BMW Group, Tobias Brunner, 13.11.2013.

HYDROGEN FUEL CELL TECHNOLOGY.

OPTION FOR ELECTRIC MOBILITY ON THE LONG RANGE.

BMW GROUP

BORN ELECTRIC.

BMW i3 – WE DELIVER AS PROMISED.

130 – 160 km
All Electric Range

0 – 60 / 100 km/h
in 3.7 / 7.2 s

1195 kg
Curb weight

12.9 kWh / 100km

„Purpose Design“

New Vehicle Concept

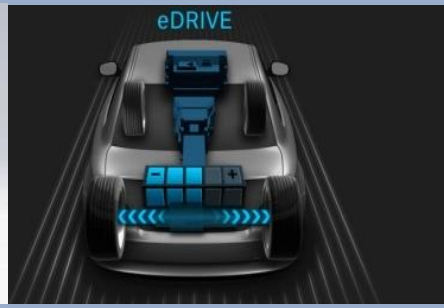
„Carbon Fiber RP“

New Materials & Recycling

„LifeDrive“

New Production Concept

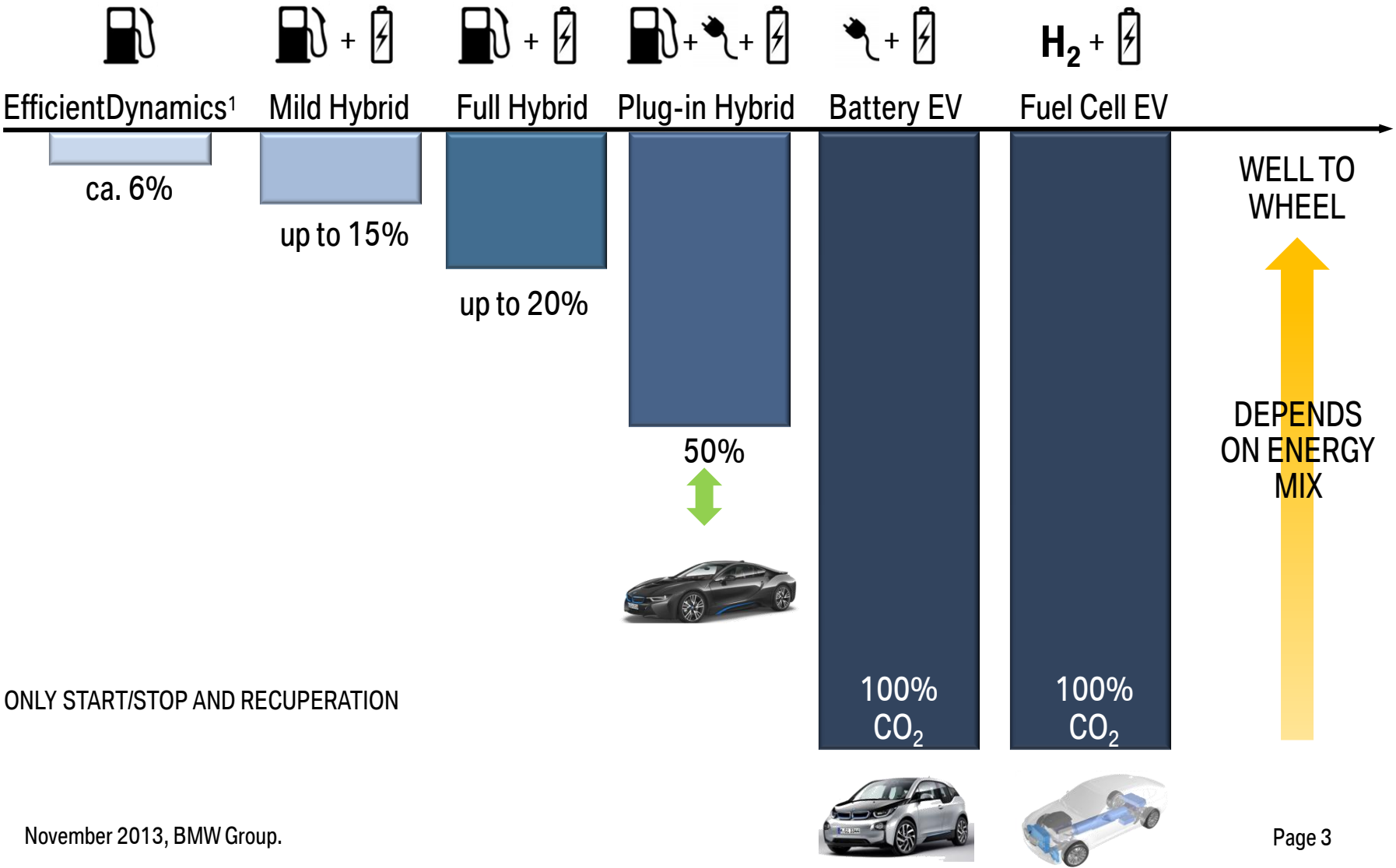
„eDrive“



New All Electric Drive Train

MOTIVATION FOR HYDROGEN.

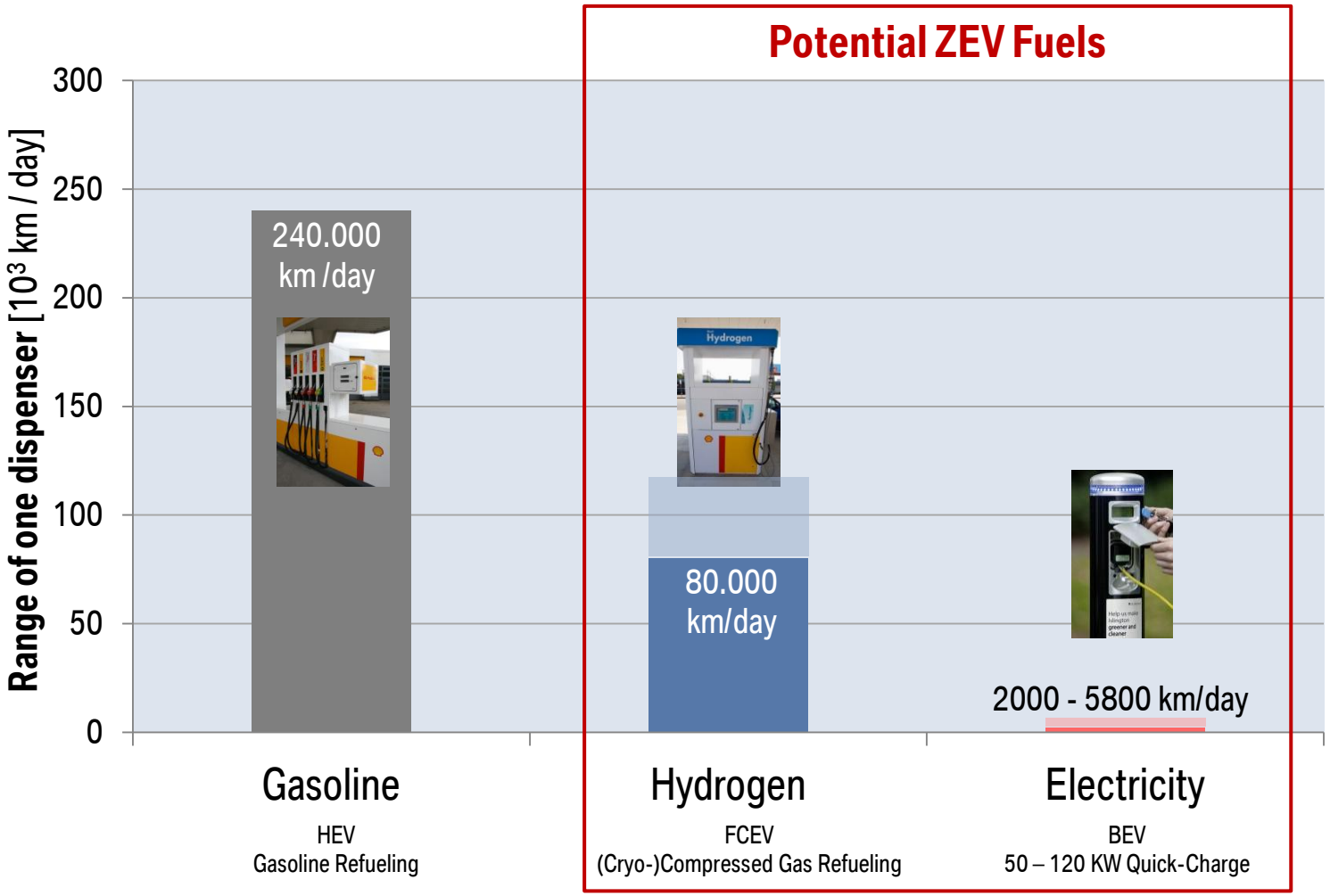
ADVANCED ELECTRIFICATION ENABLES GREEN HOUSE GAS REDUCTION.



[1] ONLY START/STOP AND RECUPERATION

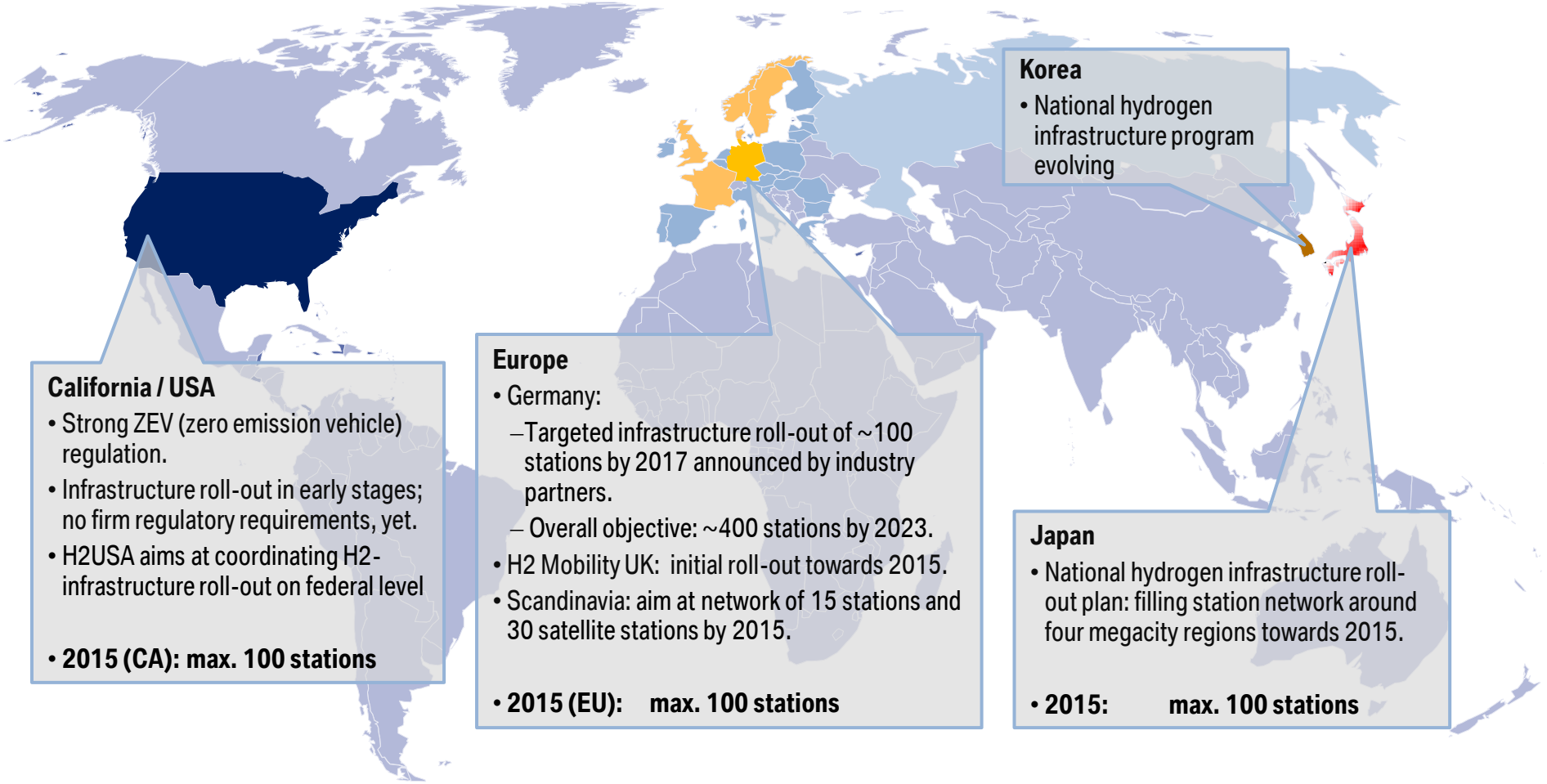
MOTIVATION FOR HYDROGEN.

REFUELING TIME FAVORS HYDROGEN …



MOTIVATION FOR HYDROGEN.

… BUT WIDE-SPREAD HYDROGEN INFRASTRUCTURE IS STILL YEARS AWAY.



California / USA

- Strong ZEV (zero emission vehicle) regulation.
- Infrastructure roll-out in early stages; no firm regulatory requirements, yet.
- H2USA aims at coordinating H2-infrastructure roll-out on federal level

- **2015 (CA): max. 100 stations**

Europe

- Germany:
  - Targeted infrastructure roll-out of ~100 stations by 2017 announced by industry partners.
  - Overall objective: ~400 stations by 2023.
- H2 Mobility UK: initial roll-out towards 2015.
- Scandinavia: aim at network of 15 stations and 30 satellite stations by 2015.

- **2015 (EU): max. 100 stations**

Korea

- National hydrogen infrastructure program evolving

Japan

- National hydrogen infrastructure roll-out plan: filling station network around four megacity regions towards 2015.

- **2015: max. 100 stations**

FUEL CELL TECHNOLOGY.

REMAINING CHALLENGES NEED SIGNIFICANT EFFORTS TOWARDS 2020.

BMW Fuel Cell Technical Targets:

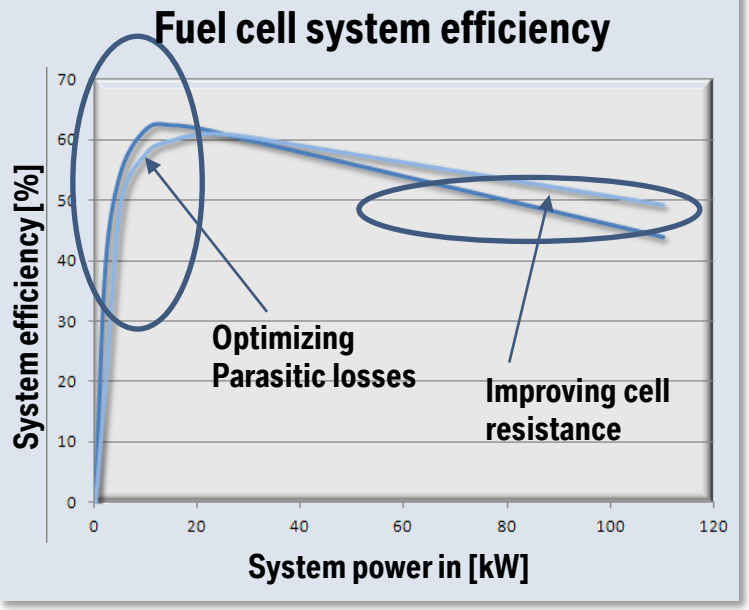
- 80 – 110 kW Fuel Cell System power output
- System power density > 1 kW/kg
- High dynamic gradients > 100 kW/s
- Operating temperature > 90 °C
- System efficiency optimized to 45-50% in full load
- Peak efficiency optimized for high efficiency during city cycles to >60 % (part load)
- Lifetime (5500 h – 6000 h with < 15% degradation),
- Cold start capability to -30°C.

Fuel Cell Main Challenges for BMW:

- **Cooling** under high load and critical ambient conditions (e.g. high-speed uphill driving)
- **FC System Cost** (Membrane, Catalyst, Bipolar Plate, auxiliary systems) at target performance & durability.

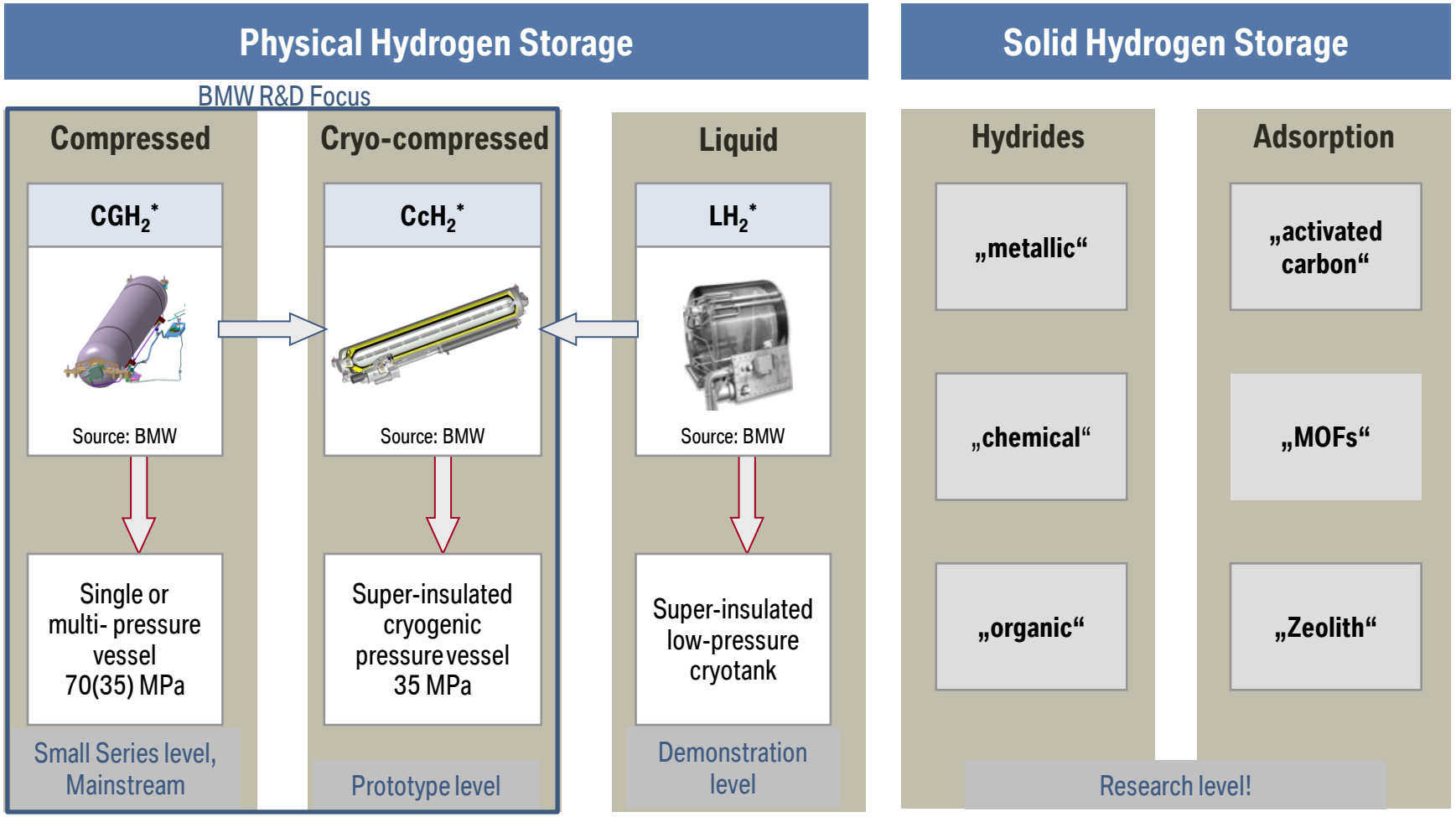
Fuel Cell System including Stack & Auxiliary Systems: e.g.

Air Compressor
H_2 Recirculation Pump
Water Pump
De-Ionizer
Inverter
DC/DC Converter



CRYO-COMPRESSED HYDROGEN STORAGE.

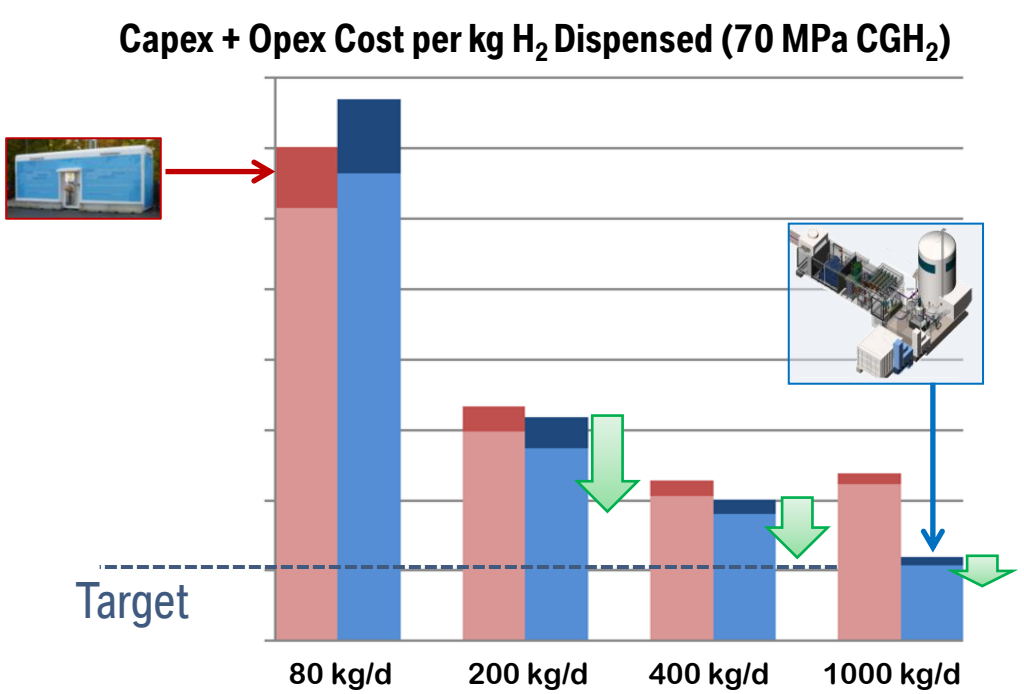
COMPACT AFFORDABLE HYDROGEN VEHICLE STORAGE IS KEY.



*) **CGH_2** := Compressed Gaseous Hydrogen (70 MPa) **CcH_2** := Cryo-compressed Hydrogen (1 MPa – 35 MPa) **LH_2** := Liquid/Liquefied Hydrogen (0.1 MPa – 1 MPa)

HYDROGEN INFRASTRUCTURE.

LARGE STATIONS WITH LH_2 DELIVERY & CRYOGENIC COMPRESSION SHOW PROMISING LONG TERM BUSINESS CASE.



* Fixed Opex p.a. w/o electricity, incl SG&A (selling, general and administrative expenses)
** Currently under evaluation

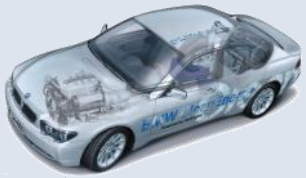
Gaseous trucked-in more economical for smaller, whereas liquid supply more suited for larger stations. Pure 300 bar CcH_2 stations would lead to lowest CAPEX / OPEX cost at large stations.

* Fixed Opex p.a. w/o electricity, incl SG&A (Selling, General and Administrative Expenses)
** Currently under quantitative evaluation

BMW HYDROGEN STRATEGY.

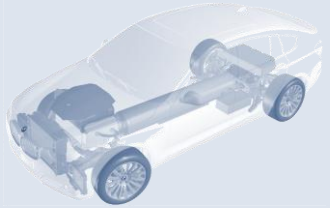
FCEV CAN COMPLEMENT ELECTRIC MOBILITY, ONCE THE REMAINING TECHNICAL AND COST CHALLENGES HAVE BEEN OVERCOME.

Hydrogen 7 small series | **Advanced key components** | **Next vehicle & infrastructure**

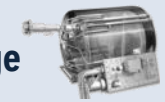


Technology Leap Storage & Drive train

Advancement Key Components



LH_2 Storage

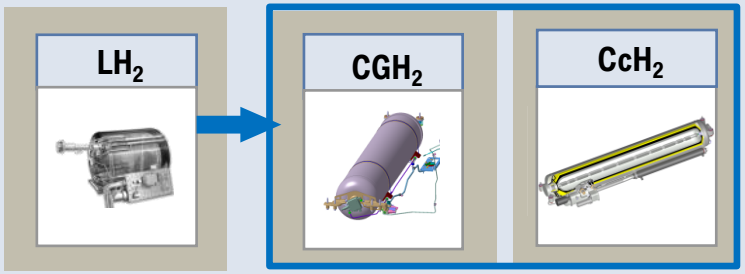


- Capacity ✓
- Safety ✓
- Boil-off loss ✗
- Pressure supply ✗
- Complexity ✗
- Infrastructure ✗

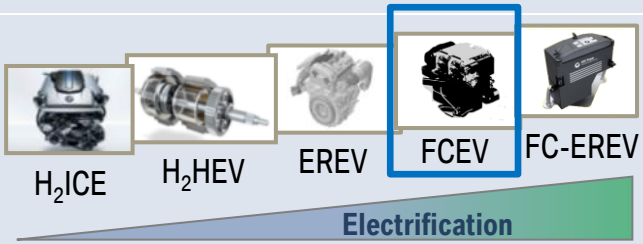
IC Engine (PFI)

- Power density ✓
- Dynamics ✓
- Durability & cost ✓
- Efficiency ✗

H_2-Storage



H_2 Drive train



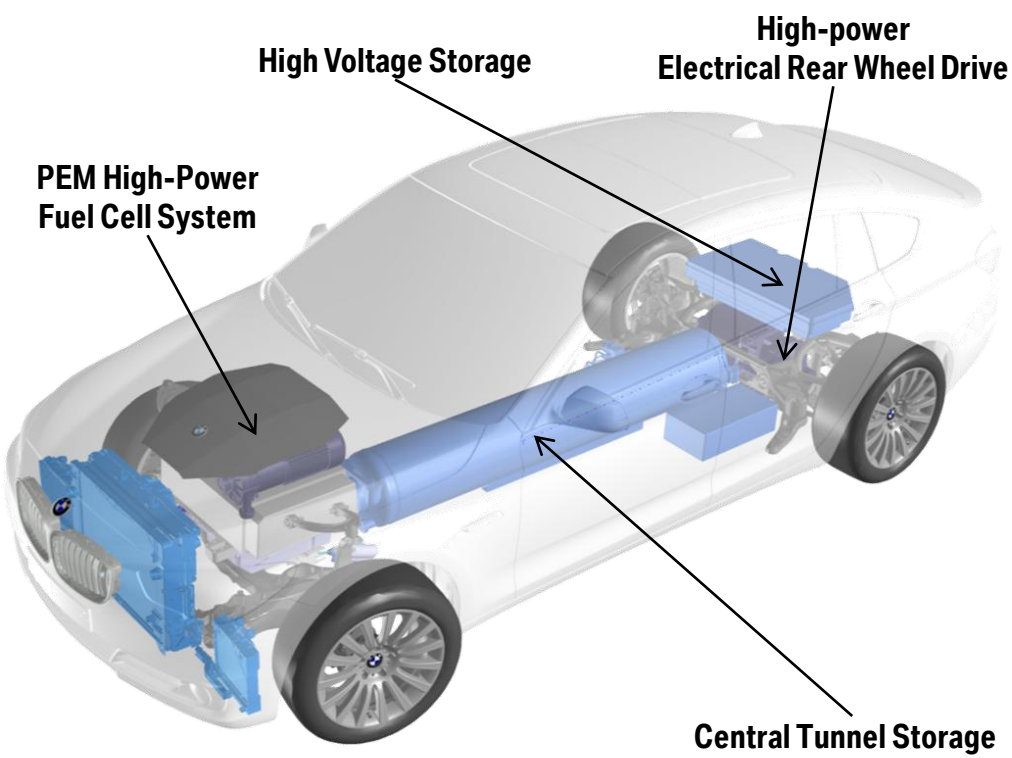
Long-range eDrive:

- Zero Emission.
- Focus on vehicles with high energy demand.
- Range > 500 km (5-7 kg H_2)
- Fast refueling (< 4 min / 7 kg)
- Optimized safety oriented vehicle package & component integration
- Loss-free operation for all relevant use cases
- Compatibility to competitive infrastructure standards

BMW FCEV DEMONSTRATOR FLEET 2015.

BMW TECHNOLOGY DEMONSTRATOR VEHICLES 2015 WITH COMPRESSED AND CRYO-COMPRESSED HYDROGEN STORAGE.

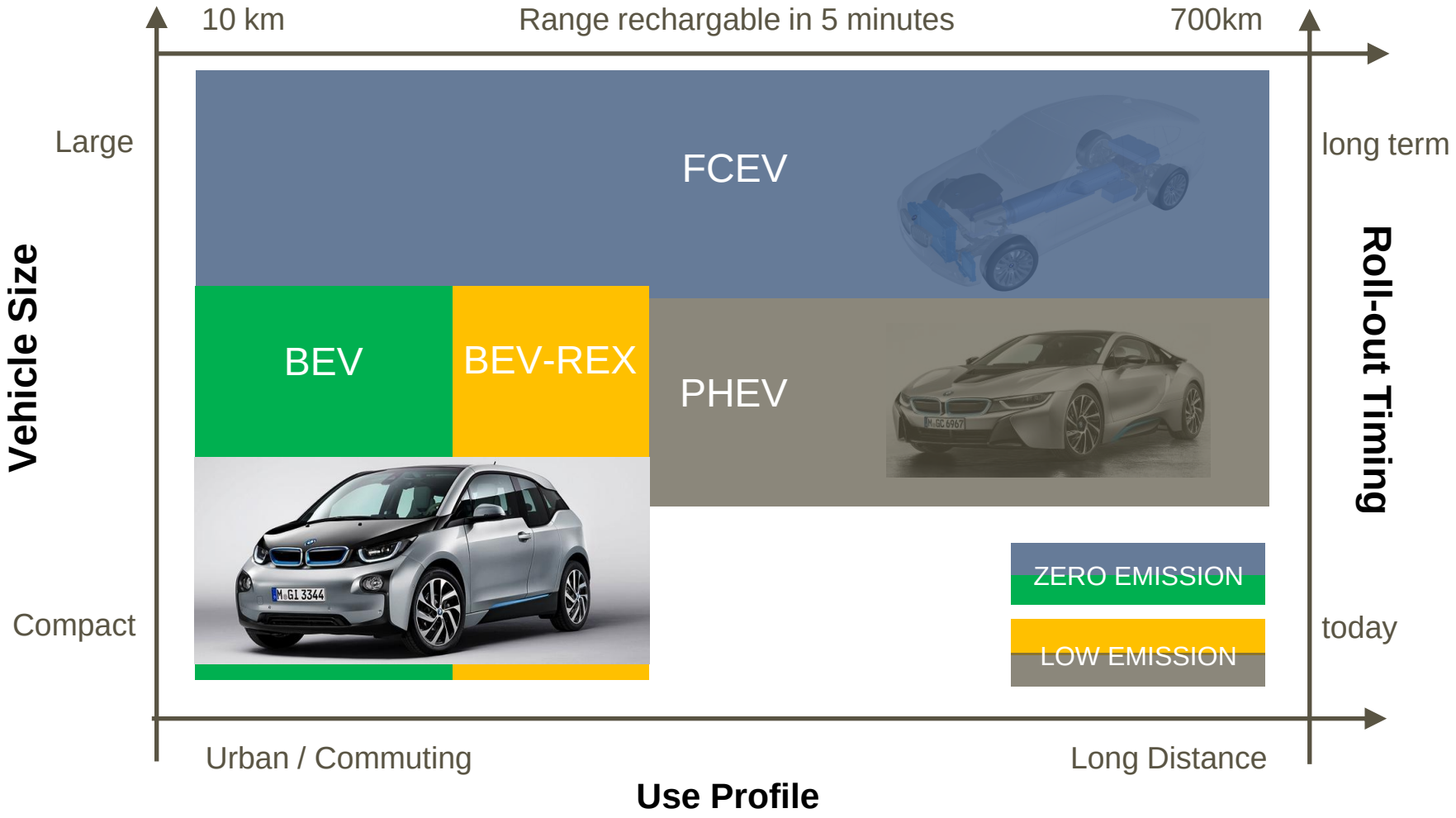
700 bar CGH_2 (Compressed Gas)		350 bar CcH_2 (Cryo-compressed Gas)
> 350 (500*) km Range		> 500 (700*) km Range
Refueling time < 5 min for 350 km		Refueling time < 5 min for 500 km
-		Boost cooling mode for additional performance
High bonfire and crash safety		Highest bonfire and crash safety
Non-compromised compartment space		Non-compromised compartment space



*) projected real world range (drive cycle range (FTP72))

TECHNOLOGY PORTFOLIO.

TECHNOLOGY COST & CUSTOMER CONVENIENCE WILL DECIDE.



BMW EfficientDynamics

Less emissions. More driving pleasure.