

Battery Metals Conference

Platinum-Based Fuel Cell Adoption in Future EV Powertrains

23-24 September 2019



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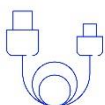
OUR DNA



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1850
PIGEON



1858
CABLE



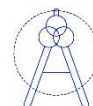
1865
TELEGRAPH



1964
STOCKMASTER



1973
MONITOR



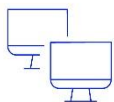
1980
TRIARCH



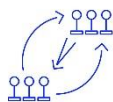
1981
DEALING



1989
DEALING 2000



1999
REUTERS 3000
EXTRA



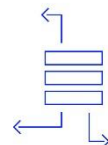
2001
RMDS



2001
TREP



2001
EIKON



2013
ELEKTRON



2016
EIKON APP
STUDIO



2017
ELEKTRON
DATA
PLATFORM

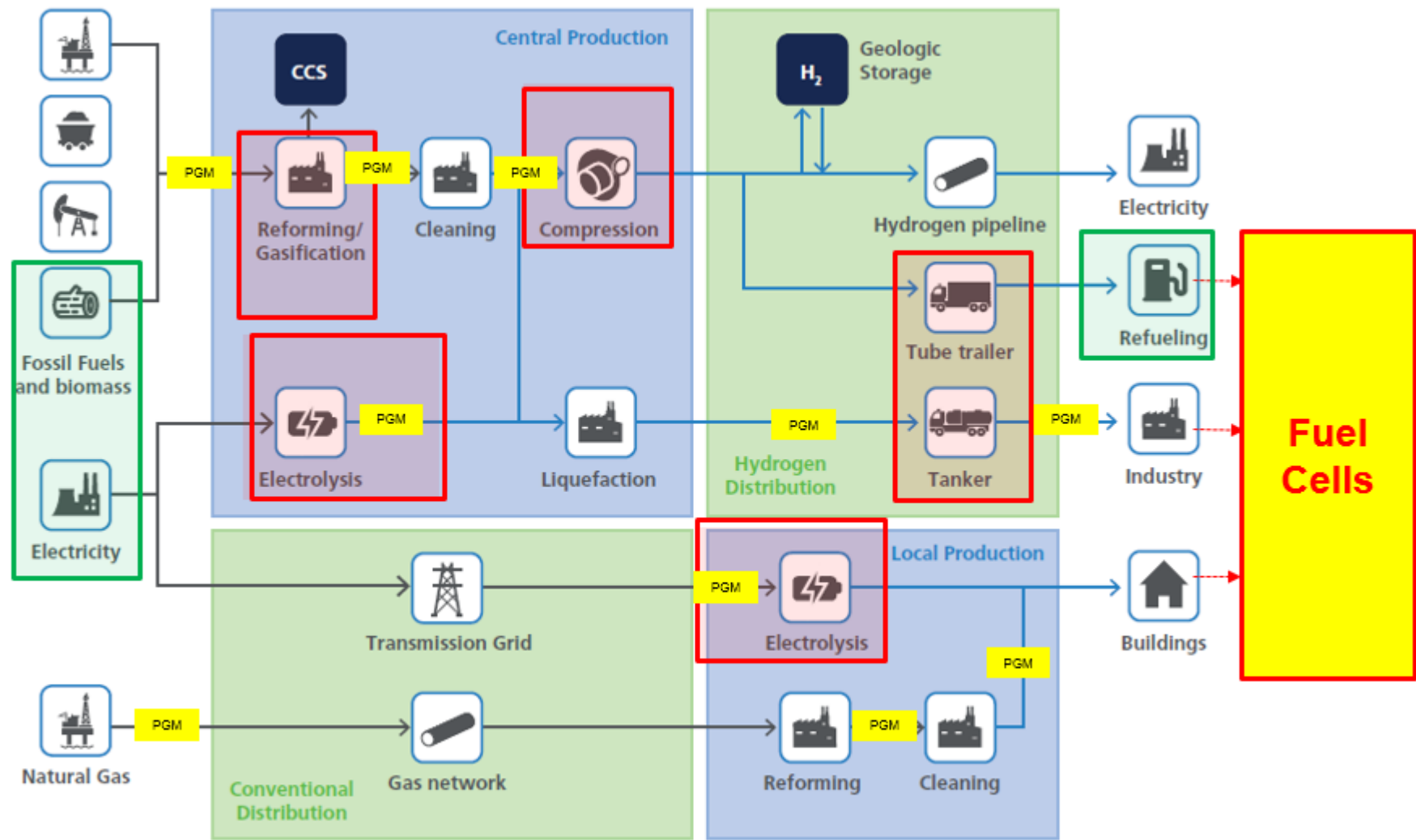


2018
REFINITIV
FORMATION

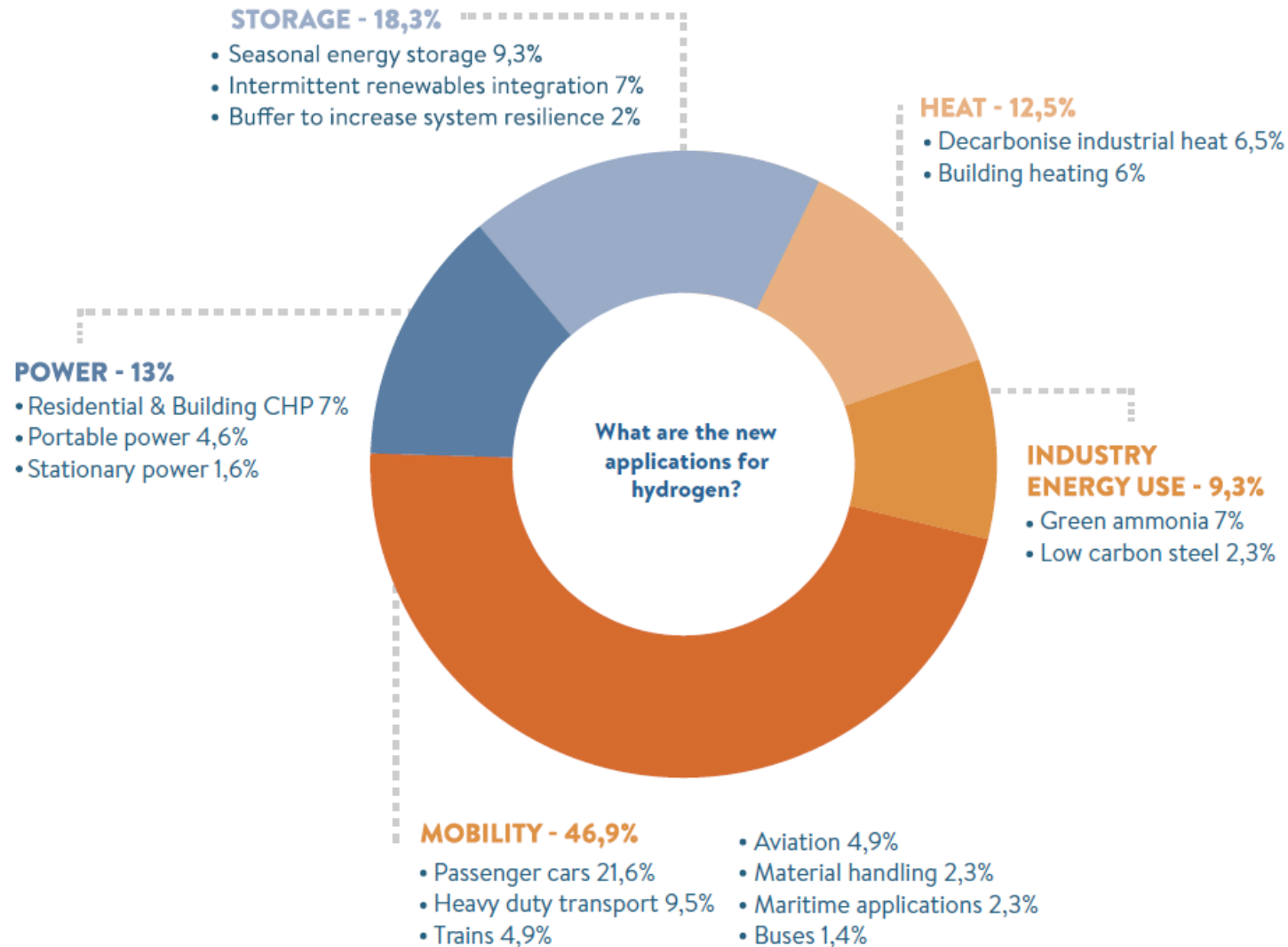
1. Hydrogen Value Chain and Economy
2. Fuel Cell Vehicles Characteristics and Competitiveness
3. Fuel Cell Vehicle Production & Implications on Platinum Market
4. Concluding Remarks

Hydrogen Value Chain and Economy

HYDROGEN VALUE CHAIN



NEW APPLICATIONS FOR HYDROGEN



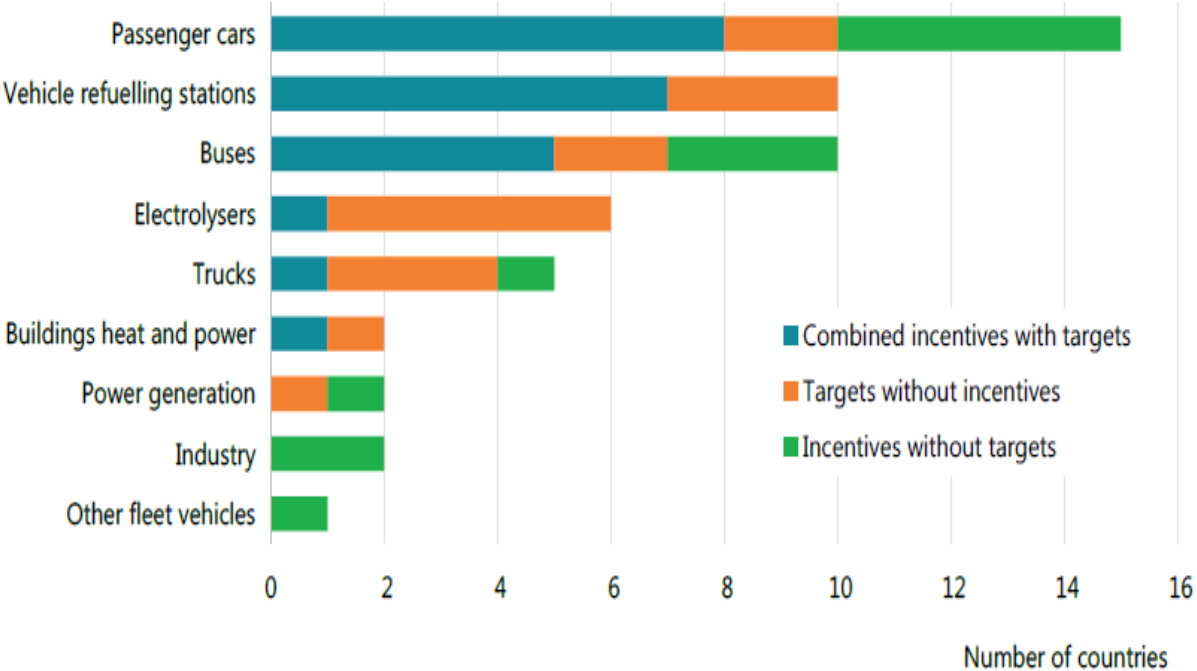
Transport

- Taxi Fleet in Paris France
- Class 8 Trucks Japan, US
- Trains Germany

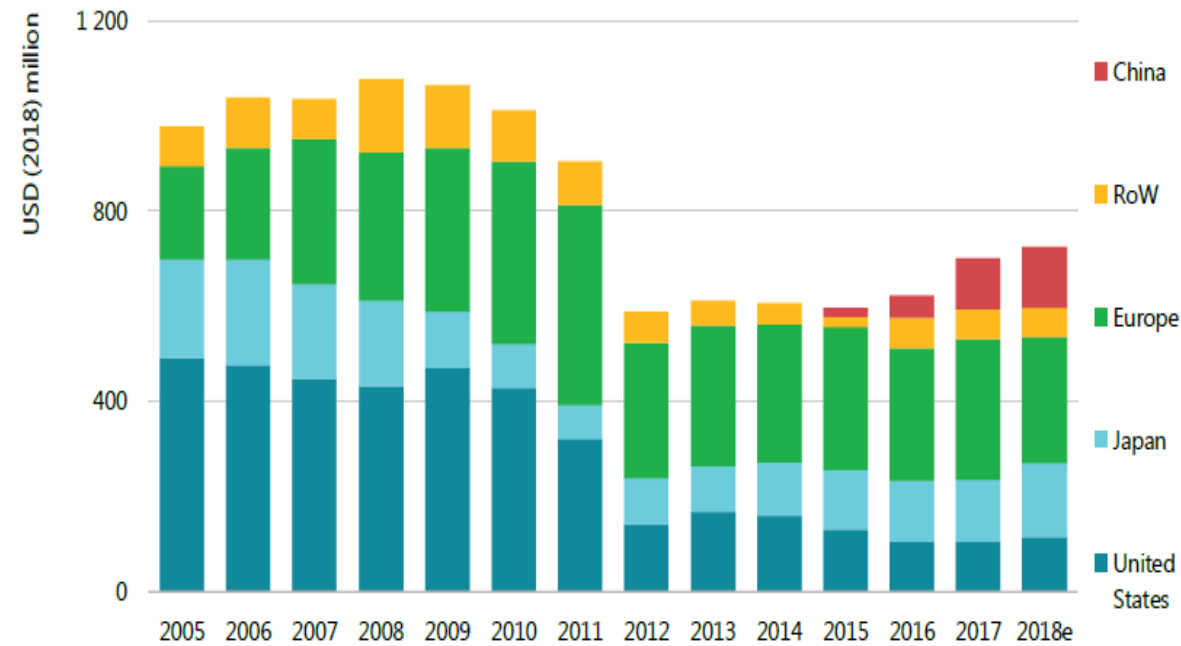
Outside of transport:

- Power systems
- Green Ammonia Technology
- Steel production
- Etc...

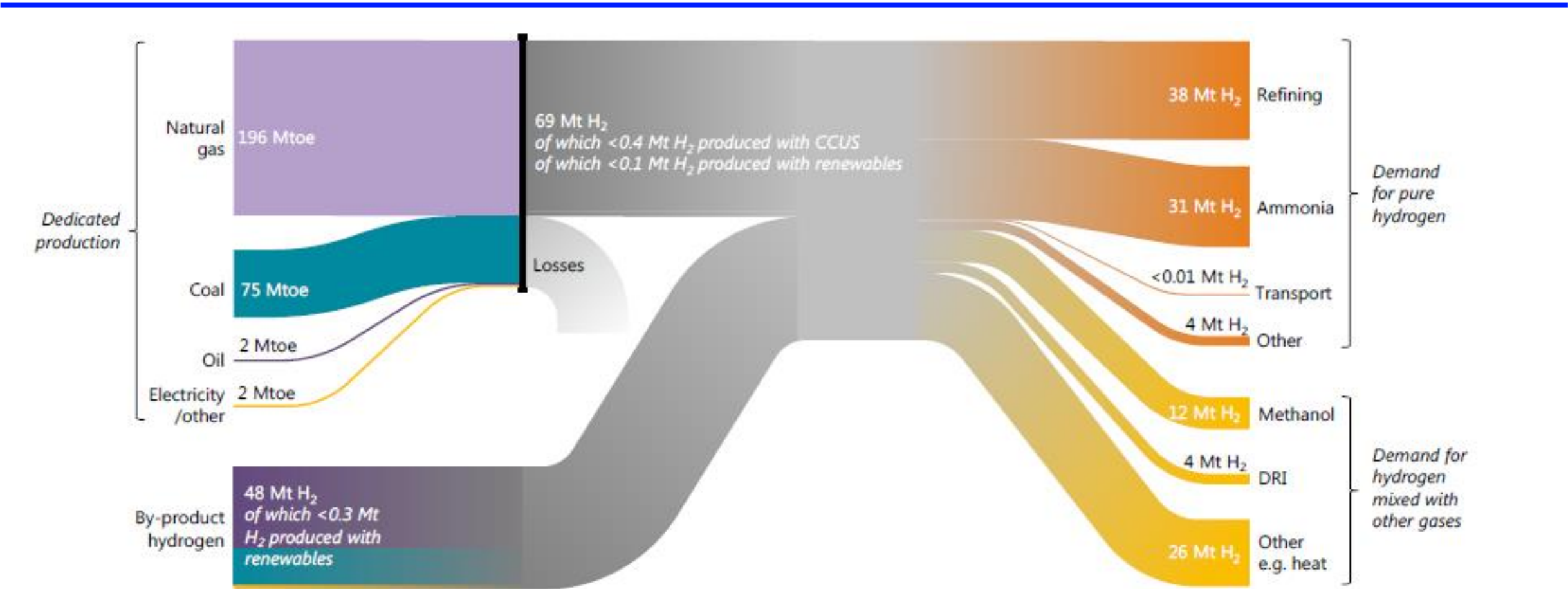
DIRECTLY SUPPORTING HYDROGEN DEPLOYMENT BY TARGET APPLICATION



GOVERNMENT RD&D BUDGETS FOR HYDROGEN AND FUEL CELLS



HYDROGEN PRODUCTION AND USES



HYDROGEN PRODUCTION AND CHARACTERISTICS

Grey, Blue or Green?

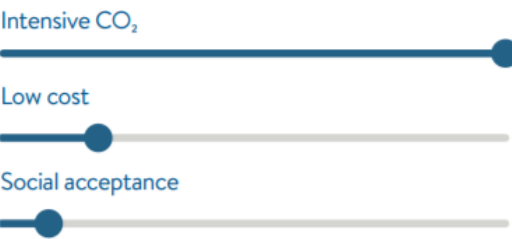
GREY HYDROGEN

Currently, 96% of hydrogen is produced from fossil fuels via carbon intensive processes.

Main production routes

-  Steam Methane Reforming (SMR)
-  Coal Gasification

Characteristics



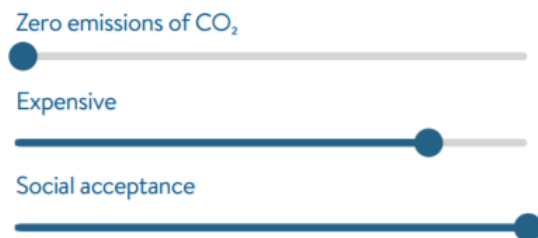
GREEN HYDROGEN

Low or zero-emission hydrogen produced using clean energy sources.

Main production routes

-  +  Electrolysis using renewables

Characteristics



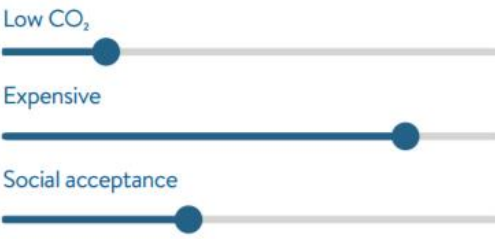
BLUE HYDROGEN

Grey hydrogen whose CO₂ emitted during production is sequestered via carbon capture and storage (CCS).

Main production routes

-  +  SMR + CCS
-  +  Coal gasification + CCS

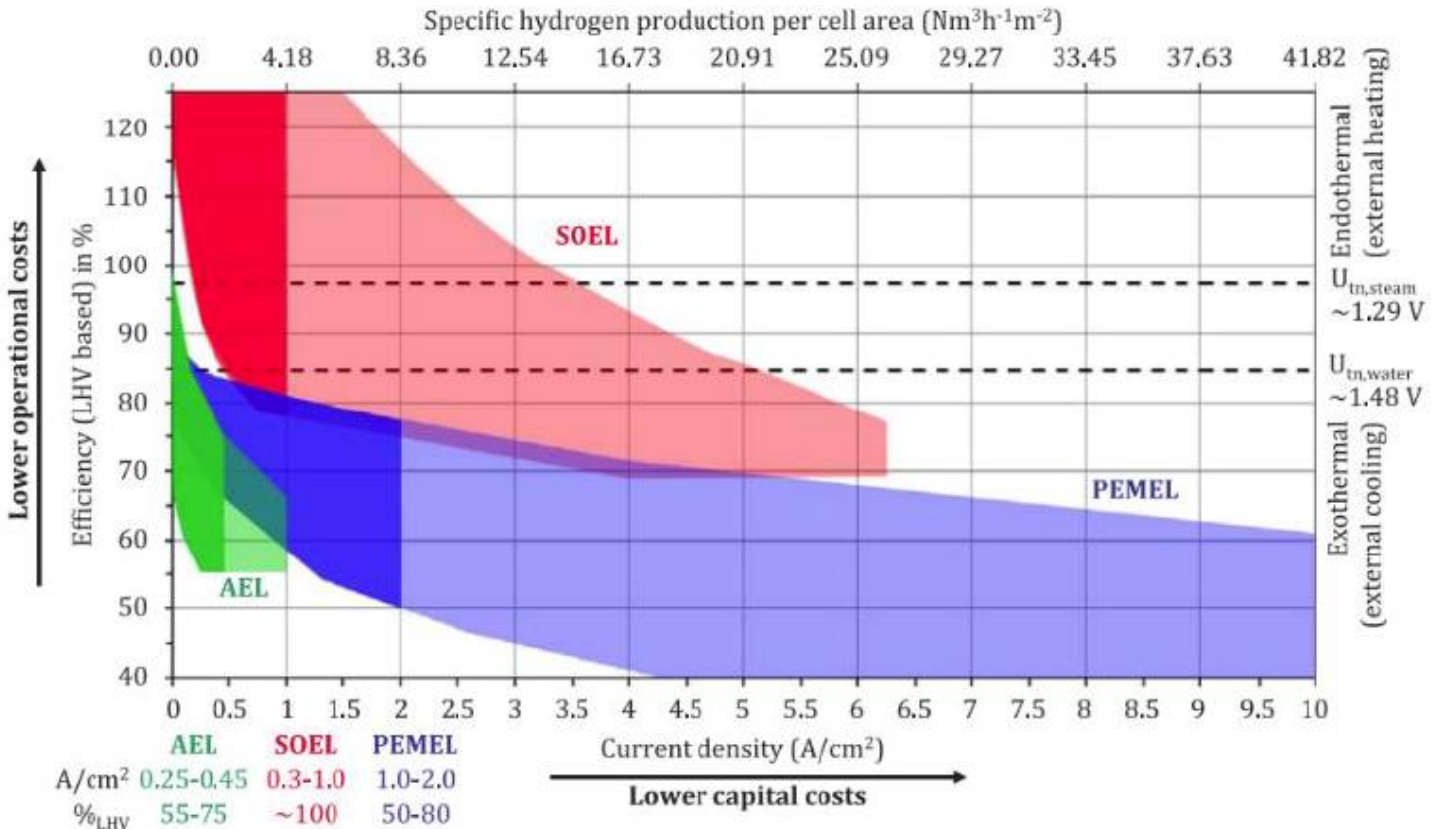
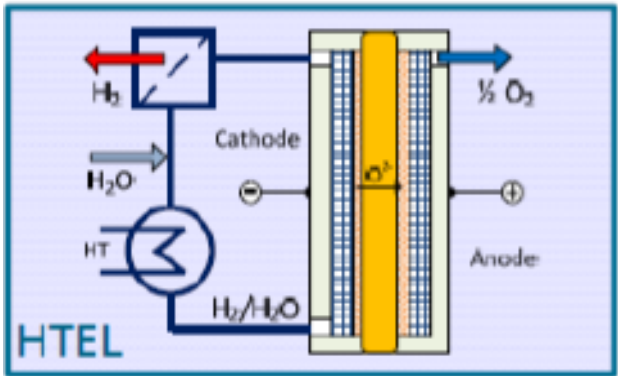
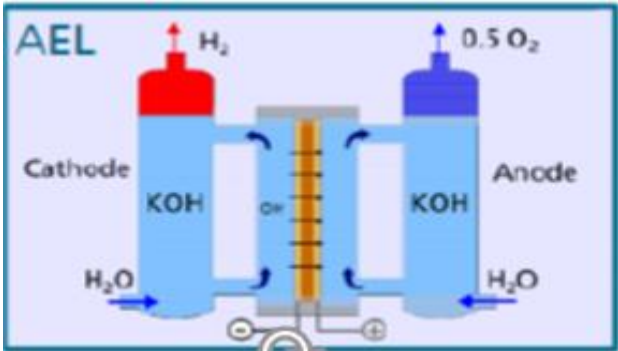
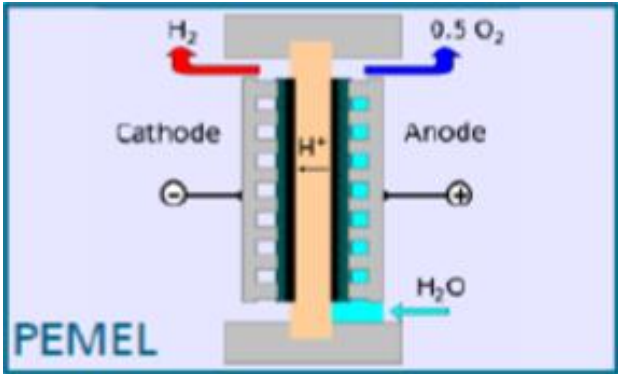
Characteristics



- Grey h₂, high Co₂ but low cost and low social acceptance.
- Blue h₂ supposedly improved CO₂ due to carbon capture, but higher costs and acceptance
- Green h₂, no CO₂, but very expensive but also high consumer acceptance.

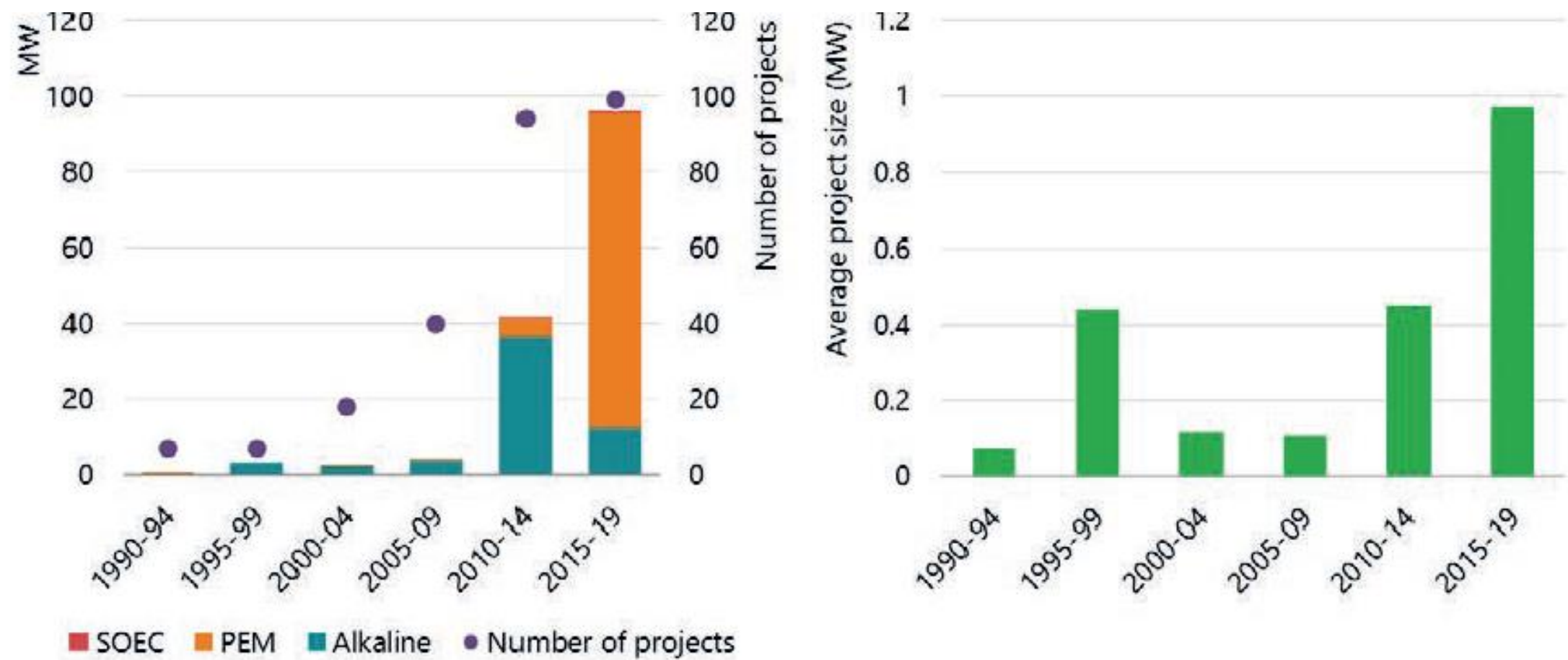
MAIN TYPES OF WATER ELECTROLYSIS

Summary of Efficiency and Operational Range of AEL, PEMEL and SOEL in Water Electrolysis for H2 Production



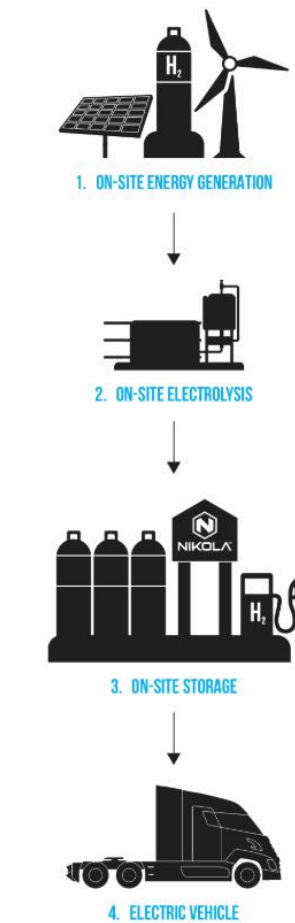
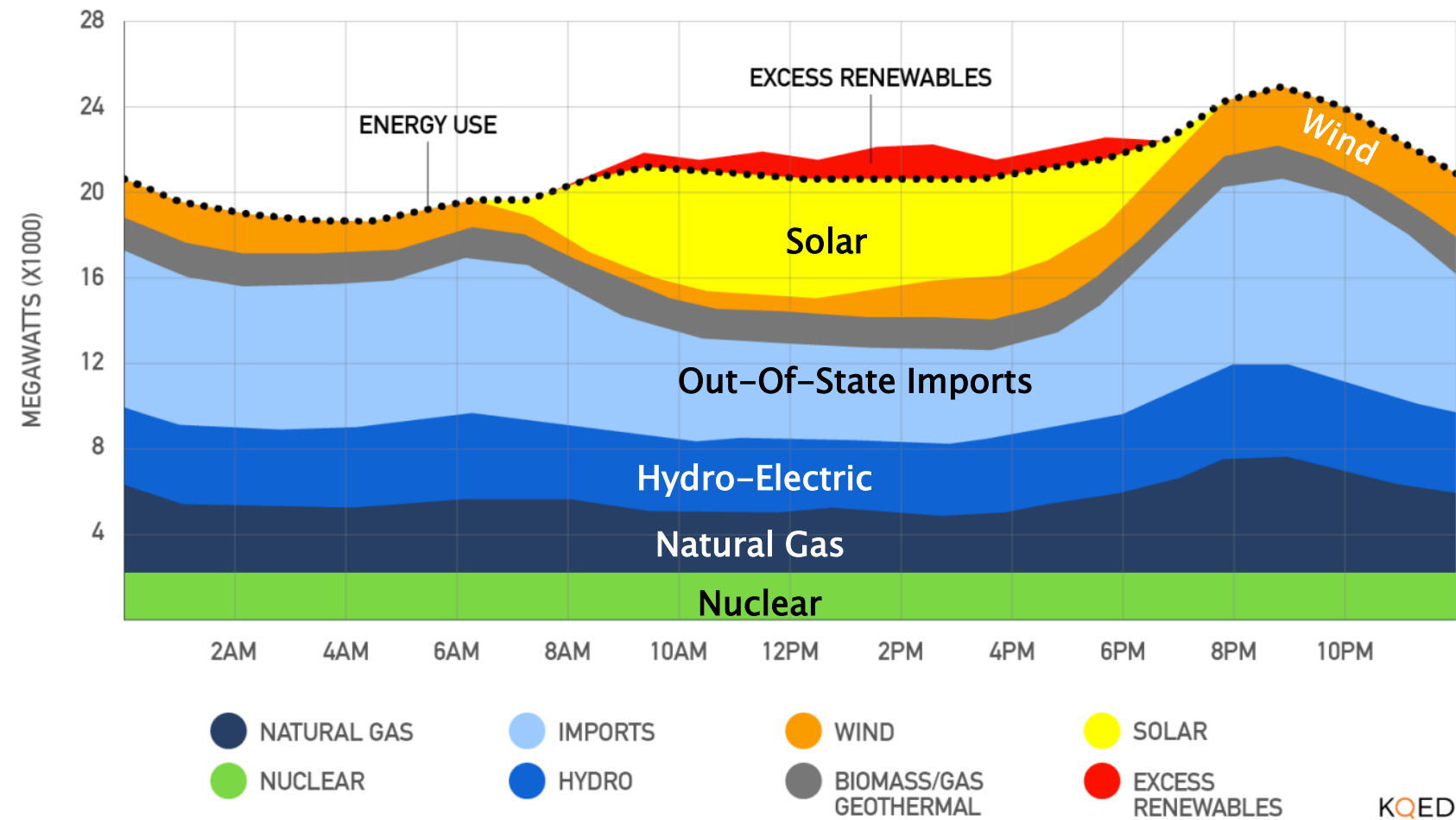
ELECTROLYSER CAPACITY ADDITIONS

Development of electrolyser capacity additions for energy purposes and their average unit size, 1990–2019



DEALING WITH EXCESS ENERGY GENERATION THROUGH USE OF H2

CALIFORNIA POWER GENERATION ISSUES

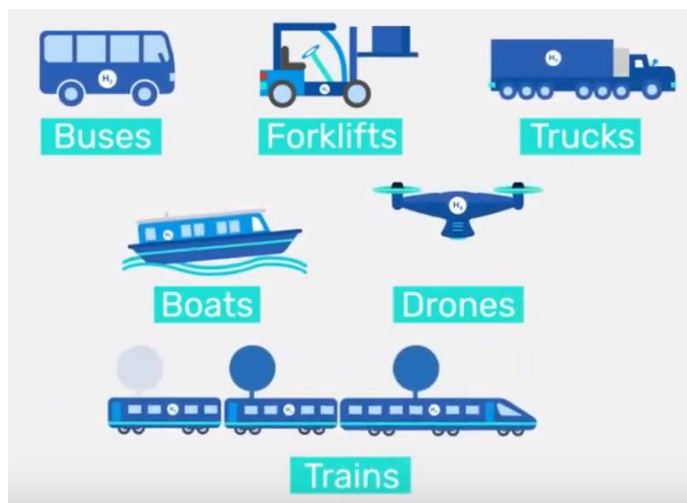


DATA STORAGE EXAMPLE



WHERE DO YOU STORE IT?

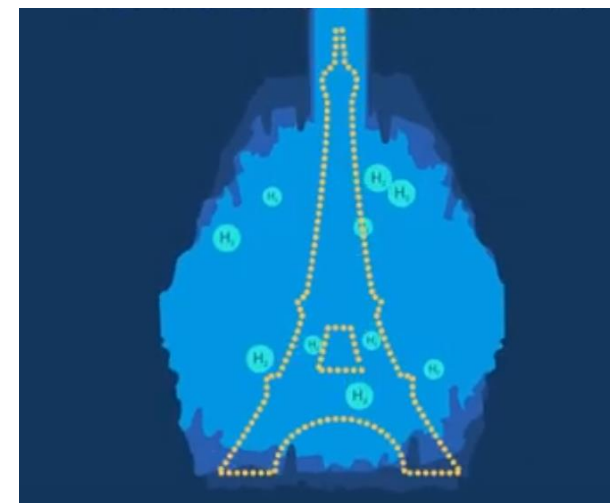
Onboard in Tanks



Stationary Storage

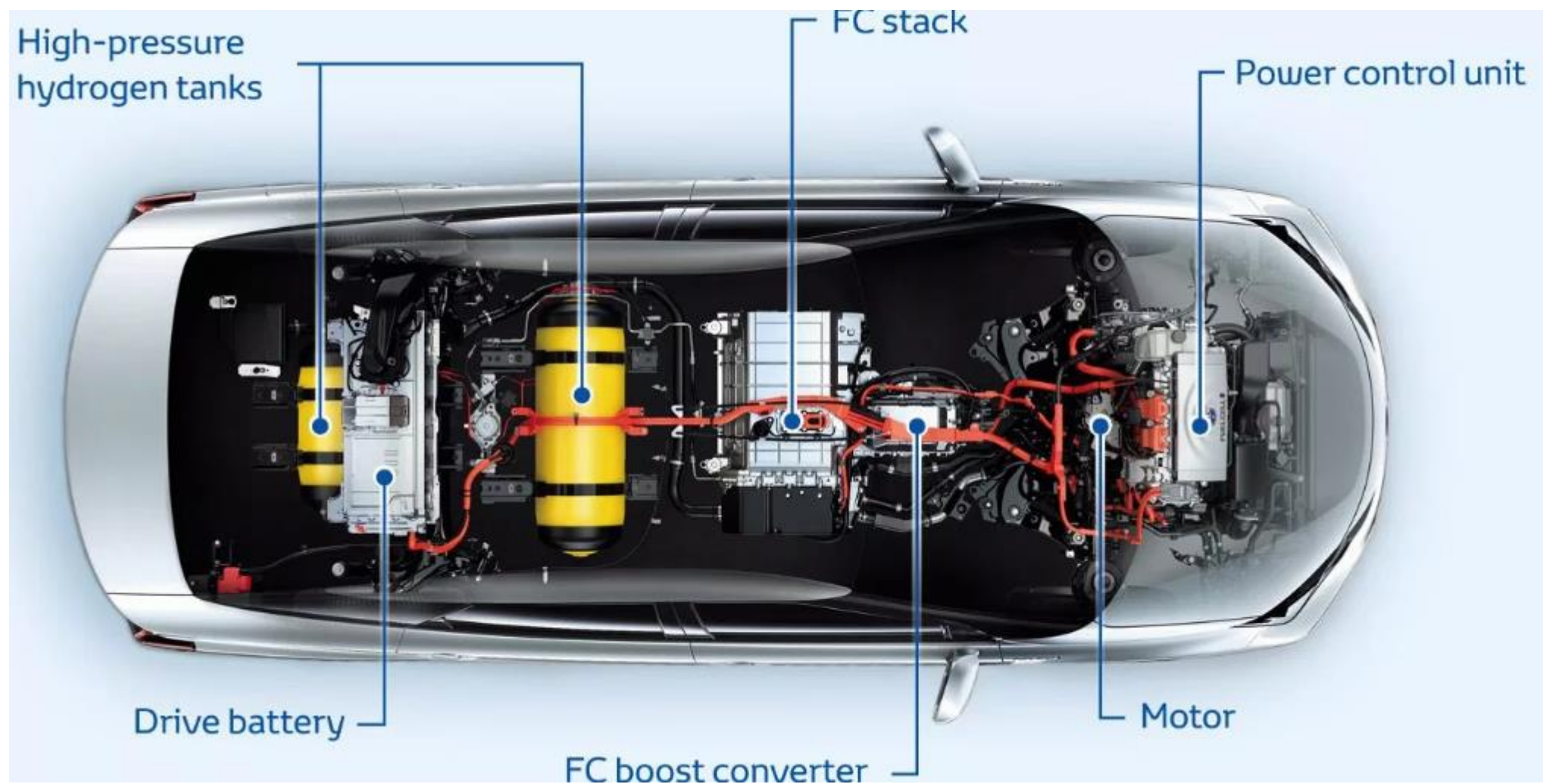


Large Underground Storage



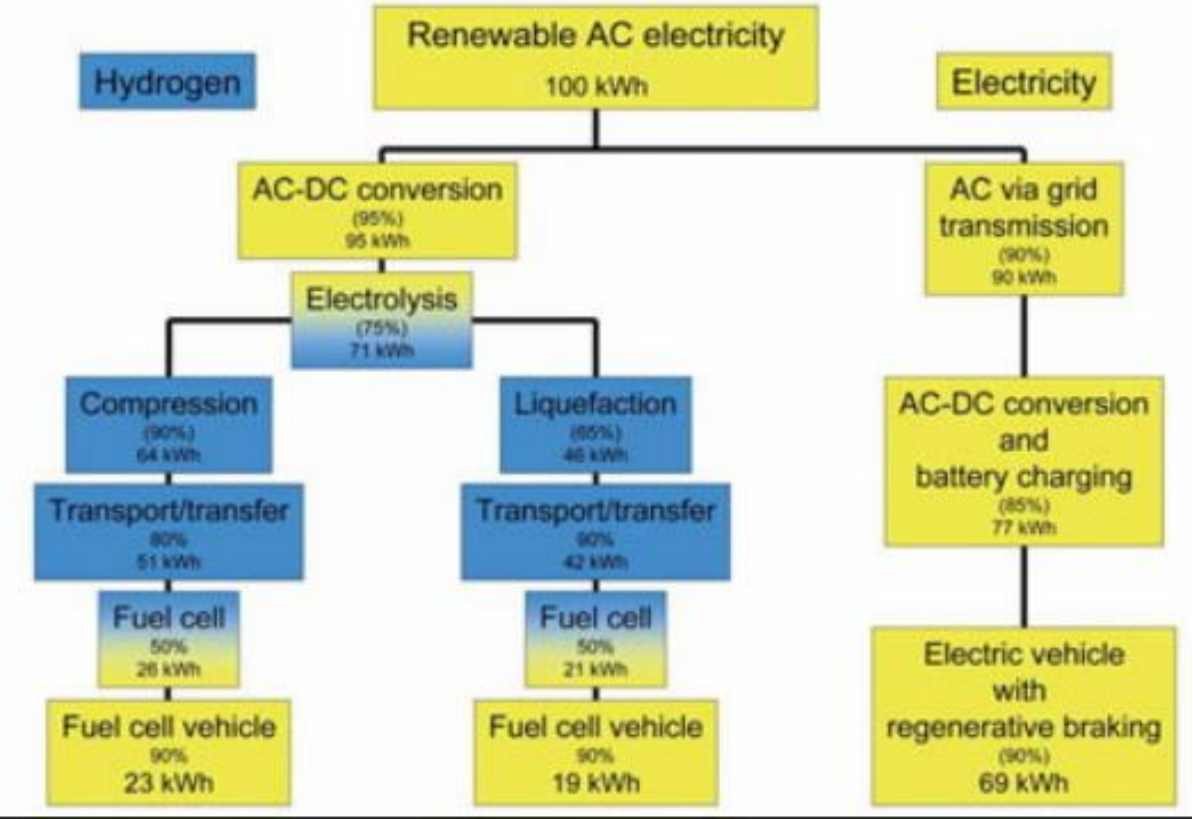
Fuel Cell Vehicles Characteristics and Competitiveness

DISECTED FUEL CELL VEHICLE TOP VIEW



POWER CONVERSION

BEV and FCEV Power Conversion Example



Source: Psycho.org

TECHNOLOGY ADAPTION DRIVERS

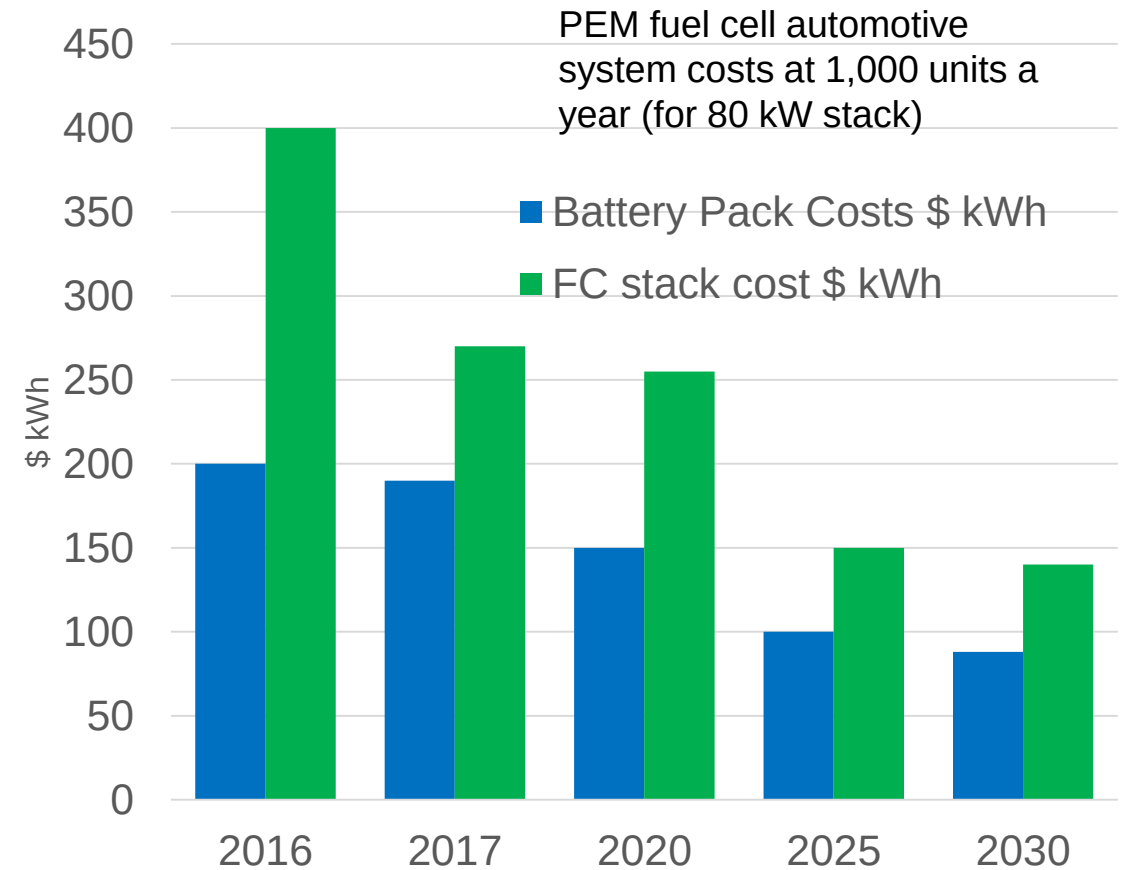
FC LIGHT VEHICLE UPFRONT COSTS

Comparison of current vehicle running characteristics:

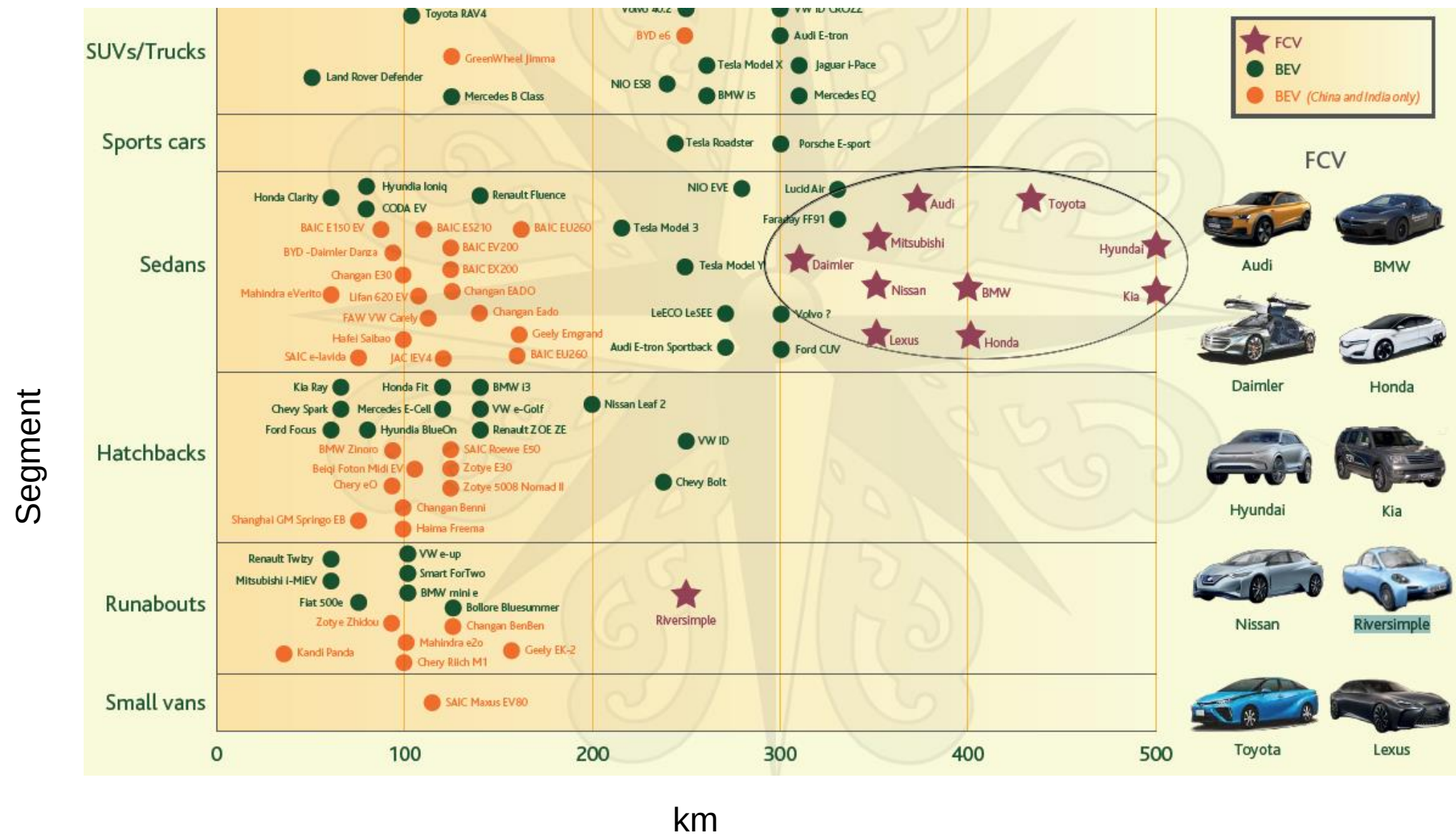
Type	Fuel cost per km (\$)	Range (km)	Refuel / charge time (mins)
Gasoline	7.5c	500	5
Diesel	6.0c	600	5
FCV	20c	500	5
BEV	2.5c	300-500	75-720

Source: Mitsubishi from PWC, US DOE, EU FCJU; LMC Automotive

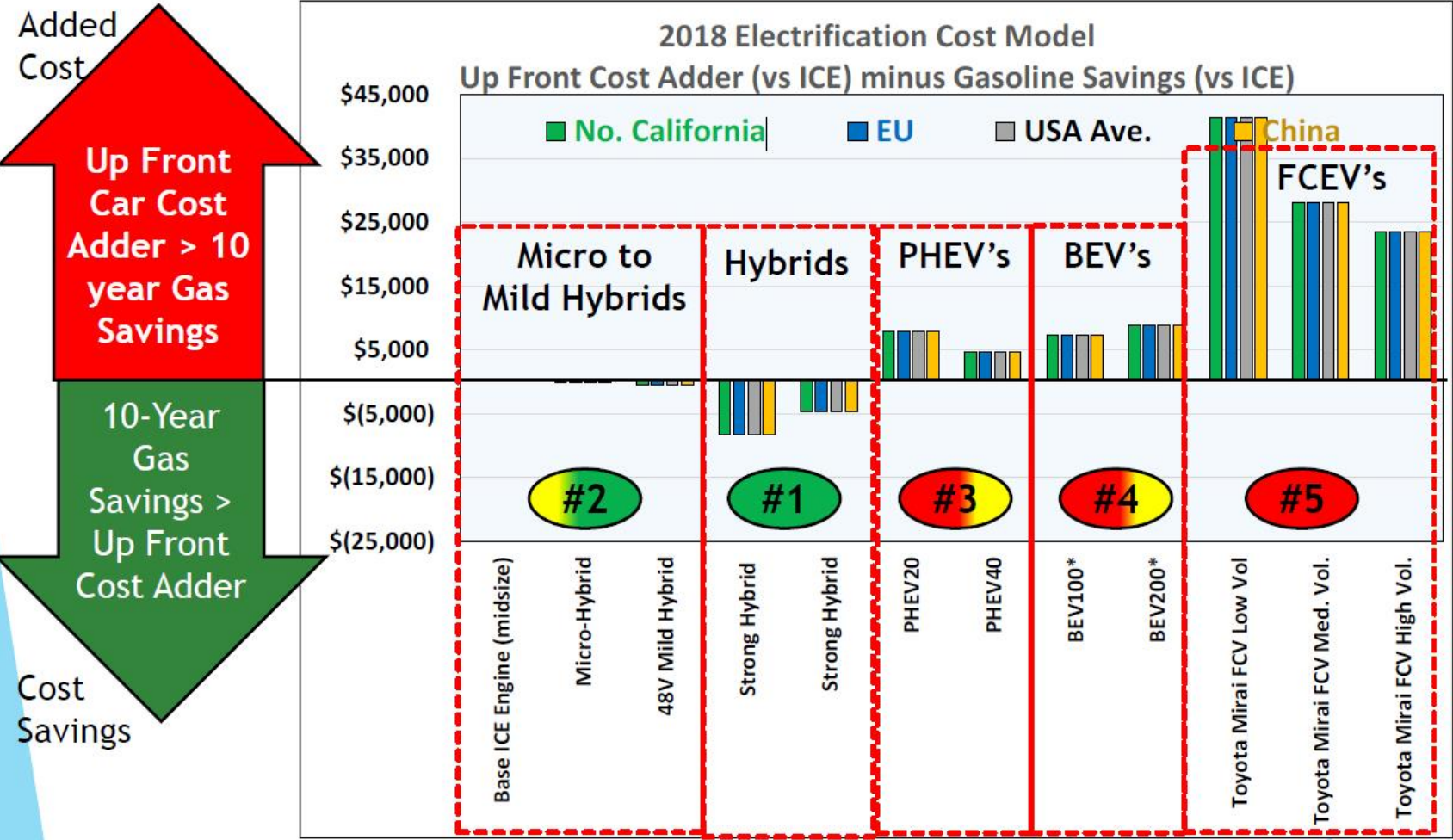
PEMFC and BEV automotive system cost



ELECTRIFICATION AND FUEL CELLS VEHICLE RANGE

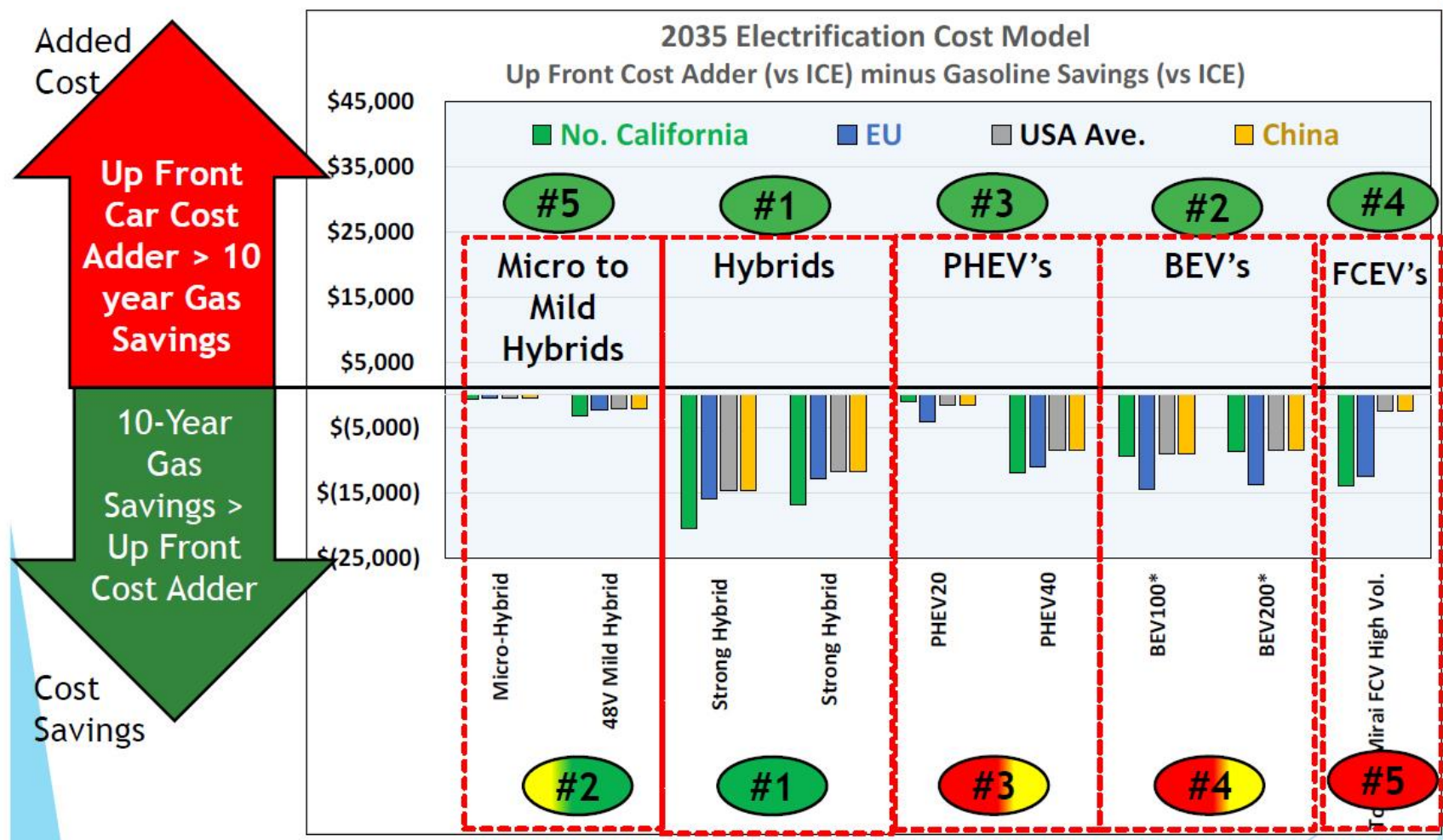


2018 EV COST COMPARISON MODEL



- Hybrids lowest TCO: better TCO than gas
- BEC 3rd, best play for short distance
- FCEV:
 - Highest cost by far
 - New green electrolyzed H2 will alter cost curve
 - Low vol drives up front cost adder

2035 EV COST COMPARISON MODEL



- Assume:
 - Doubling gas price
 - Power price doubles
 - E-gallons doubles
 - H2 retail price -50% with electrolysis
- FCEV become place 4, positive return, 10 year gas savings higher than up front cost adder
- Make FCEV more viable alternative on high volume, moving from premium segment to main market LDV

TECHNOLOGY ADOPTION DRIVERS

FCV light duty running costs

At volume, total cost of ownership become similar to BEVs (\$25,000) and only a little higher than ICEs (\$20,000). As upfront costs come down, zone of adoption will grow to mid range and volume type

RANGE					
		Short	Mid	Long	Very long
TYPE	Budget				
	Volume	BEV		FCV?	FCV
	Premium	BEV		FCV	FCV

Source: Mitsubishi from PWC, US DOE, EU FCJU

COMPLEMENT NOT COMPETE



Source: CHANGE

“In 2040, I picture autonomous BEVs being used in cities while passenger FCEVs are used for weekend trips. Trains, buses, ships and long-range vehicles will also use fuel cells. 2040 May be too early for airplanes, but things may accelerate due to stringent regulation on emissions from air transport.”

KATSUHIKO HIROSE, TOYOTA MOTOR CORPORATION

When working on the design of production units, you clearly see that hydrogen and batteries are complementary. Batteries ensure fast-balance response and hydrogen complement on a longer period of time. To store large excess of power, hydrogen is fit for purpose. And it can either be transformed again into power thanks to fuel cells or injected into the gas grid

MICHELE AZALBERT, ENGIE

Source: World Energy Council

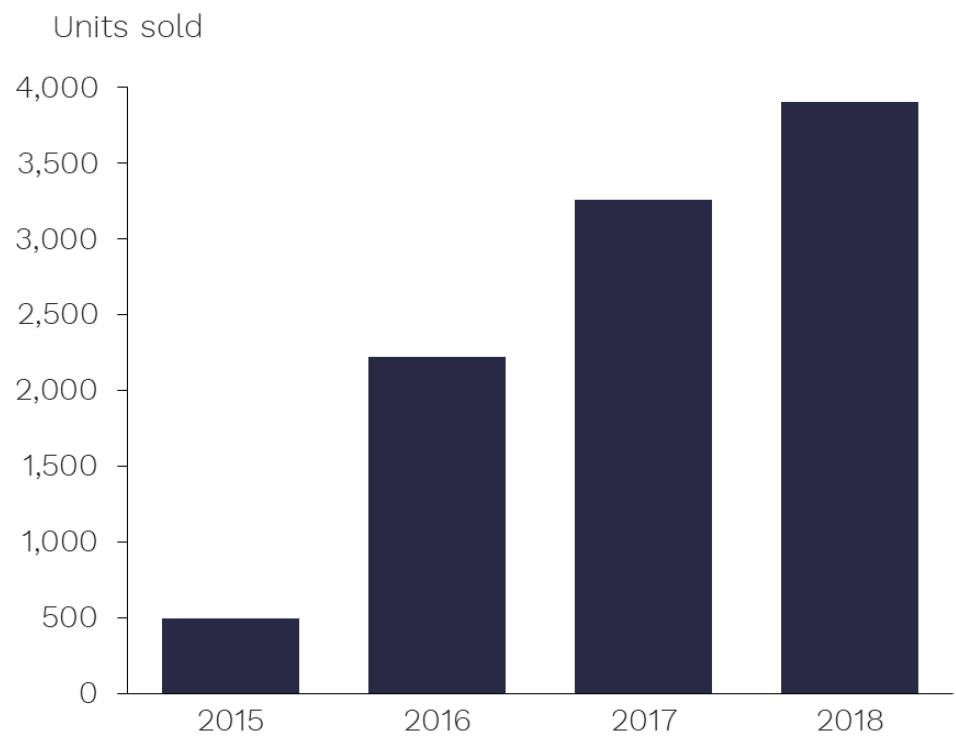


Fuel Cell Vehicle Production & Implications on Platinum Market

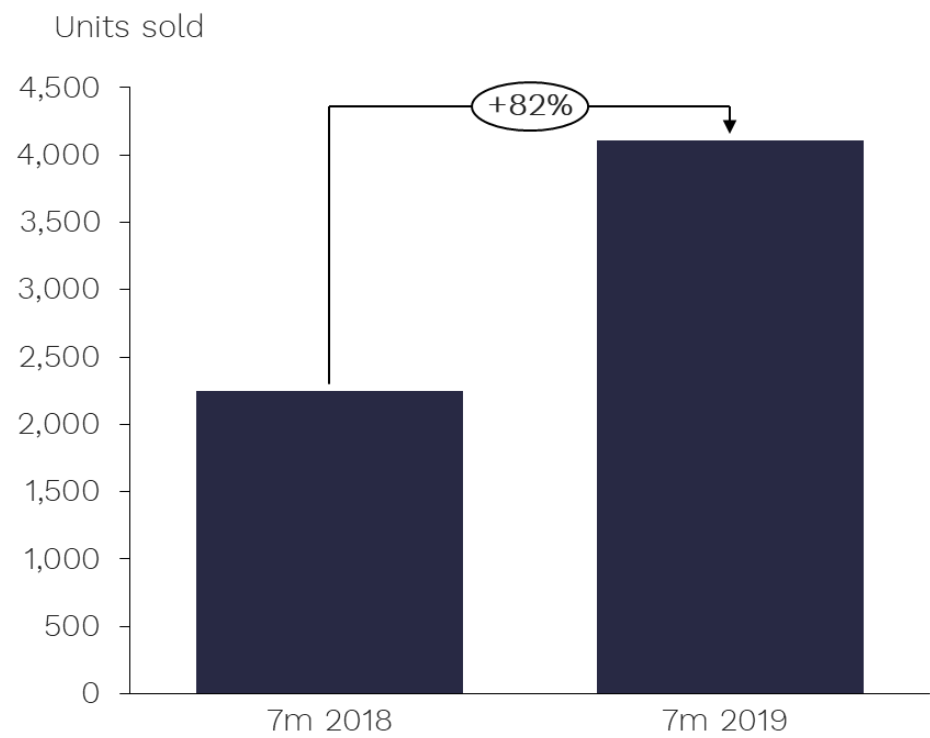
HISTORICALLY FUEL CELL SALES REMAIN LOW, BUT CONTINUE TO GROW

YTD SALES FOR 2019 ARE UP 82%

Annual passenger car FCV sales, 2015-2018



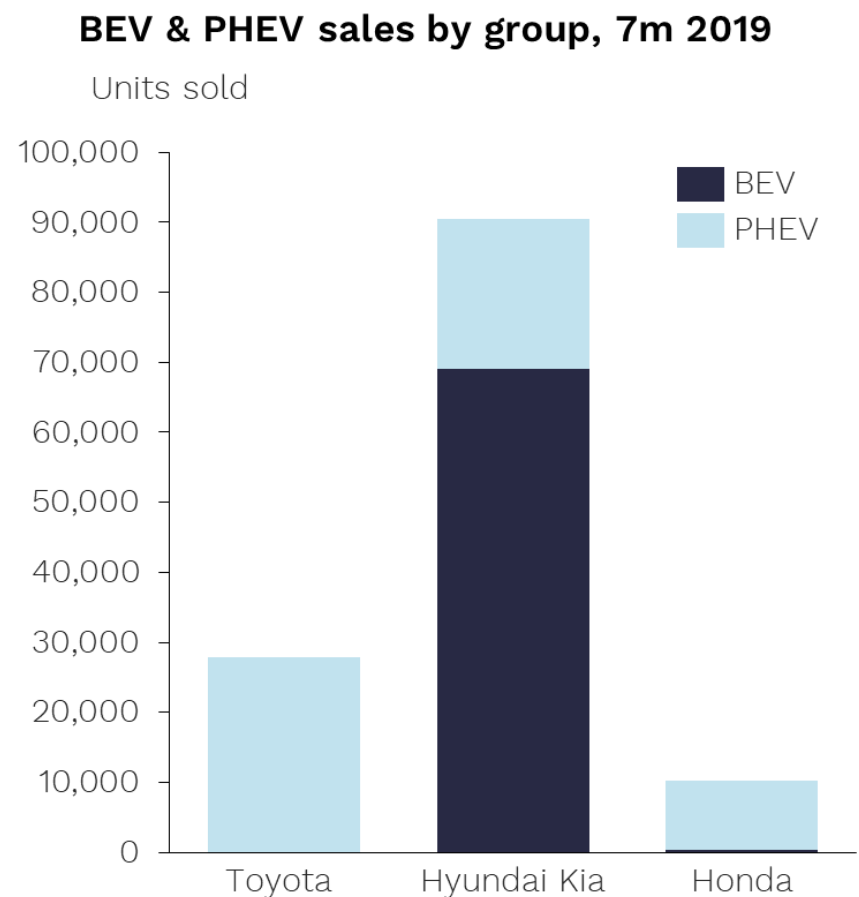
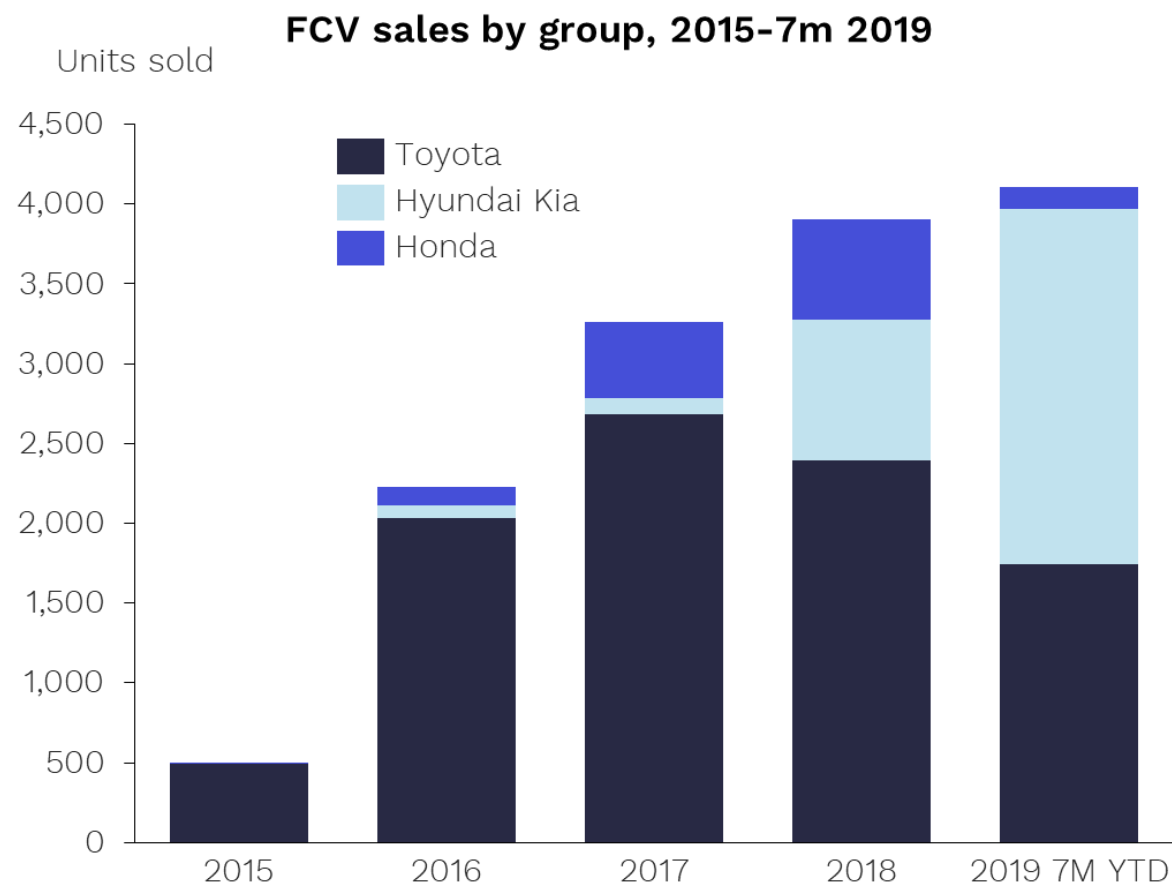
7m YTD passenger car FCV sales, 2018-2019



Source: Rho Motion, Marklines

FUEL CELL PRODUCTION IS CONCENTRATED TO EAST ASIA

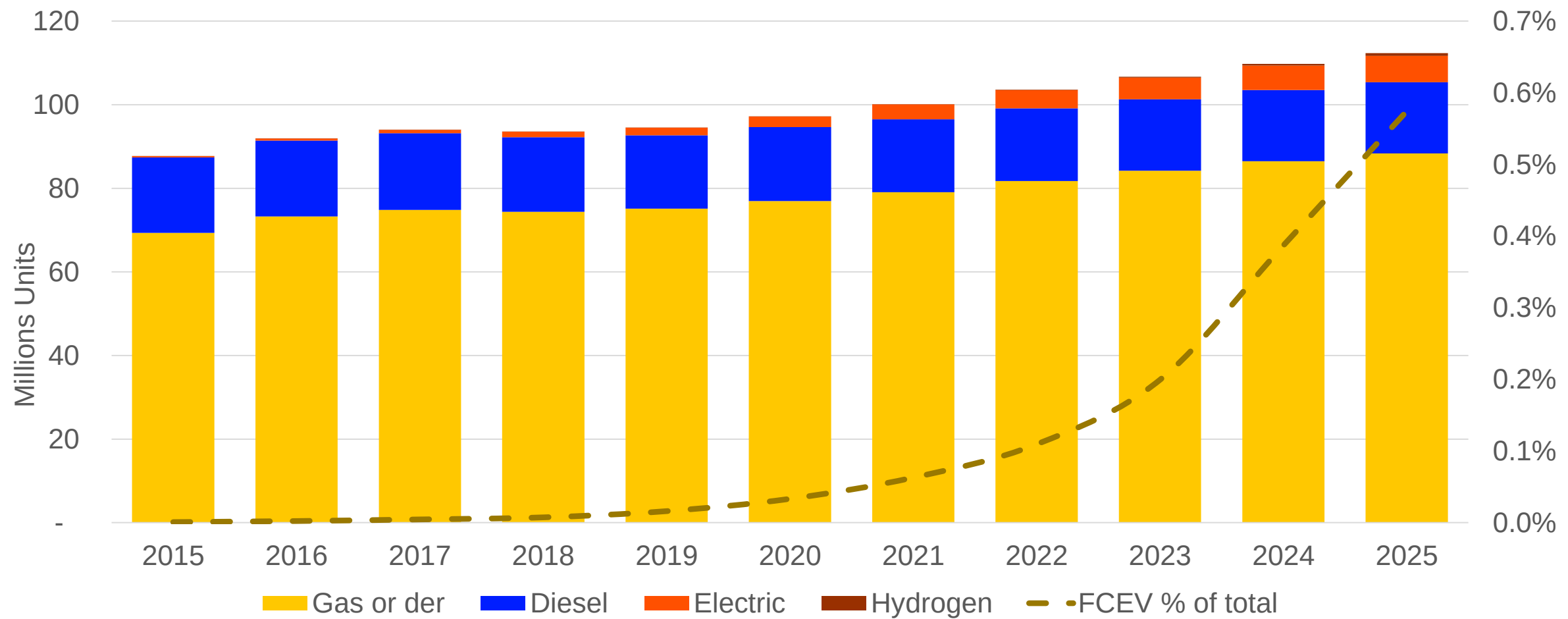
BUT SALES STILL ECLIPSED BY PLUG-IN HYBRID



Source: Rho Motion, Marklines

LDV PRODUCTION FORECAST

LDV production with FCEV Modification

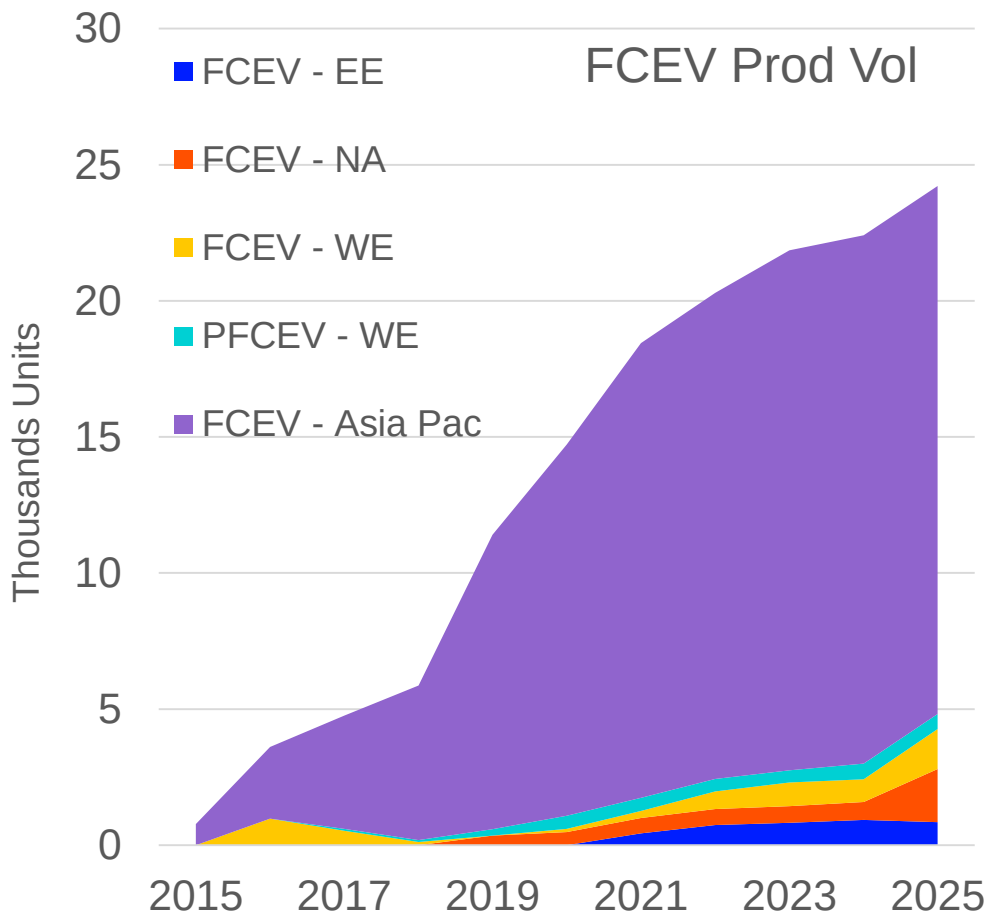


Source: LMC Automotive

LDV FUEL CELL PRODUCTION

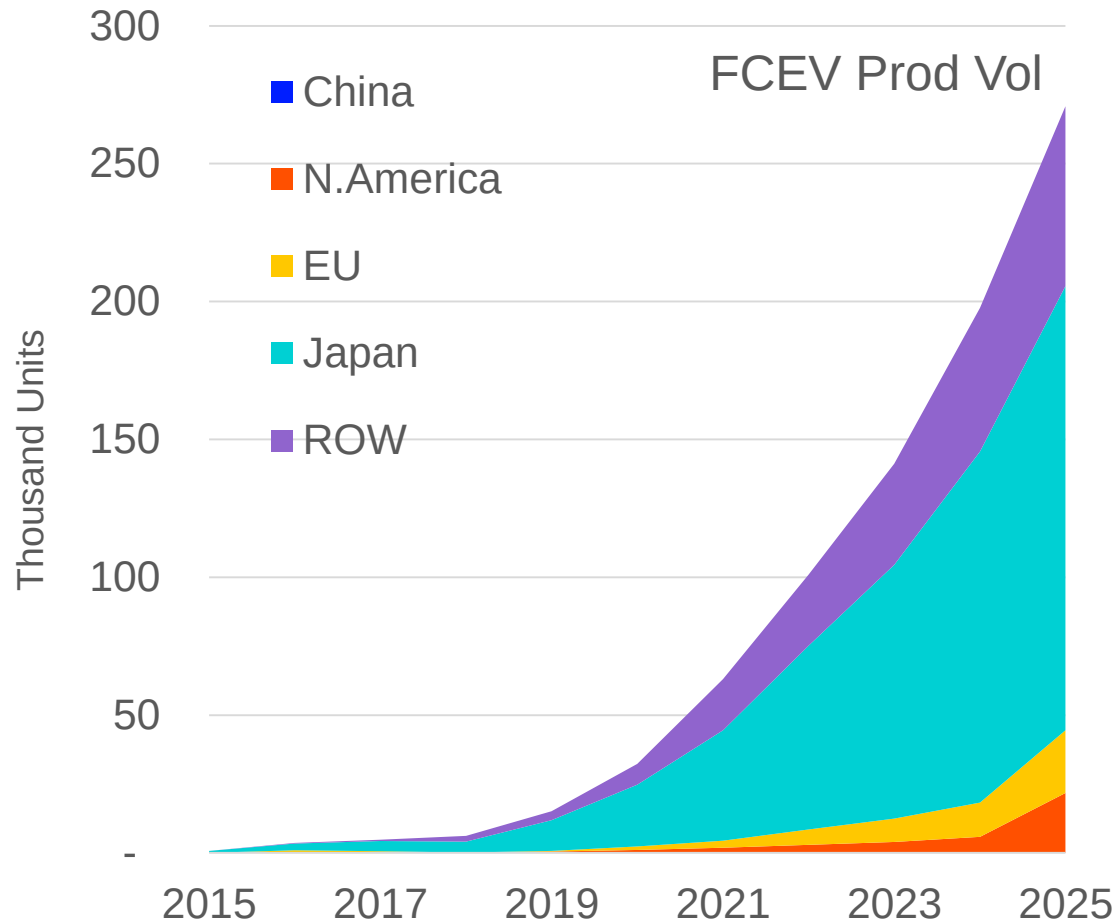
Growth rates huge coming from low base and easing over time

LMC: Conservative



Source: LMC Automotive

PMCM: Progressive

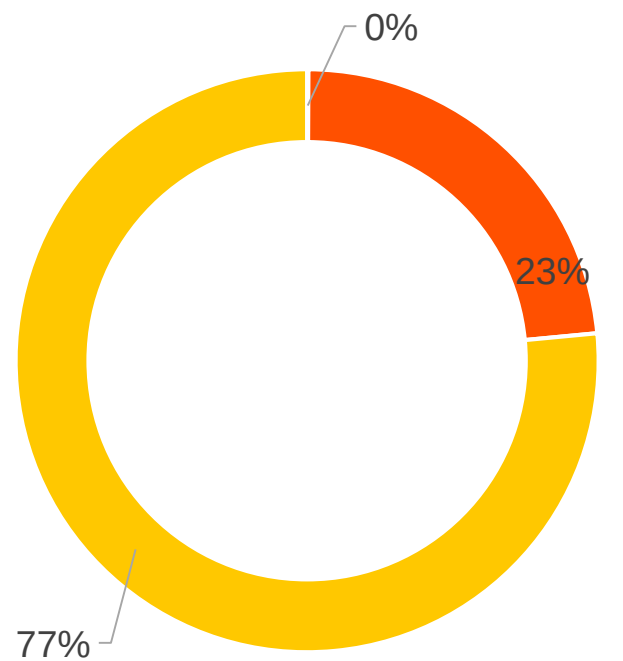


Source: Precious Metals Commodity Management

EVOLUTION OF FUEL CEL APPLICATIONS

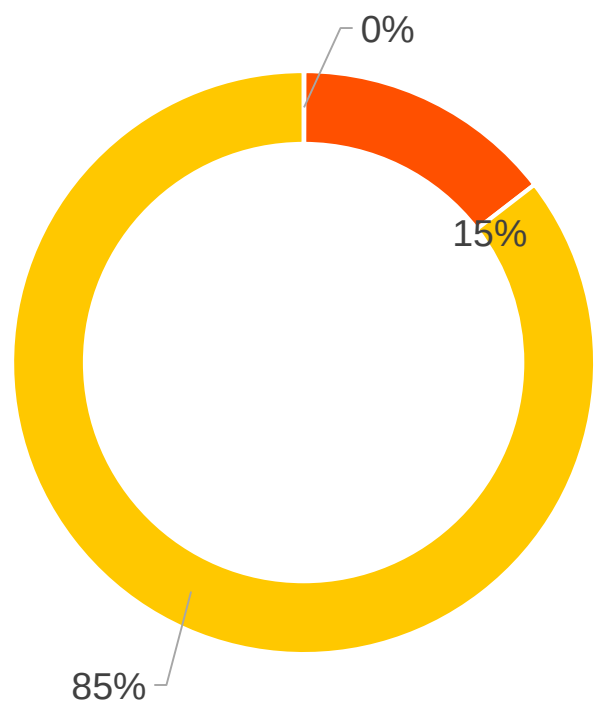
Transport to evolve in dominating fuel cell applications

2009



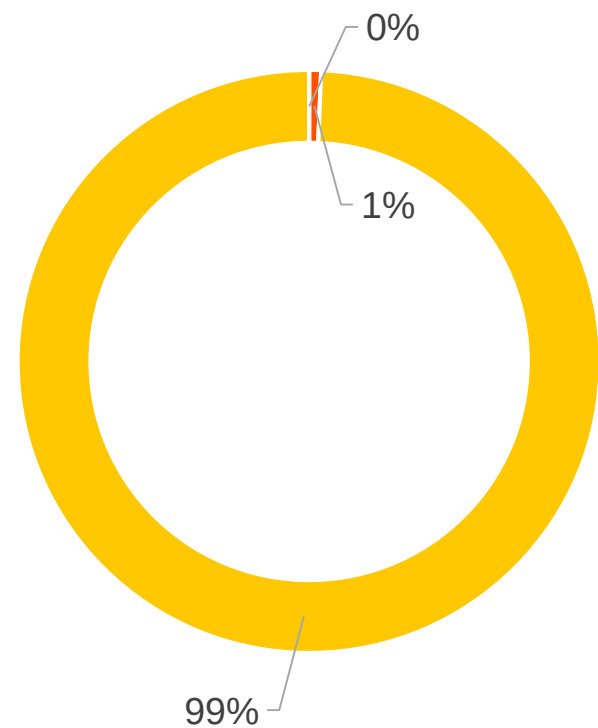
■ Portable ■ Stationary ■ Transport

2018



■ Portable ■ Stationary ■ Transport

2025



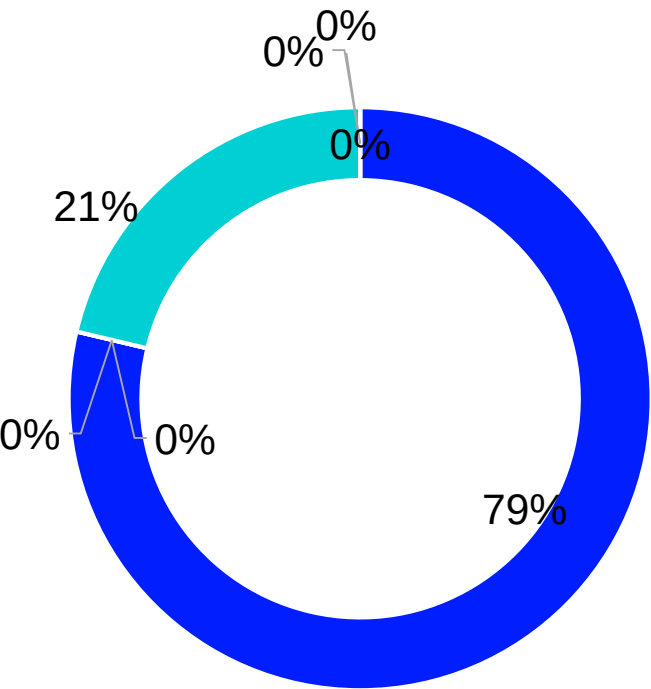
■ Portable ■ Stationary ■ Transport

Source: E-4tech

EVOLUTION OF MW BY FUEL CELL TYPE

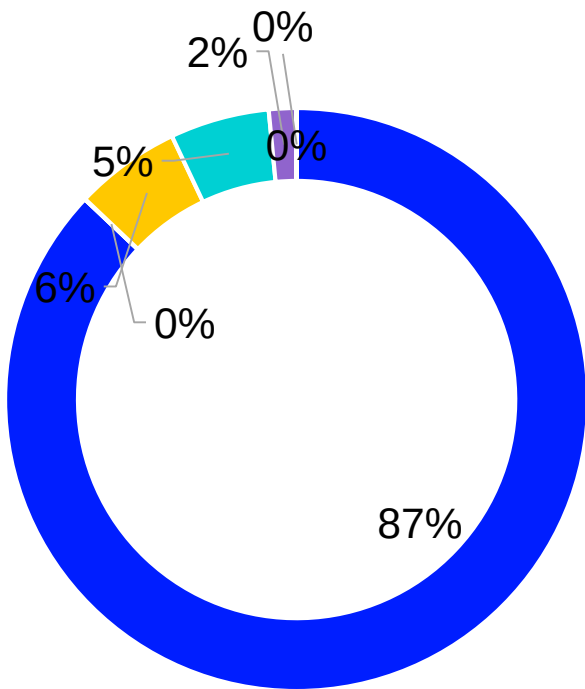
PEMFC to become the dominant technology

2009



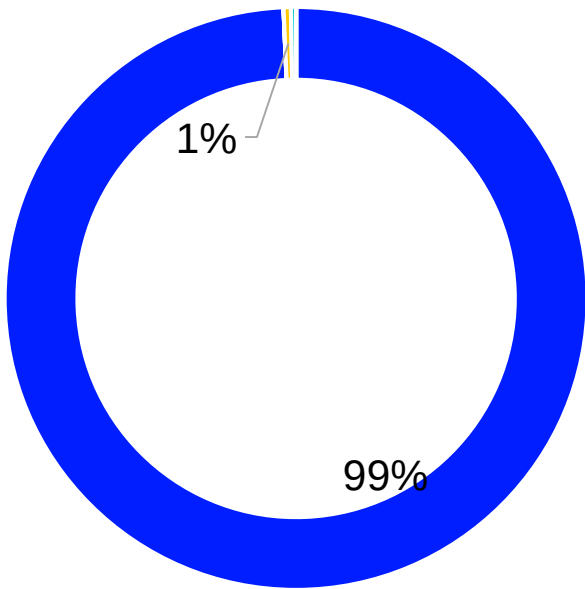
- PEMFC*
- DMFC
- PAFC*
- SOFC
- MCFC
- AFC*
- Other

2018



- PEMFC*
- DMFC
- PAFC*
- SOFC
- MCFC
- AFC*
- Other

2025

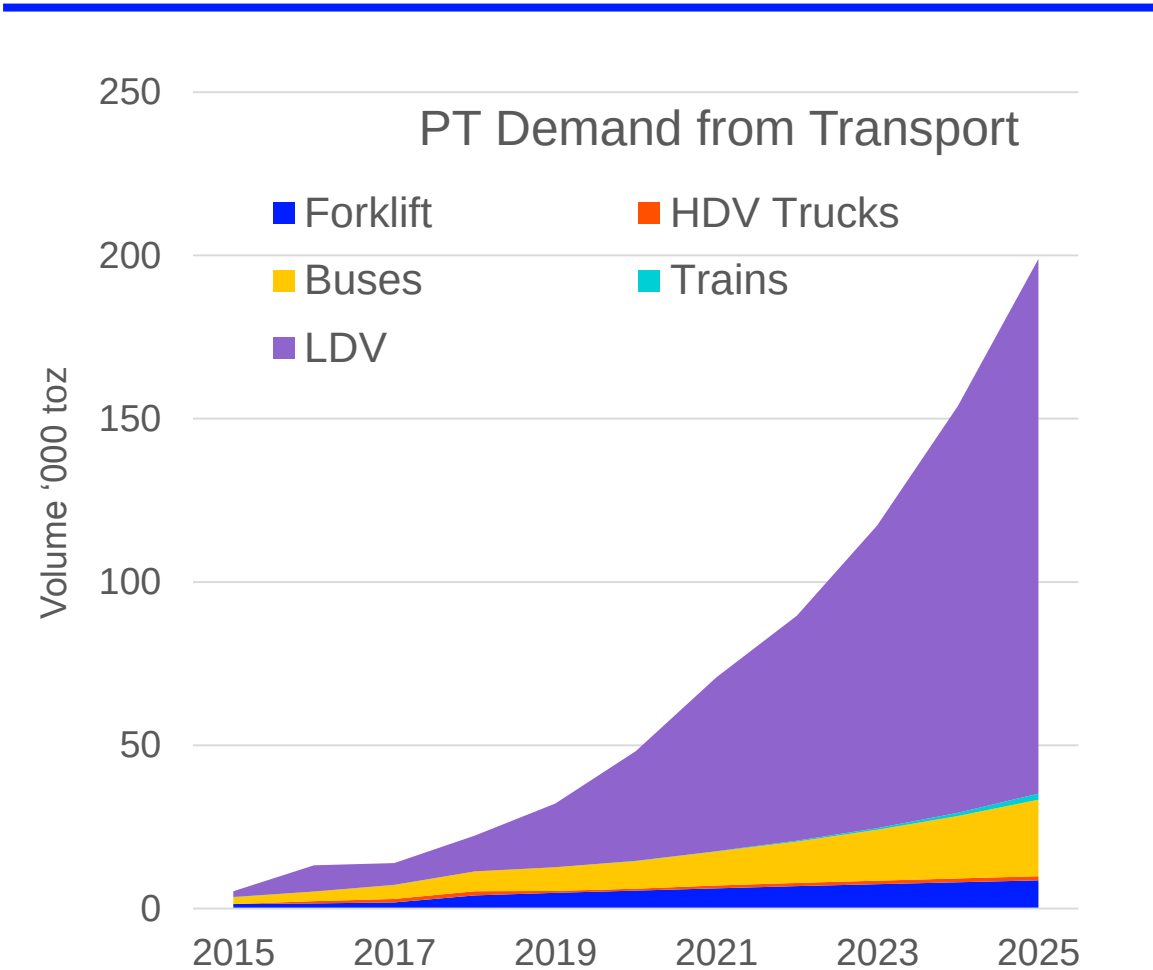
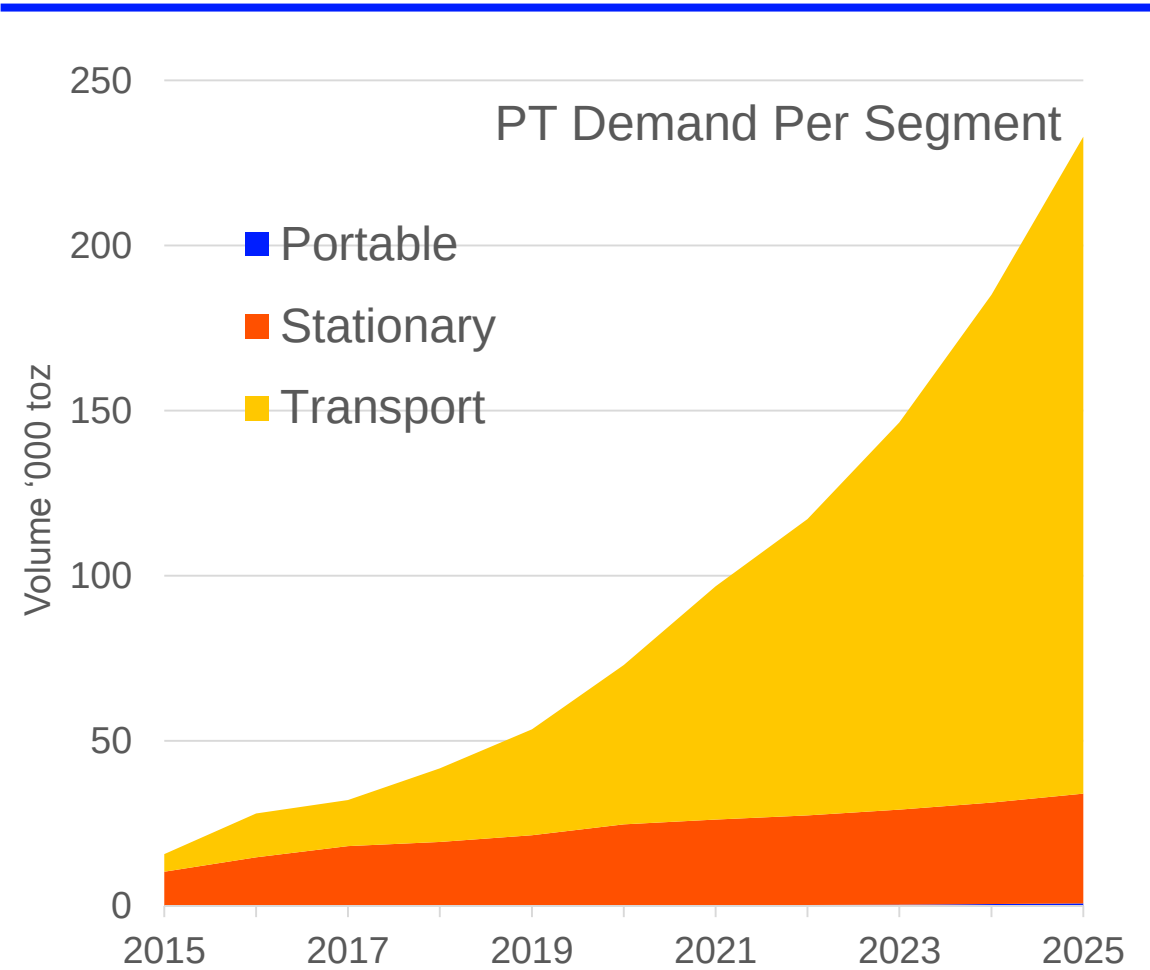


- PEMFC*
- DMFC
- PAFC*
- SOFC
- MCFC
- AFC*
- Other

Source: E-4tech

PLATINUM DEMAND

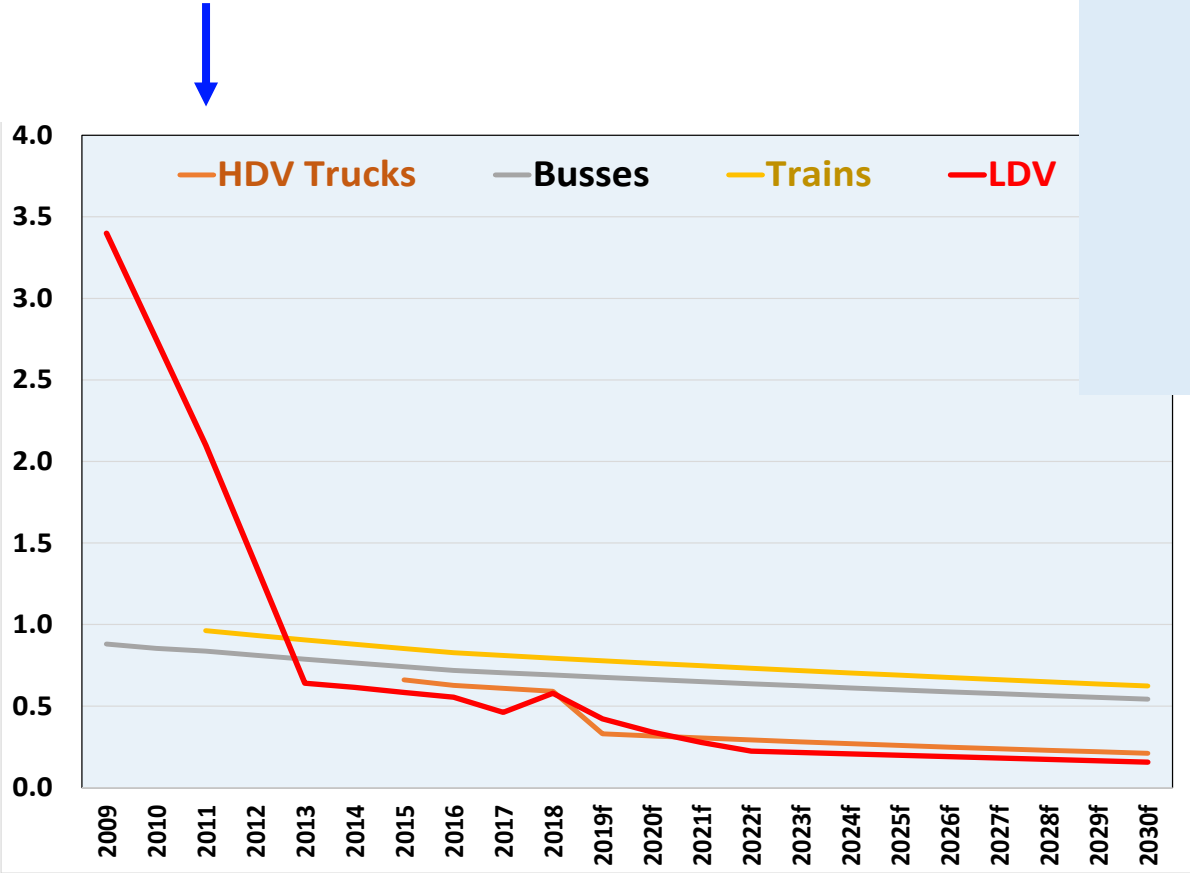
Transport Dominates Pt consumption and within transport its LDV



TRANSPORTATION APPLICATION

g/kW

Trains and busses less efficient because often there are secondary systems operating for the HVAC and other electrical systems



Light duty Vehicles

Make	Model	Year	kW	g/LDV	g/kW
Toyota	Mirai	2017	114	33	0.289
Toyota	Mirai	2018/19	114	30	0.263
Toyota	Mirai	2020/21	114	14-16	0.132
Toyota	Mirai	2018/19	114	30	0.263
Honda	Clarity	2018/19	120	30	0.250
Hyundai	Tuscon SUV	2017	120	76	0.633
Hyundai	Nexo SUV	2018/19	100	56	0.633

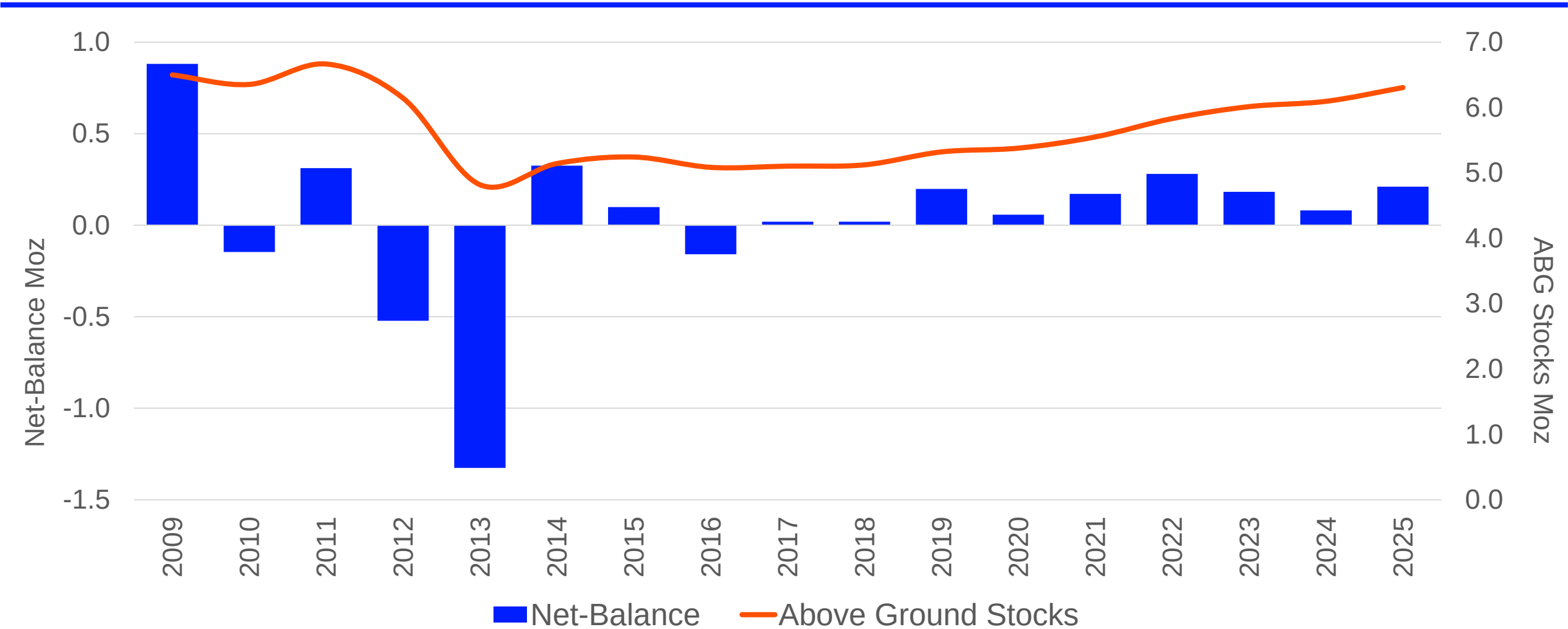
Pt loadings to come down further on latest Toyota Mirai model launches

PT Market SHOCK ABSORBER WITH DIFFERENT FC MARKET PENETRATION

Table 1A		Consumption of Pt in fuel cells in LDV, Moz			
	2025	110	M units		
		Loading Thrifting, gr/vehicle (100 kWh)			
		25	20	15	10
Market Penetration	1%	0.9	0.7	0.5	0.3
	2%	1.7	1.4	1.0	0.7
	5%	4.3	3.4	2.6	1.7
	10%	8.6	6.8	5.1	3.4
Table 1B		Consumption of Pt in fuel cells in LDV, % of total market supply			
	2025	8.5	Moz		
		Loading Thrifting, gr/vehicle (100 kWh)			
		25	20	15	10
Market Penetration	1%	10%	8%	6%	4%
	2%	20%	16%	12%	8%
	5%	50%	40%	30%	20%
	10%	101%	81%	60%	40%

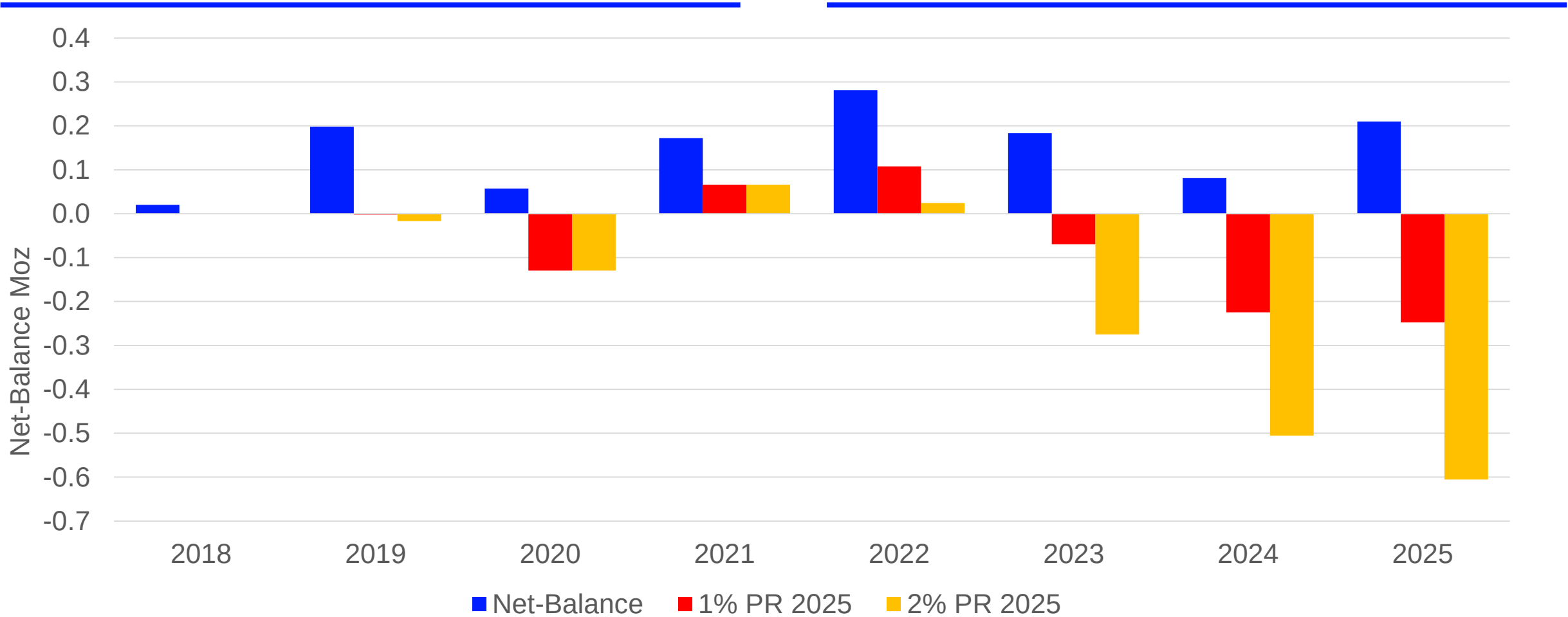
MARKET BALANCE BASE CASE

Market remaining in surplus throughout the forecast



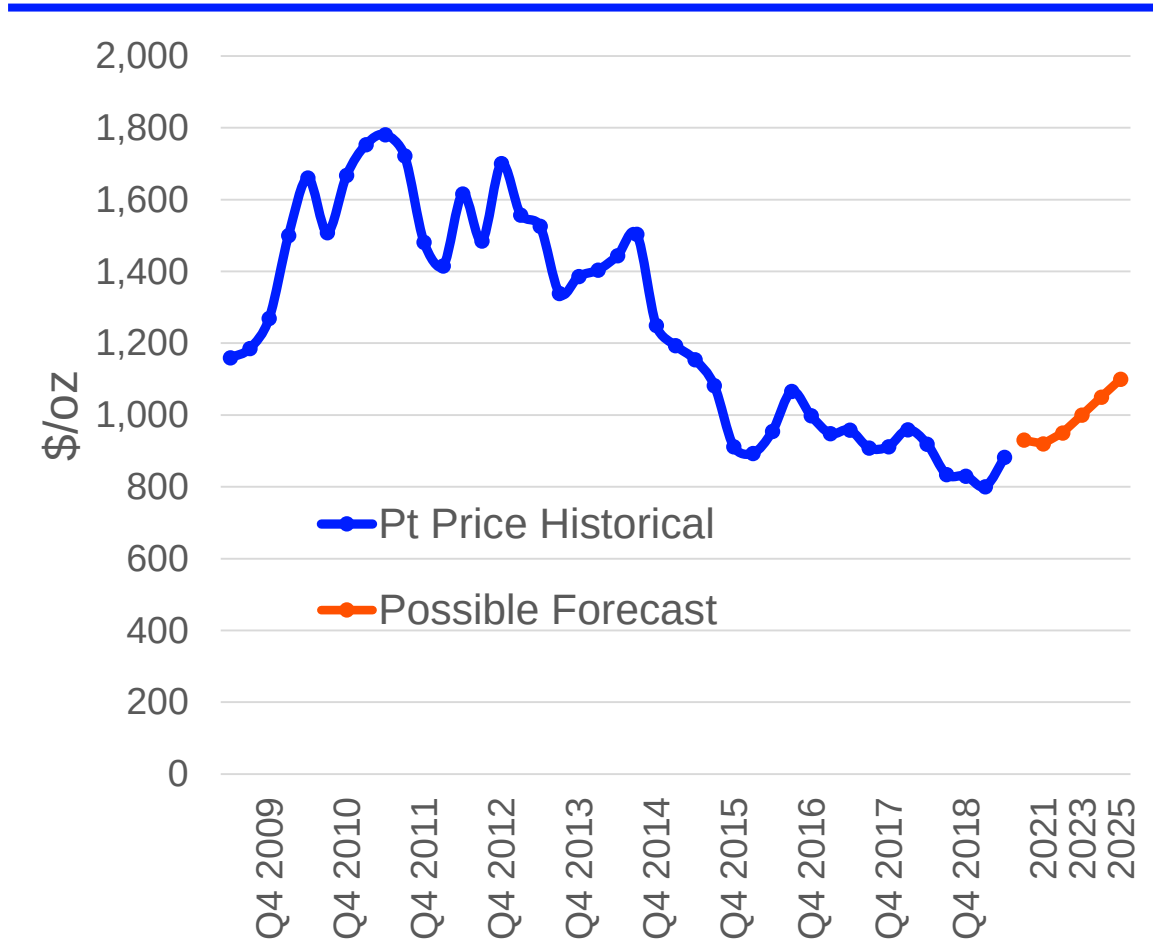
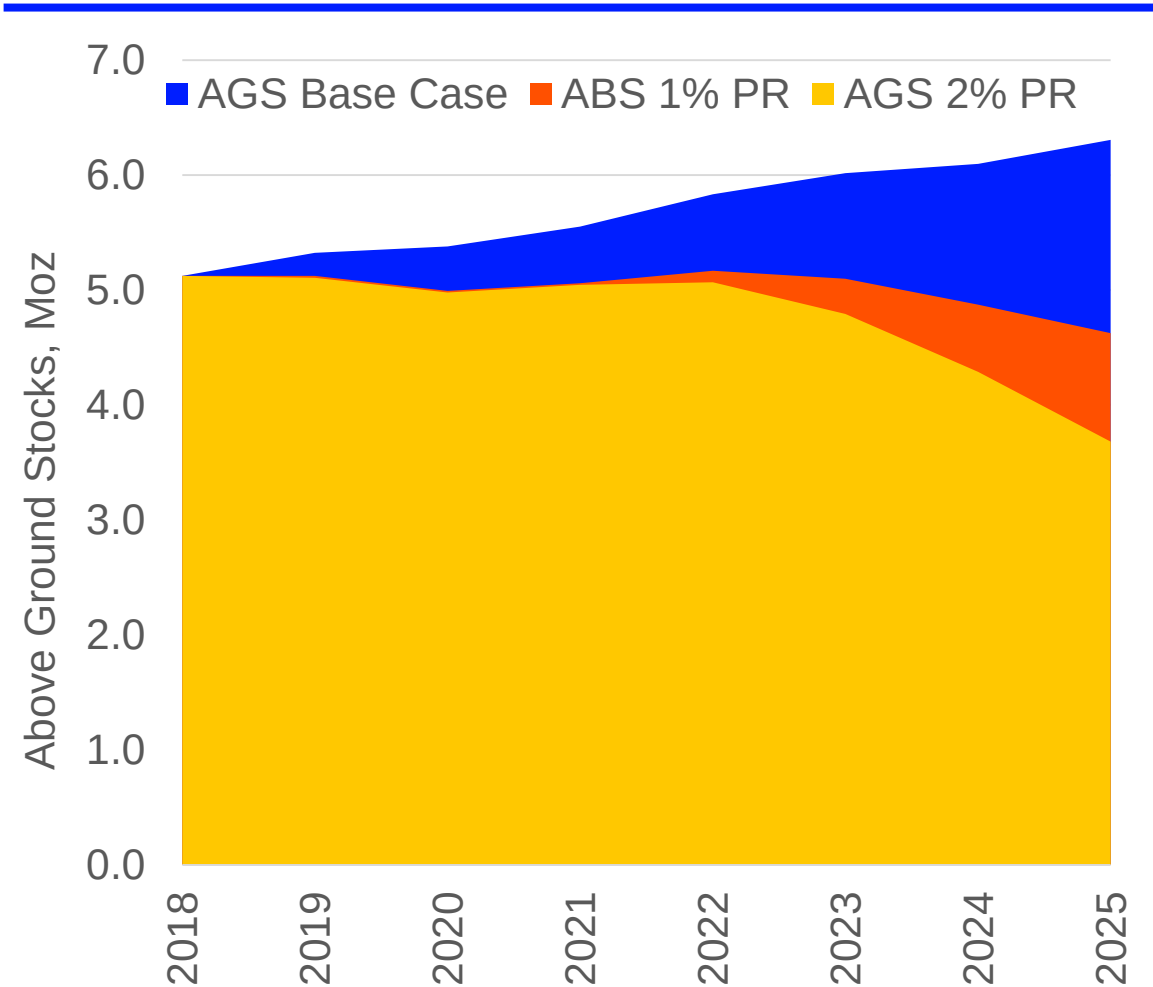
MARKET BALANCE WITH PENETRATION RATES

Market switching to deficit in 1% and 2% penetration rate by 2025



ABOVE GROUND STOCKS AND PLATINUM PRICE FORECAST

Above ground platinum stocks reduce on higher penetration rate



Concluding Remarks

CONCLUDING REMARKS

- Hydrogen fuel available but investment and dedication required to go into electrolysis process to make carbon neutral.
- AWE established technology but PEMEL likely to increase share rapidly in coming years.
- FCEV many challenges present, but promising powertrain along side BEV and other options.
- Breakthrough has been in the making for many years, but developments are accelerating.
- Interesting proposition for other segments in transport, particularly HDV, range and torque.
- FC still need platinum which will move to 10gr/vehicle in the forecast horizon.
- Taking a more progressive approach shows units rapidly accelerate towards 250k+ units. LDV will account for approx. 80% of that, equivalent to 200koz.
- Pushing penetration rate to 1% and 2% would demand approx. 350-750koz.
- Demand shock would push market balance in deficit and quickly start running down ABS.
- Is there enough short term supply available to feed that need in the case it occurs?
- What will happen to the price/market dynamics? Supply (mine and recycling) and price response

Thank You

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Lead Analyst Precious Metals, GFMS

