



The Smart Energy 6 Pack Series

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17th March 2021



Company

Hensel Recycling Group

Founded	1998
Main Office	Aschaffenburg, Germany
Employees	220
Subsidiaries	Australia, Austria, France, Great Britain, Malaysia, South Korea, USA, China (Joint Venture)
Sales Offices	South Africa, Czech Republic
Services	Purchasing service, toll refining, fast settlement, analysis & determination, logistics, precious metals management
Materials	Catalytic converters from automobile / industrial applications, diesel particulate filters, oxygen sensors, e-scrap, cable harnesses, aluminium rims, etc.
Certificates	Certified waste management company in accordance with § 56 of the German Closed Substance Cycle and Waste Management Act (KrWG), German law on emission protection (BImSchG), DIN EN ISO 9001, DIN EN ISO 14001, DIN EN ISO 45001
Memberships	ARA, BIR, BVSE, FVEM, IPMI, VDA



Consortium BEST4Hy (Horizon 2020)

- Environment Park SpA (Italy)
- CEA Liten (France)
- Politecnico di Torino (Italy)
- Hensel Recycling GmbH (Germany)
- Elringklinger AG (Germany)
- Aktsiaselts Elcogen (Eastland)
- RINA Consulting SpA (Italy)
- Univerza v Ljubljani (Slovenia)
- Start January 2021
- 36 months duration



Environmental Relief through Recycling

Total quantities in 2019

Mine production	14.195.000 oz
Recycling (including jewellery)	4.950.000 oz

PGM from auto catalysts

New production	12.475.000 oz
Cats recycling	4.010.000 oz
Hensel Recycling	354.000 oz
	= 11.000 kg



Environmental Relief through Recycling

Emissions in the PGM Recovery

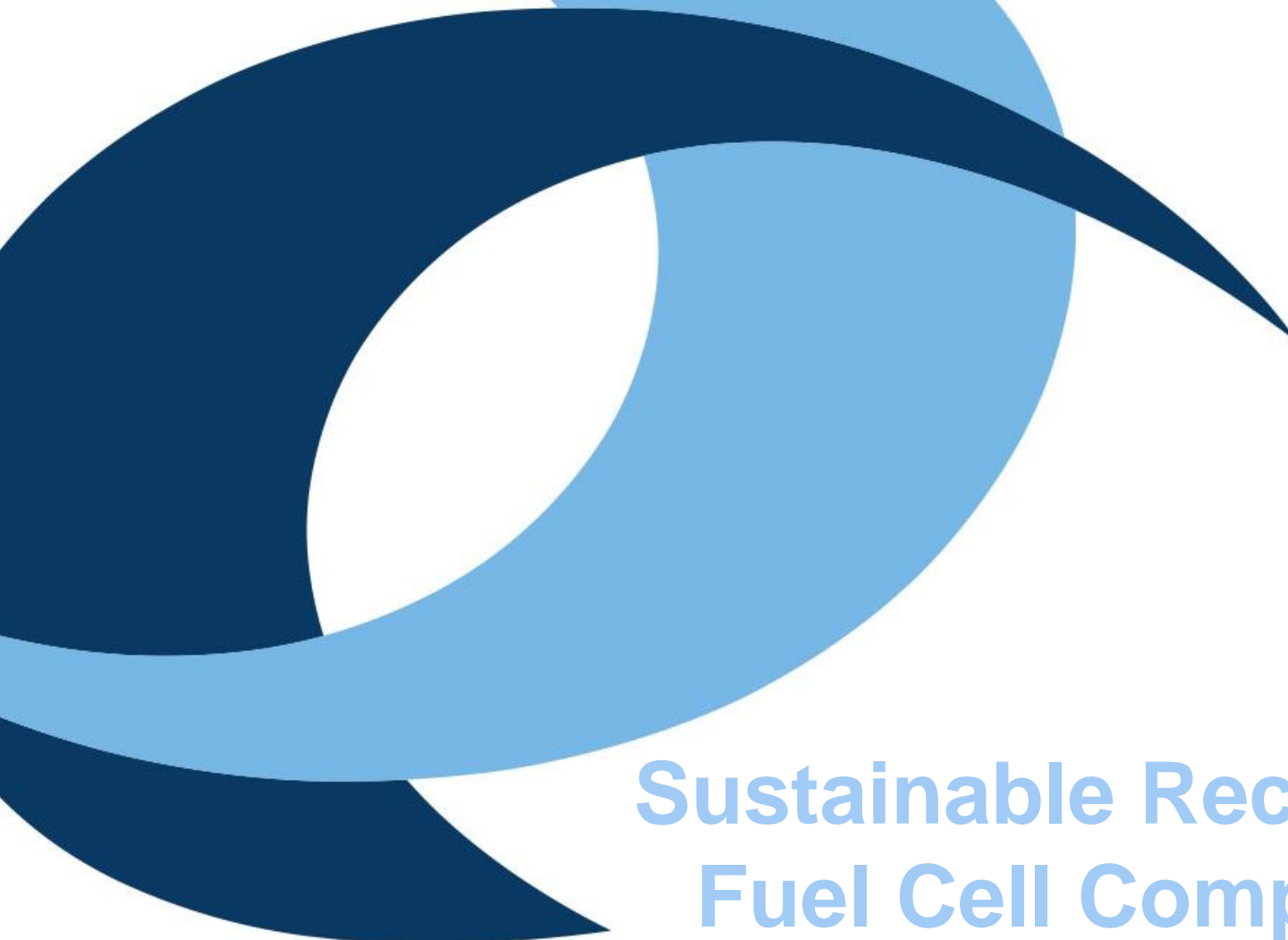
Primary / Mine	15.600 kg CO ₂ pro kg
Secondary / Recycling	1.248 kg CO ₂ pro kg

Recycling Quantity **11.000 kg/a**

Primary	171.600 t/a CO ₂
Hensel Recycling	13.728 t/a CO ₂
Operations related emissions	300 t/a CO ₂

Economisation / Year ~ 150.000 t/a CO₂



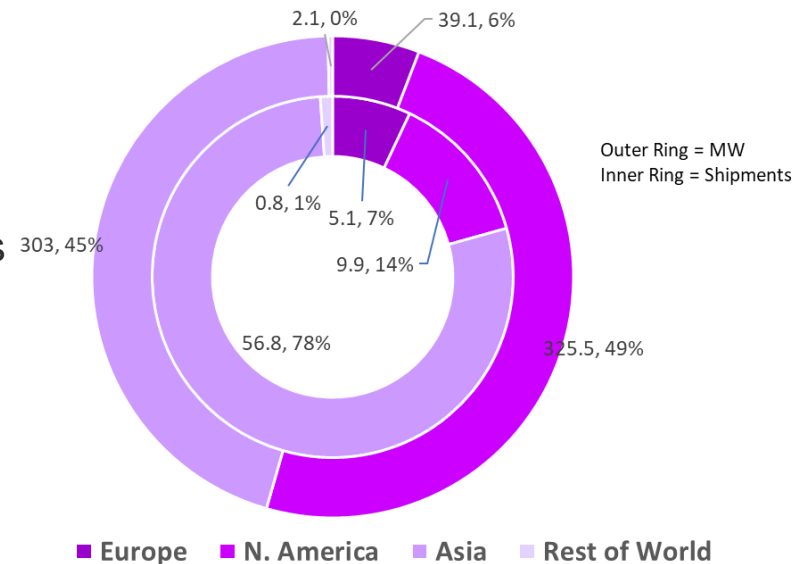


**Sustainable Recovery of
Fuel Cell Components:
an outlook**

Fuel Cell Market Summary (1)

- Transportation as key growth application in MW terms
- Asia and North America as major fuel cell scrap generators
- China, Japan and South Korea: key Asian Countries with fuel cell deployment
- North America is an important market for recyclers with plans to import large numbers of FCEV, while both importing and producing PAFC and PEMFC stationary systems and electrolyser hydrogen
- PEMFC as largest PGM recycling opportunity in terms of MW in the transportation sector
- PAFC represent the key PGM-bearing technology in stationary systems, with PEMFC making inroads

Fuel Cell Market by Global Region, 2017



Fuel Cell Market Summary (2)

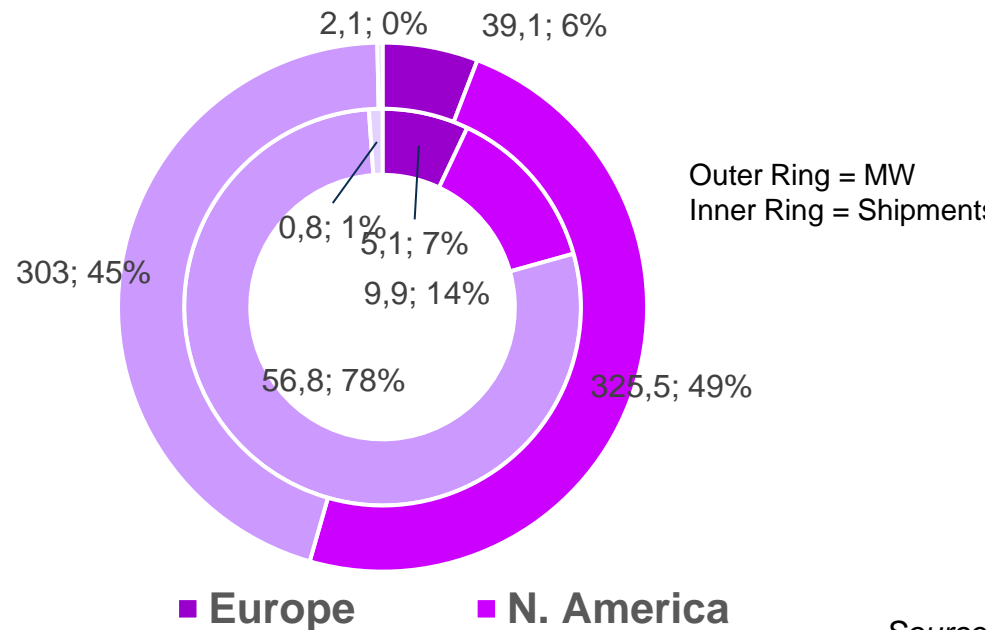
- Compared with an auto catalyst, a fuel cell stack is vastly more complicated
- From a recycler's perspective, this is an immediate game changer.
- At the heart of the stack is the CCM and this is a coated polymer (Nafion/ePTFE) or other PerFluorinated Sulphonic Acid (PFSA) material.
- There is a choice for recyclers – whether to become involved in processing the stack, or simply the MEA's which may be mechanically taken out of the deconstructed stack and sent on their own for processing



Regional Markets

- Asia dominated the shipments in 2017 with almost 80% of the total.
- Europe remains vastly under-represented with just 6% of MW deployed in 2017 and there was almost no activity outside of the three major world regions

Fuel Cell Market by Global Region, 2017



Source: E4Tech 2017 Review



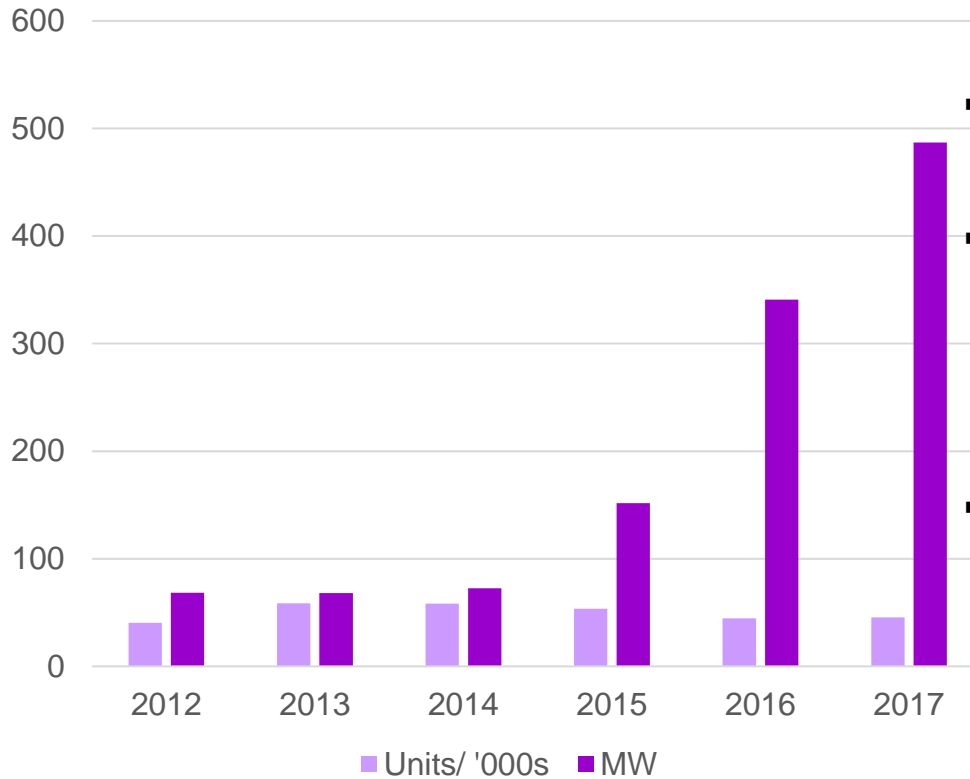
Recycling opportunities – regional perspective

- In terms of domestic fuel cell shipments, Asia may sit in second place
- In Asia, the ramp up in intra-regional exports to China for transport, is a major growth area. Units sold for stationary power in Japan and Korea are also large pockets of demand
- China has the most prominent growth in transport demand for fuel cells
- In North America, the PEMFC shipments for transportation are growing based on imports of PEMFC for Toyota, Honda and Hyundai's FCEV. These OEM have bullish plans for increases in FCEV sales post-2020 which could see the total annual sales of over 50,000 early next decade and collectively into the millions by 2030
- Growth of opportunity in Europe is hampered by the relatively slow roll-out of FCEV
- Three big German automakers (Daimler, BMW and VW) have all announced partnerships to advance introduction of FCEV
- Daimler has introduced its Mercedes-Benz GLC F-CELL vehicle, but with limited numbers as of 2018
- It is also looking to introduce its PEM into data centres
- Other less mainstream companies such as Riversimple and Microcab are also piloting FCEV in the European region



Market for PEMFC

Global Market for PEMFC



- In 2017 the market for PEMFC in units shipped reached 45,500
- The majority of growth has been focussed in the transport and stationary markets
- In transport, introduction of passenger vehicles by Japanese automakers as well a strong support from China for introduction of FC based buses and trucks have lead to an explosion in demand for larger PE units
- PEMFC also find their way into other types of transport including rail, marine, unmanned vehicles including drones and UAV Materials' handling (e.g. forklift trucks are also significant PEMFC consumers

PEMFC	2012	2013	2014	2015	2016	2017
Shipments in Units/ 1000's	40.4	58.7	58.4	53.5	44.5	45.5
Shipments by MegaWatt	68.3	68.0	72.7	151.8	341.0	486.8
kW/Unit Shipped	1.7	1.2	1.2	2.8	7.7	10.7

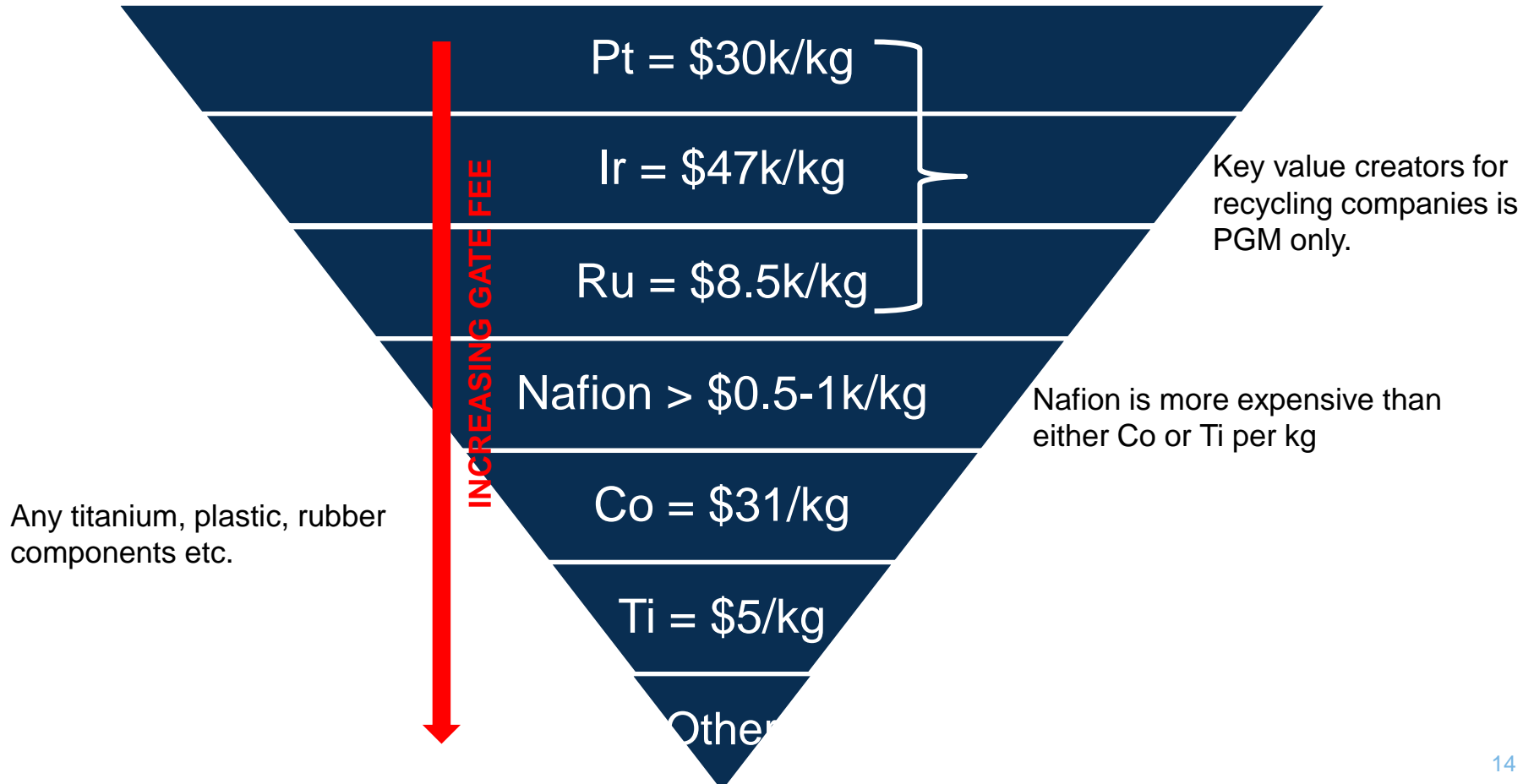
Intrinsic Value of a FC

- Depending on the type of fuel cell and its application its inherent value will be different. Key components within the stack include
- The inherent value of a fuel cell and its components is the key question and will diminish over time as technology improve:
 - Platinum Group Metal (Pt/Ru/Ir)
 - Strategic Metals (Co)
 - Other metals (Ti)
 - Composite membrane- Nafion, ePTFE (Gore Select Membrane)
 - Mixed plastics





PGM are the only real profit centres while the other components, especially Nafion need a payable fee to process economically.



Fuel Cell Recycling – Opportunity Identification

- 1 Factors which favour the market for recycling platinum in fuel cells
 - High PGM Content (> 3 g per unit)
 - Number of units produced (>10,000's with potential for 100,000s or millions)
 - Market growth prospects
 - Low fuel cell lifetime (< 6 years)
- 2 Very few FCEV will reach their EOL before 2025 and even then, the units may be repurposed for stationary energy storage. The recycling opportunity may be more significant after 2030, however it is good to form partnerships from now onwards to secure supply chain position.
- 3 The biggest nearest term opportunity is in heavy duty trucks and buses. Although fuel cell lifetimes are outstripping expectations, they will still be shorter than cars and with larger quantities of platinum. The market for electric buses and trucks is expected to soar and fuel cells will outperform diesel. (McKinsey 2018). China is moving to 100% electric buses and Europe will follow, albeit with a lower proportion of FC.
- 4 Electrolysers are the opportunity to watch. Mass decarbonisation of transport, heat, industry and stationary applications will all increase the need for electrolyser hydrogen. The sticking point maybe sufficient supply of minor metals and much thrifting will be required to allow scale up.



Four main areas of opportunity, FCEV will have the highest total PGM deployment although very long lifetimes and repurposing. Heavy Duty buses and trucks may be the best near term opportunities for recyclers.

1	Heavy Duty 3 tons Pt/year for 100,000 vehicles	<ul style="list-style-type: none">• 30-50 g per vehicle• 6 year life• 400,000s systems in place by 2030 (Hydrogen Council Target)• Market entry via relationship with Ballard, Dongfeng & approved leasing partners/facilities managers
2	Stationary 2.5 tons Pt/year for 1000 MW	<ul style="list-style-type: none">• 1 kg per 400 kW stack (estimate)• 5-10 year life depending on the system• 1000' MWs per year by 2030• Market entry via relationship with Doosan FC & leasing partners
3	Electrolysers 0.25 tons PGM/year for 1000 MW	<ul style="list-style-type: none">• 250-300 g Pt/Ru/Ir per 2 MW Cabinet; no cobalt• 10-year life on the stacks although more data needed• 10 per year produced, unlimited potential• Market Entry via relationship with ITM Power & competitors
4	FCEV 6 tons Pt/year for 1 m vehicles	<ul style="list-style-type: none">• 12 g per vehicle 2020, down to 6 g by 2025• 1 million vehicles per year by 2030• 12-15 year life and repurposing may become commonplace• Market entry via relationship with Toyota, Daimler, Honda, Hyundai and approved scrap merchants



Glossary

AFC	Alkaline Fuel Cell	MW	Megawatts (10 ⁶ watts)
CCM	Catalyst Coated Membrane	NDA	Non-Disclosure Agreement
CEA	Commissariat à l'Énergie Atomique et aux Énergies Alternatives	NIP	National Innovation Program
CHP	Combined Heat and Power	NSTF	Nanostructured Thin Film
CSA	Cell Stack Assembly	PAFC	Phosphoric Acid Fuel Cell
DMFC	Direct Methanol Fuel Cell	PEM	Proton Exchange Membrane
EOL	End-Of-Life	PEMEL	PEM Electrolyser
EV	Electric Vehicle	PGM	Platinum Group Metal
FC	Fuel Cell	PFSA	Perfluorinated Sulphonic Acid
FCEV	Fuel Cell Electric Vehicle	PPA	Power Purchase Agreement
FCH-JU	(EU) Fuel Cells and Hydrogen Joint Undertaking	PTFE	Polytetrafluoroethylene
GDL	Gas Diffusion Layer	R&D	Research & Development
GSM	Gore Select Membrane	OGE	Open Grid Europe
HMG	Hyundai Motor Group	RED	Renewable Energy Directive (Europe)
HTEL	High Temperature Electrolyser	ROI	Return on Investment
IP	Intellectual Property	SOEC	Solid Oxide Electrolyser Cell
JIVE	Joint Initiative for Hydrogen Vehicles across Europe	SOFC	Solid Oxide Fuel Cell
KHNP	Korea Hydro & Nuclear Power	UAV	Unmanned Aerial Vehicle
KRIST	Korean Research Institute of Science & Technology	UPS	Uninterrupted Power Systems
OEM	Original Equipment Manufacturer	WEEE	Waste Electrical & Electronic Equipment
MCFC	Molten Carbonate Fuel Cell	ZEV	Zero Emission Vehicle
MEA	Membrane Electrode Assembly		
MEL	Microbial Electrolyser		



Thank you.

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