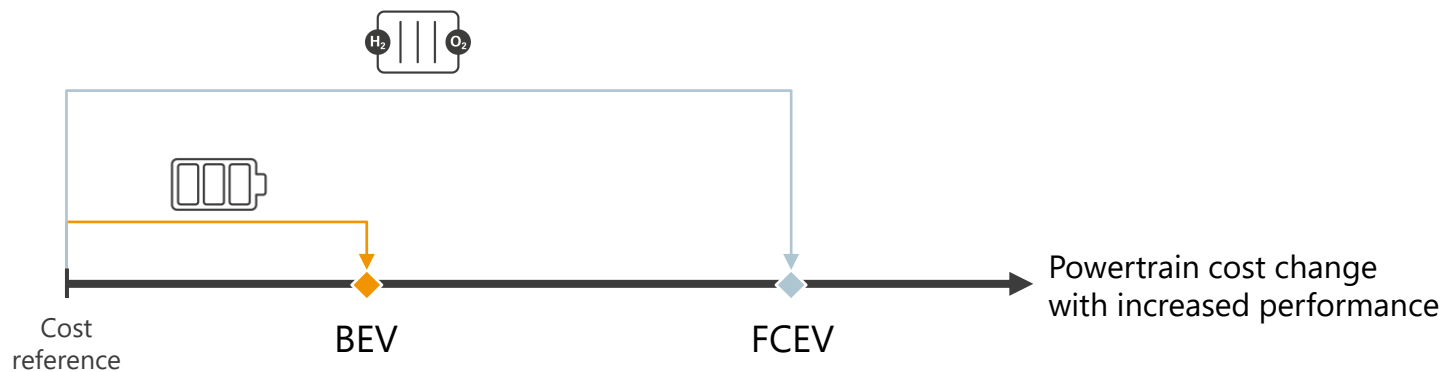
ZERO EMISSION VEHICLE (ZEV) INDEX FOR EUROPE



FUEL CELL COMPETITIVENESS IN 2030



Cost drivers for fuel cell vehicles rather depend on propulsion power than driving range compared to battery-electric vehicles



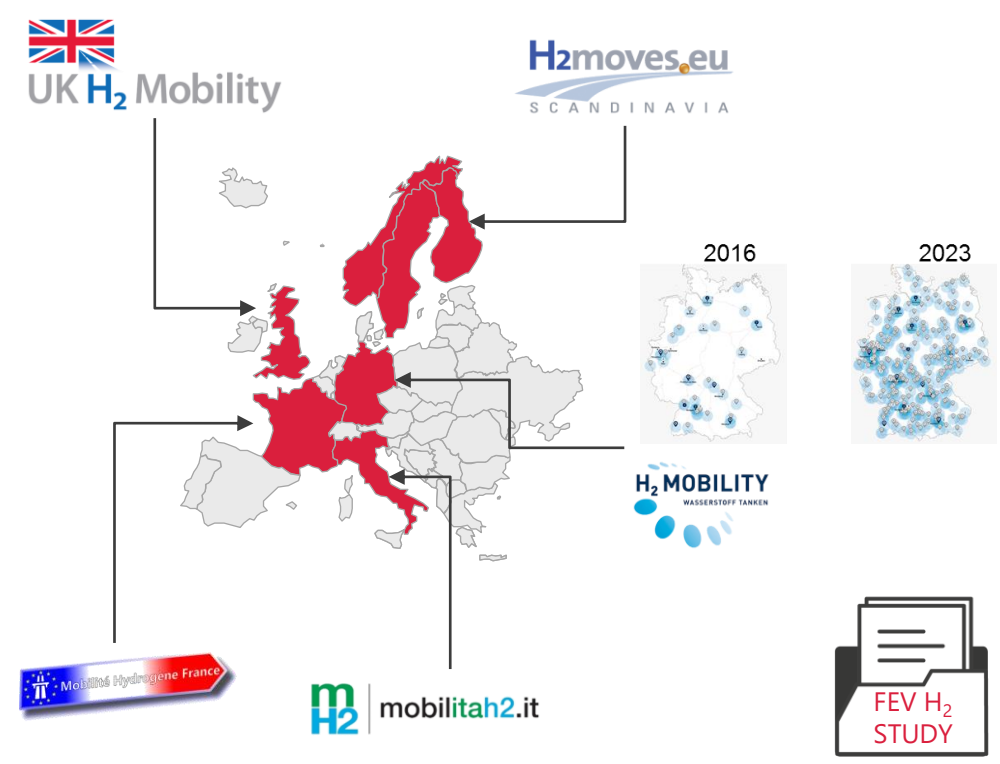
Hydrogen infrastructure is expected to significantly increase in the upcoming years, based on our recent Hydrogen study



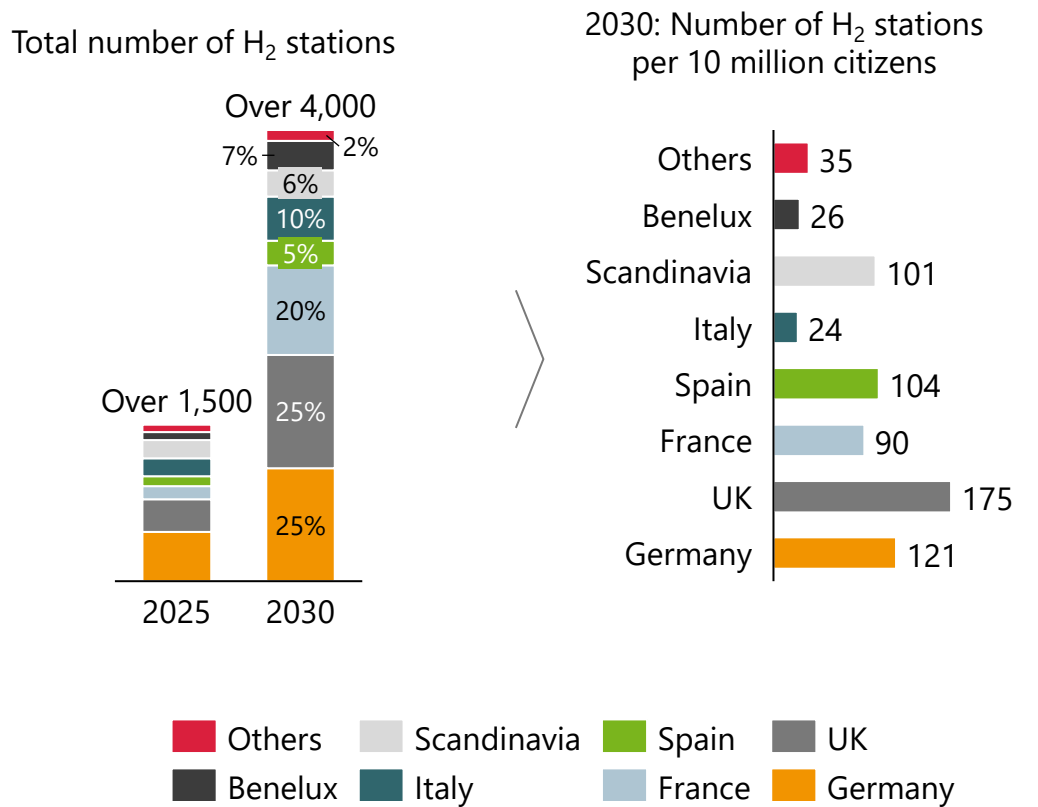
H2 INFRASTRUCTURE DEVELOPMENT INITIATIVES IN EUROPE



KEY H₂ INFRASTRUCTURE INITIATIVES

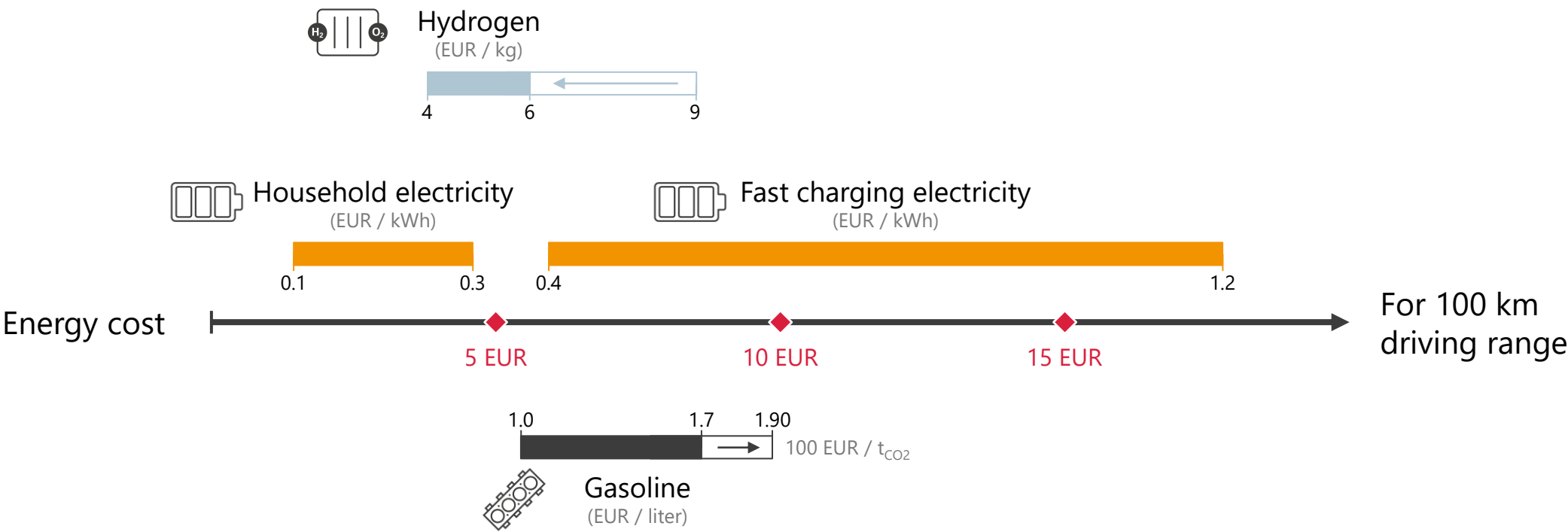


H₂ INFRASTRUCTURE DEVELOPMENT TARGETS



Private customers tend to overrate direct fuel cost instead of analyzing total cost of ownership

MOBILITY COST

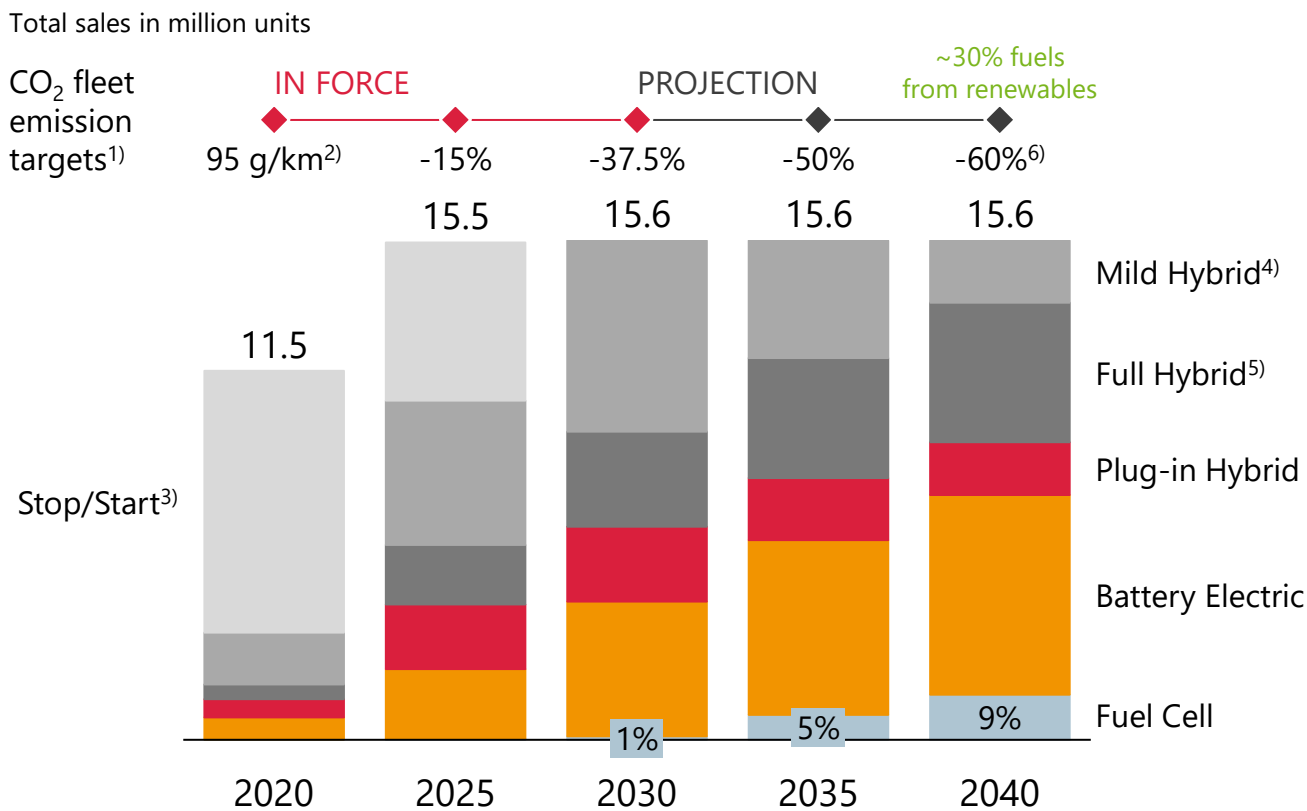


In Europe, a shift to zero-emission vehicles is expected; Even the “accelerated electrification” scenario could become reality driven by the EU Green Deal

PASSENGER CAR ELECTRIFICATION SCENARIOS – VEHICLE SALES & POWERTRAIN TYPE SHARES

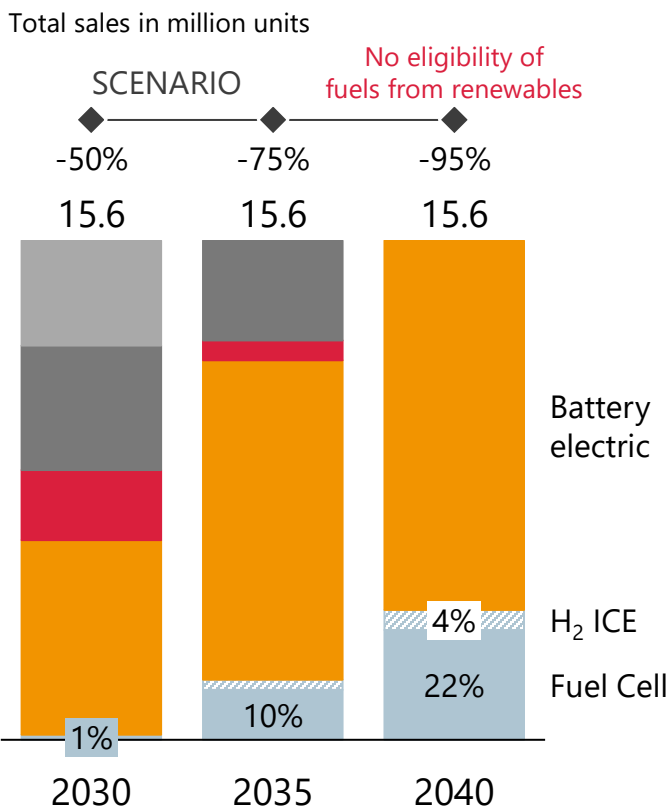


ELECTRIFICATION & RENEWABLE FUELS



1) 2021 target according NEDC; 2025 and 2030 targets and projection in reference to 2021 WLTP CO₂ emission; 2035+ target projection are tailpipe emissions values
2) In 2020 target must be achieved by 95% least emitting vehicles within each automaker's fleet, 100% compliance for 2021
3) Stop/Start and 12 V energy management; 4) 12 V and 48 V mild hybrids; 5) Includes 48 V hybrids with full hybrid functionalities
6) This projection accomplishes 95% of CO₂ emission reduction within vehicle stock in 2050 by using 238 TWh of PtL (e-fuels) in 2040 and 602 TWh in 2050 respectively
Source: FEV

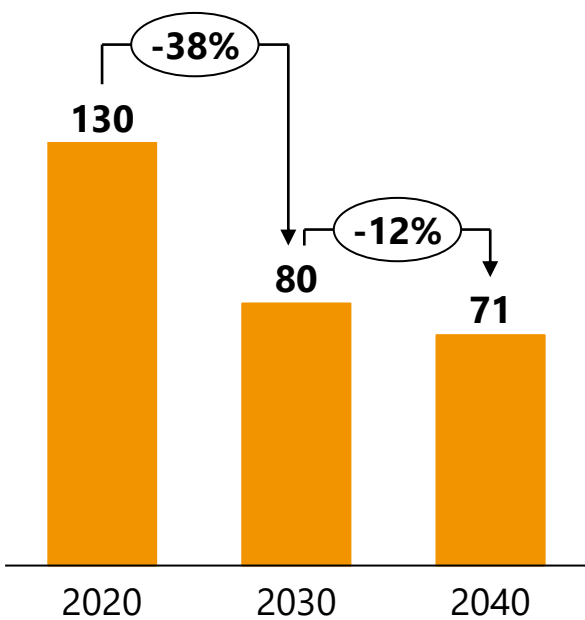
ACCELERATED ELECTRIFICATION



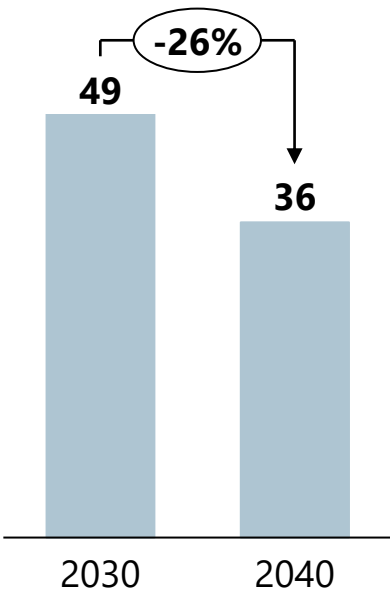
Battery cost show major cost decrease already until 2030, whereas hydrogen propulsion technologies will decrease in cost especially after 2030

KEY TECHNOLOGY ANALYSIS

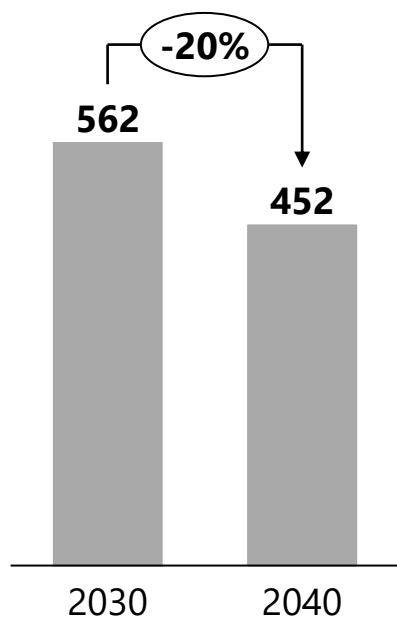
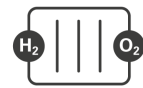
>> BASE SCENARIO 



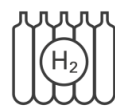
Battery pack cost¹⁾
in EUR / kWh_{installed}



Fuel cell system cost²⁾
in EUR / kW_{net}



H₂ tank system cost³⁾
in EUR / kg_{net}



Cost development
already visible in
our vehicle benchmarks



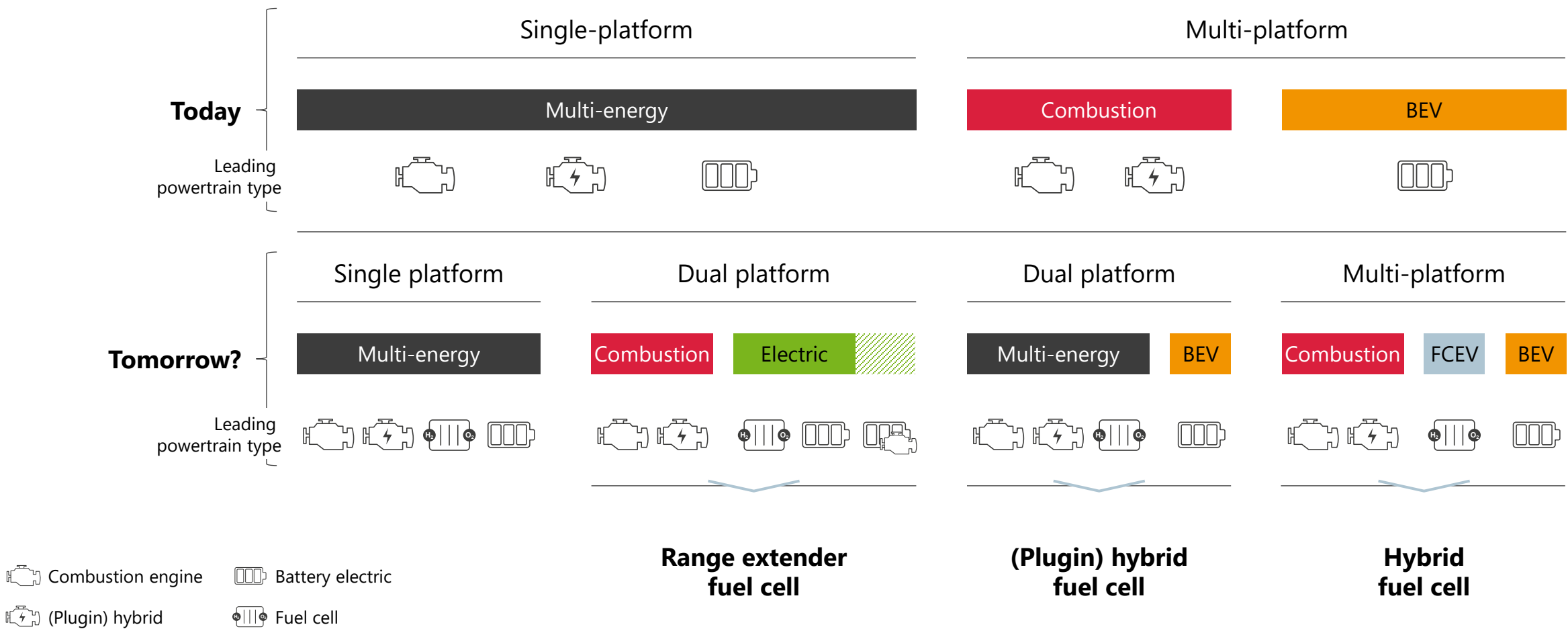
 BENCHMARKING

1) Sales weighted average battery pack cost for installed capacities of battery electric vehicles
2) Sales weighted average net fuel cell power
3) Sales weighted average net hydrogen tank capacity assuming 700 bar compressed Hydrogen
Source: FEV

There will be no “one-fits-all” solution in the future anymore, for the powertrain platform line-ups

VEHICLE PLATFORM STRATEGIES

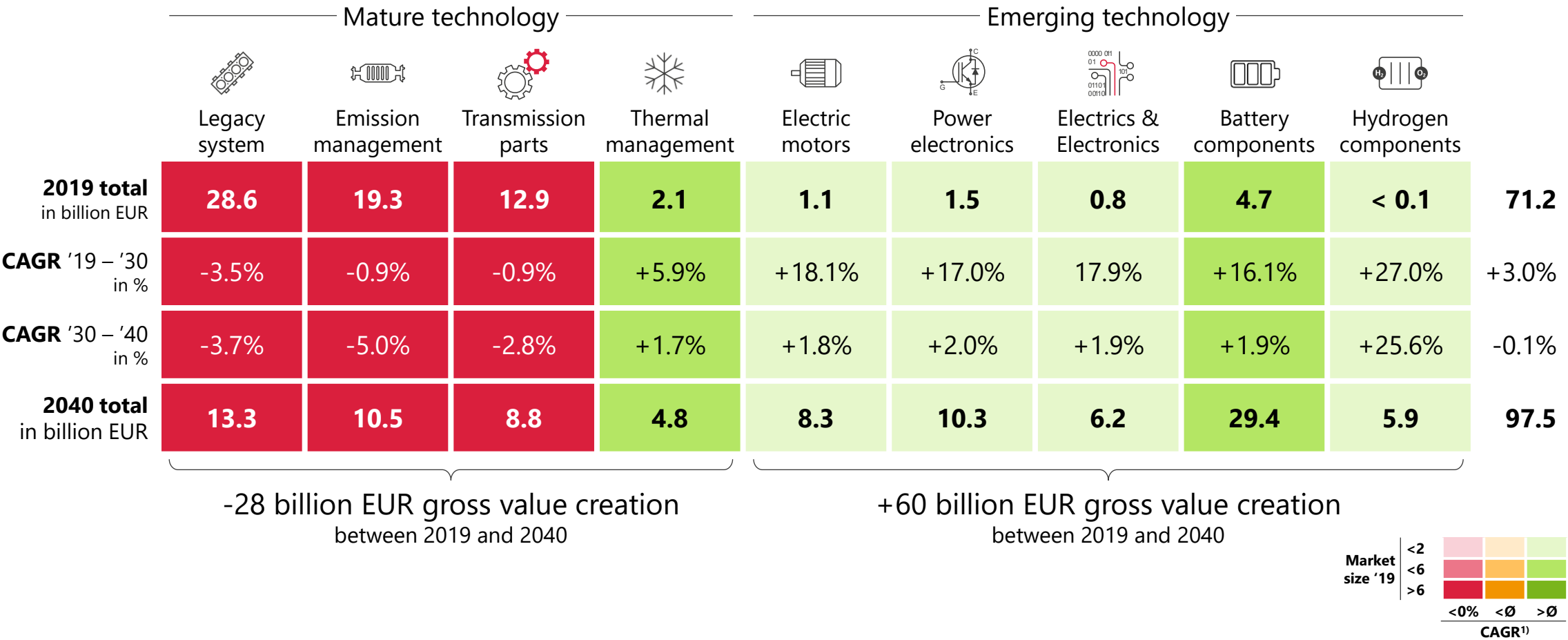
>> EXEMPLARY APPROACHES



From the mature technology groups, only thermal management components show growth as well as all emerging technologies

GROSS VALUE CREATION IMPACT

» ELECTRIFICATION & RENEWABLE FUELS



1) Compound annual growth rate, legend indicates shrinking markets, markets with below-average performance and market with above-average performance
Source: FEV

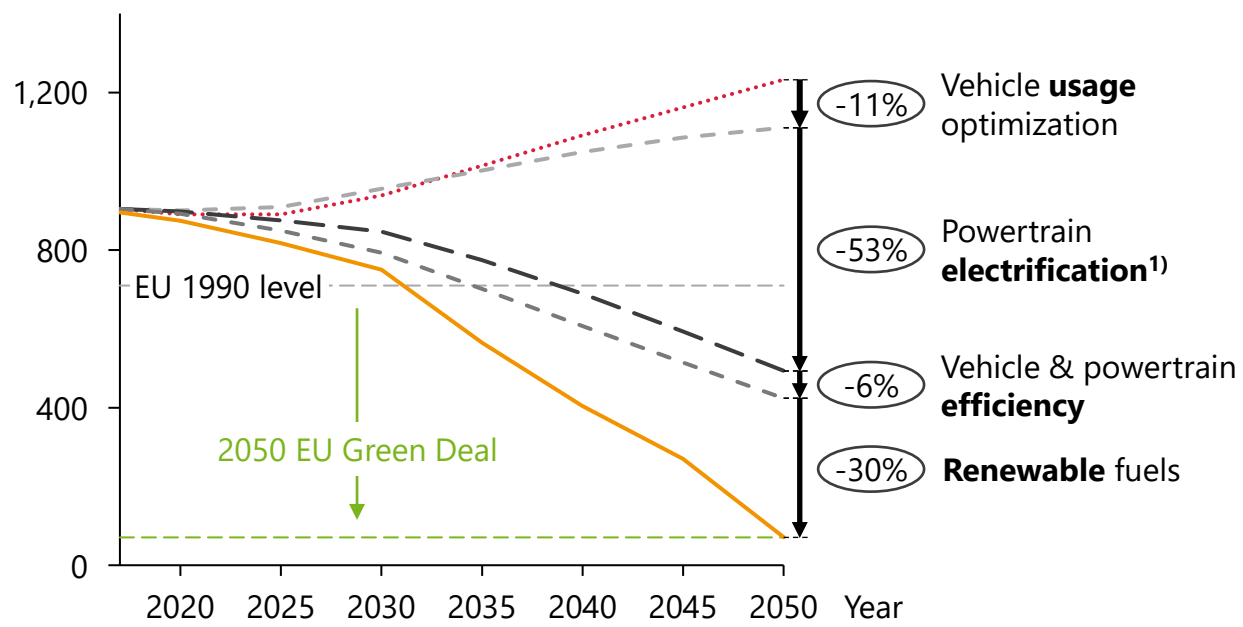
Compliance with the European Green Deal implies significant demand of green Hydrogen for on-road transport



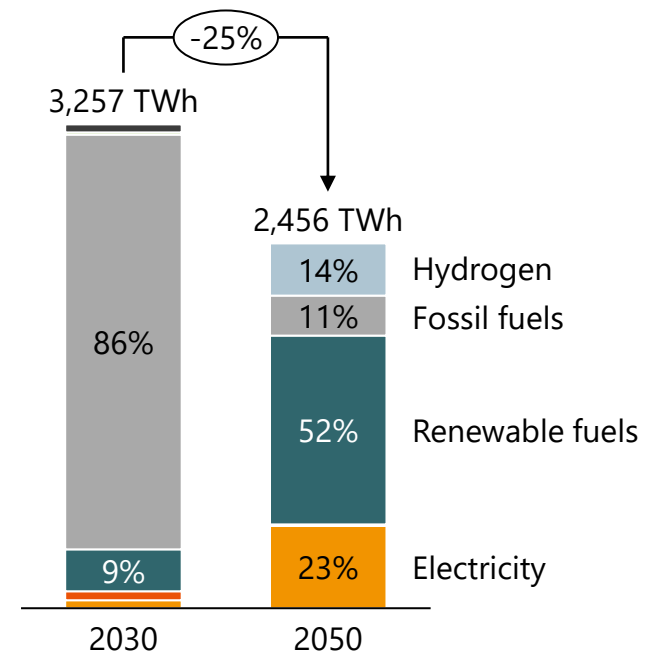
ELECTRIFICATION & RENEWABLE FUELS SCENARIO

ON-ROAD TRANSPORT CO₂ EMISSIONS

in million tons CO₂



FINAL ENERGY CONSUMPTION

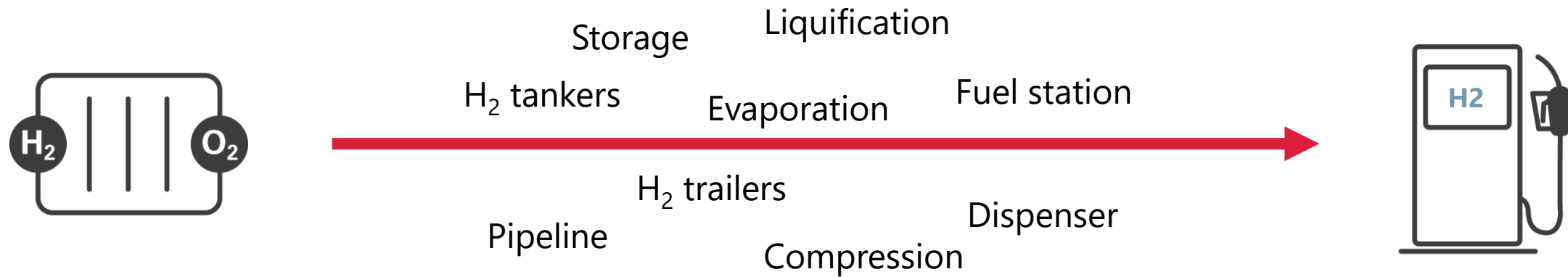


10 MEGATONS
OF CLEAN HYDROGEN REQUIRED FOR
EUROPEAN ON-ROAD TRANSPORT IN 2050

1) Including zero-tailpipe emission powertrains (fuel cell any H₂ ICE)
Source: FEV

How can the supply chain for green Hydrogen be managed?

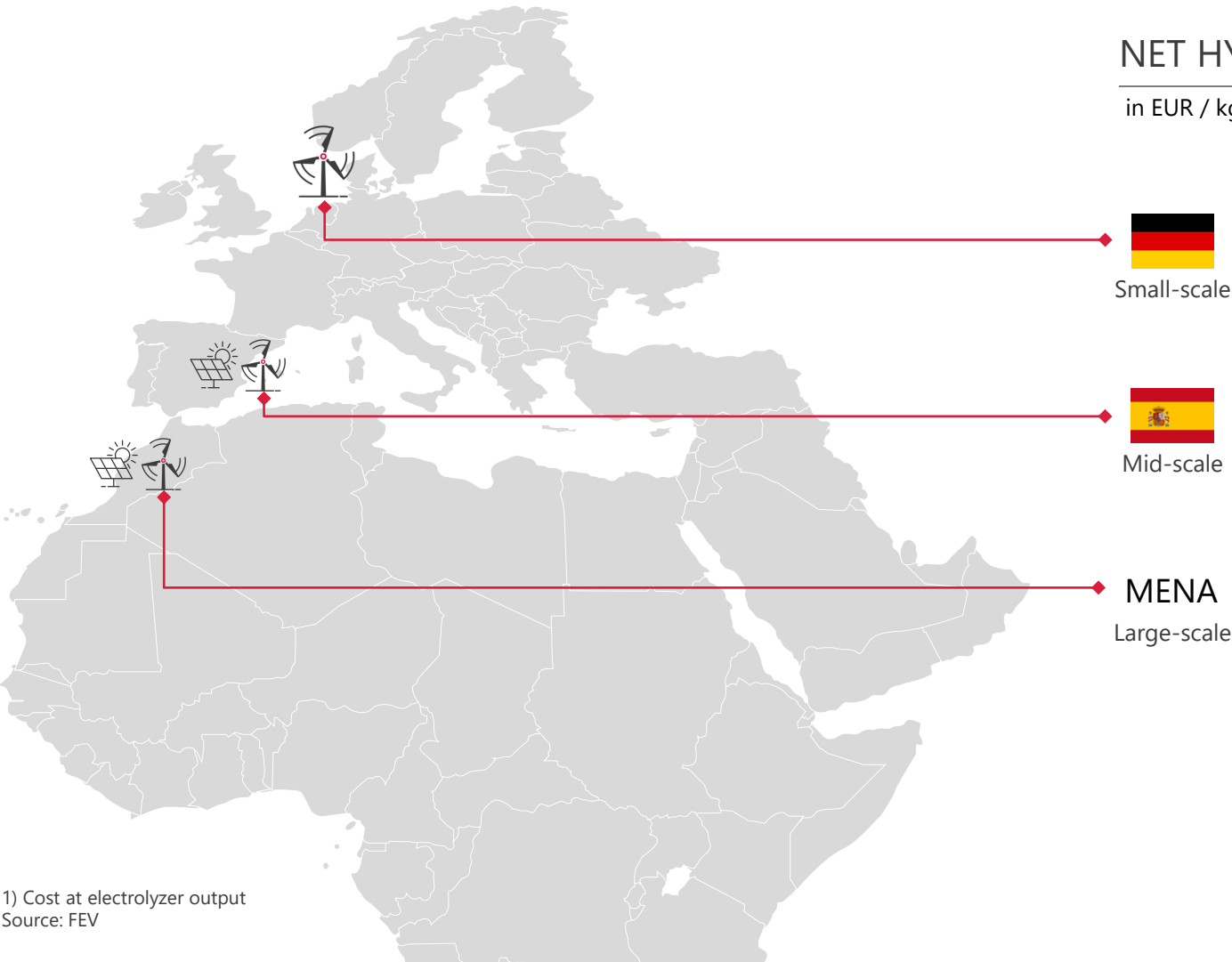
HYDROGEN SUPPLY CHAIN OVERVIEW



- » Where can Hydrogen be produced?
- » How to transport Hydrogen to the fuel pump?
- » Which cost will different types of Hydrogen and the supply chains imply?

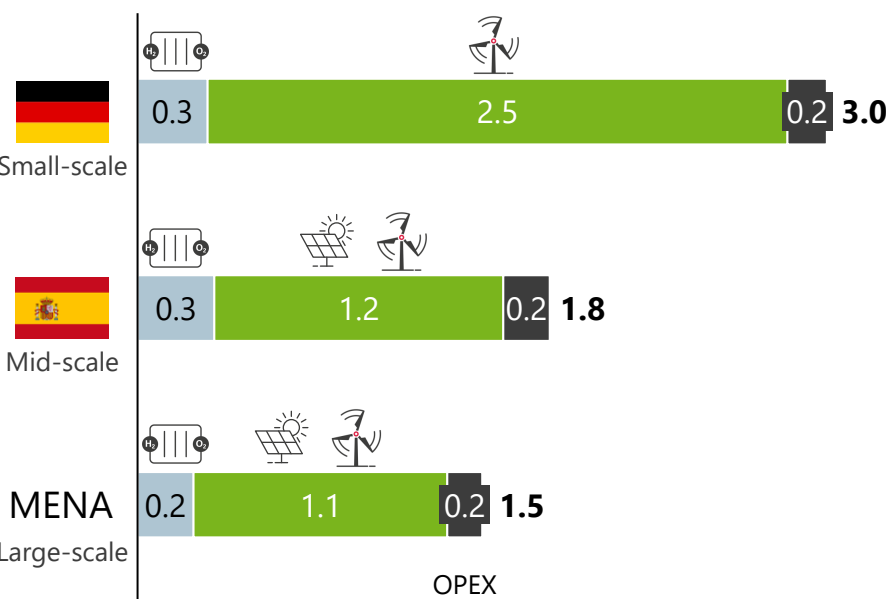
Electricity cost is the crucial factor for low-cost large-scale green Hydrogen production

WHERE CAN HYDROGEN BE PRODUCED?



NET HYDROGEN PRODUCTION COST¹⁾

in EUR / kg

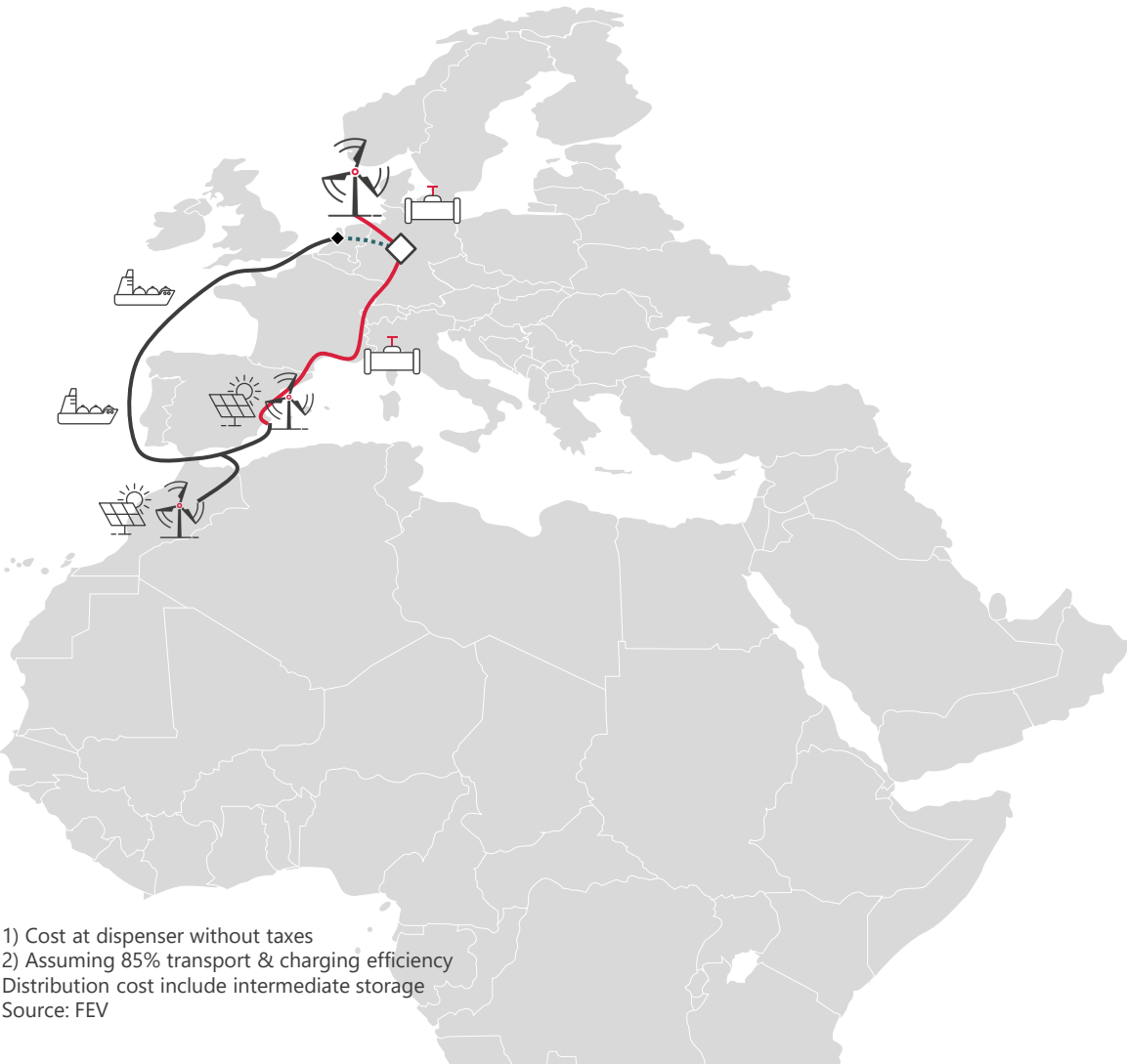


 **1,000 FULL-LOAD HOURS**
WITH NEGATIVE ELECTRICITY PRICES IN GERMANY REQUIRED
TO COMPETE IN HYDROGEN PRODUCTION WITH SPAIN

1) Cost at electrolyzer output
Source: FEV

Resulting net Hydrogen fuel cost vary between 2.7 and 4.5 EUR / kg depending on the distribution strategy and type of Hydrogen dispensed

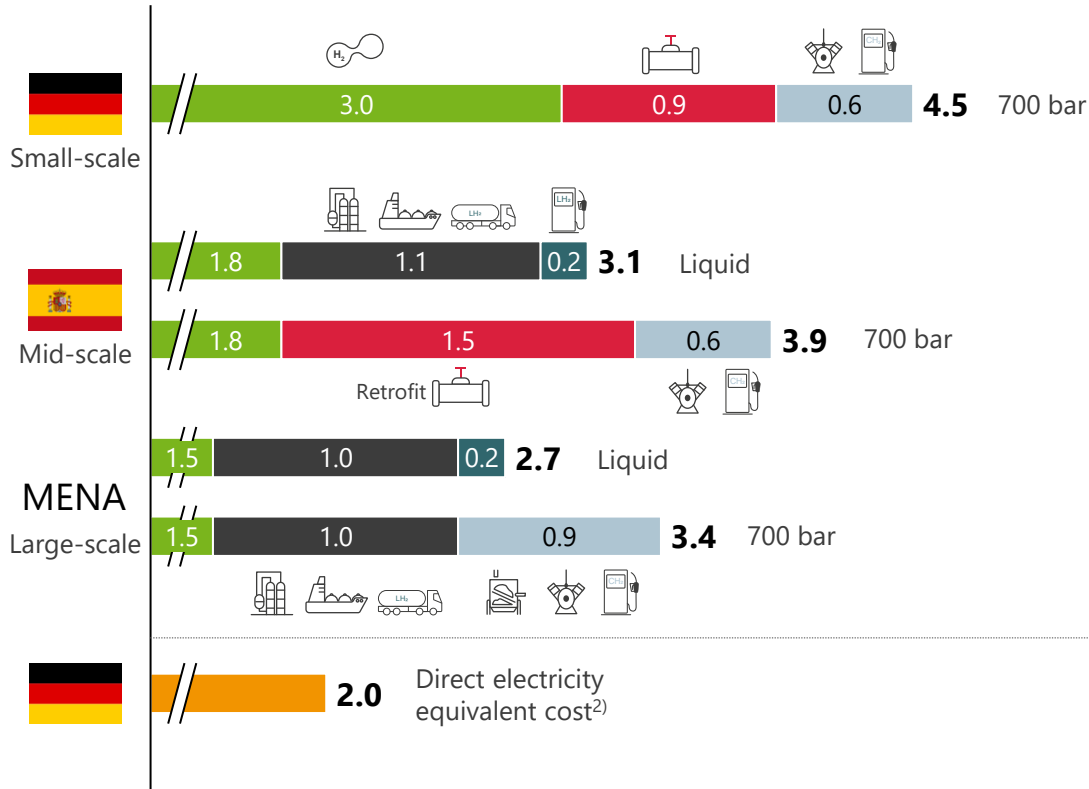
WHICH COST AT THE FUEL STATION ORIGINATE?



1) Cost at dispenser without taxes
 2) Assuming 85% transport & charging efficiency
 Distribution cost include intermediate storage
 Source: FEV

NET HYDROGEN FUEL COST¹⁾

in EUR / kg



Beside the distribution via fuel stations, there can be alternative supply solutions which can help to accelerate the usage of Hydrogen

ALTERNATE HYDROGEN SUPPLY SOLUTIONS

Mobile Hydrogen refueling stations



Hydrogen micro-grids



Hydrogen is vital for decarbonization

Hydrogen propulsion gains traction, as major competitiveness indicators are developing as our Zero Emission Vehicle Index prospects

- Some customer needs, such as flexible long driving ranges, may not be fully covered by battery-electric powertrains, but with fuel cell powertrains
 - For long-range vehicles and customers with frequent fast refueling requirements, fuel cell vehicles are suitable
 - The cost for mobility can achieve similar levels for both powertrain alternatives
 - However, fuel cell and battery-electric vehicles are expected to coexist, rather than substitute each other
- For the automotive industry, gross value creation shifts to emerging technologies
 - Beside battery-electric ones, fuel cell vehicles can counteract the shortfall in mature technologies, but implies new challenges for platform strategies
- Large-scale Hydrogen production cost are determined mainly by electricity cost
 - Using excess energy can be an option, but it may not satisfy the total demand
- Hydrogen net fuel cost at the fuel station below 5 EUR / kg are possible

Get in touch with us to learn more about the latest fuel cell vehicles



Our benchmark reports consist of different modules and cover:

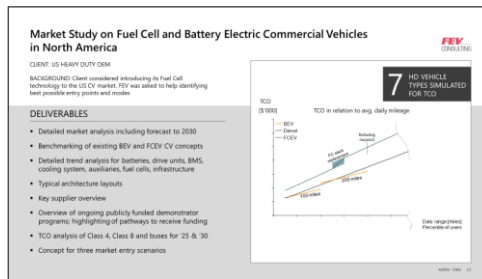
- Micro Benchmark
- NVH Footprint
- Powertrain Thermal Management
- Operations and Consumption
- Fuel Cell System Evaluation
- Component Tear Down & Documentation
- Cost Analysis
- Compressor Analysis & Mapping
- Fuel Cell Stack Investigation
- NEXO vs. MIRAI 2 comparison

Over the last several months we have seen hydrogen topics including fuel cells and H₂-ICEs significantly gaining interest and traction within the market

RECENT ACTIVITIES

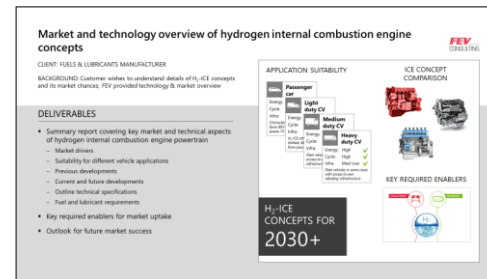
Commercial Vehicle OEM

Fuel cell market study in North America



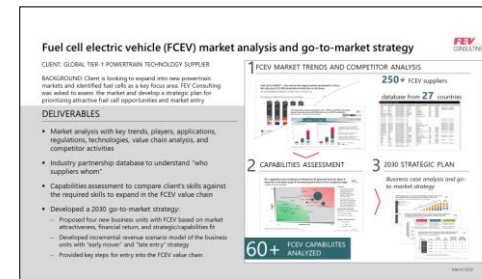
Fuel & Lubricant Supplier

H₂-ICE market & technology overview



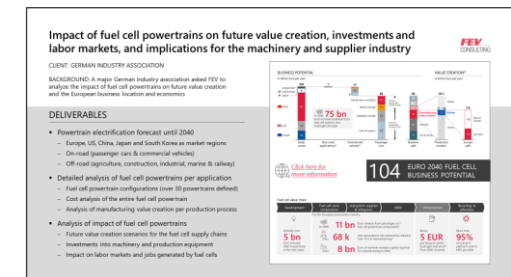
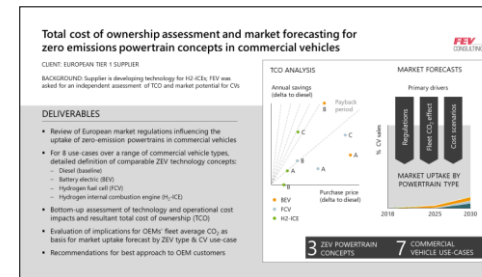
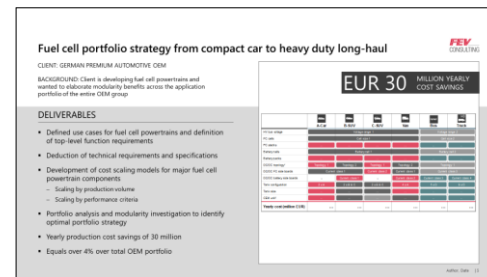
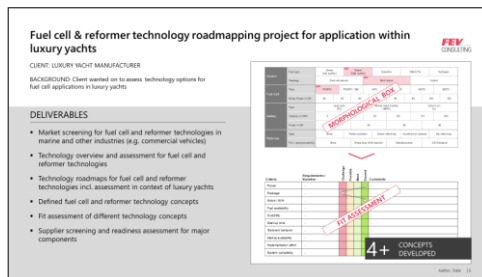
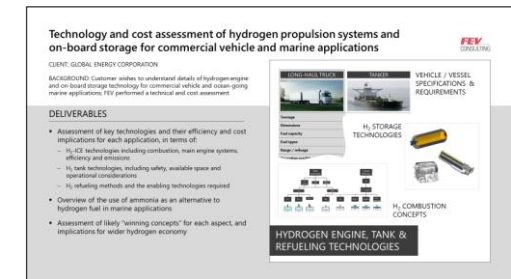
Tier-1 Supplier

Market study and go-to-market strategy



Energy Corporation

H₂ propulsion & storage technology assessment



Luxury Yachts OEM

Concept study for a Fuel Cell APU

Automotive OEM

Platform strategy for fuel cells (passenger car to heavy-duty)

Tier-1 Supplier

ZEV powertrain Total Cost of Ownership & market forecast

Industry Association

Impact of fuel cell technology on the industry

CONTACT DETAILS



ALEXANDER NASE

MANAGING DIRECTOR
FEV CONSULTING



Phone: +49 160 94110987
Email: nase@fev.com



KAI KRÜGER

MANAGER
FEV CONSULTING



Phone: +49 241 5689 9995
Email: krueger_kai@fev.com

FEV Consulting GmbH – Neuenhofstraße 181 - 52078 Aachen - Germany - www.fev-consulting.com

Aachen # Beijing # Bilbao # Cologne # Detroit # Dubai # Munich # Tokyo