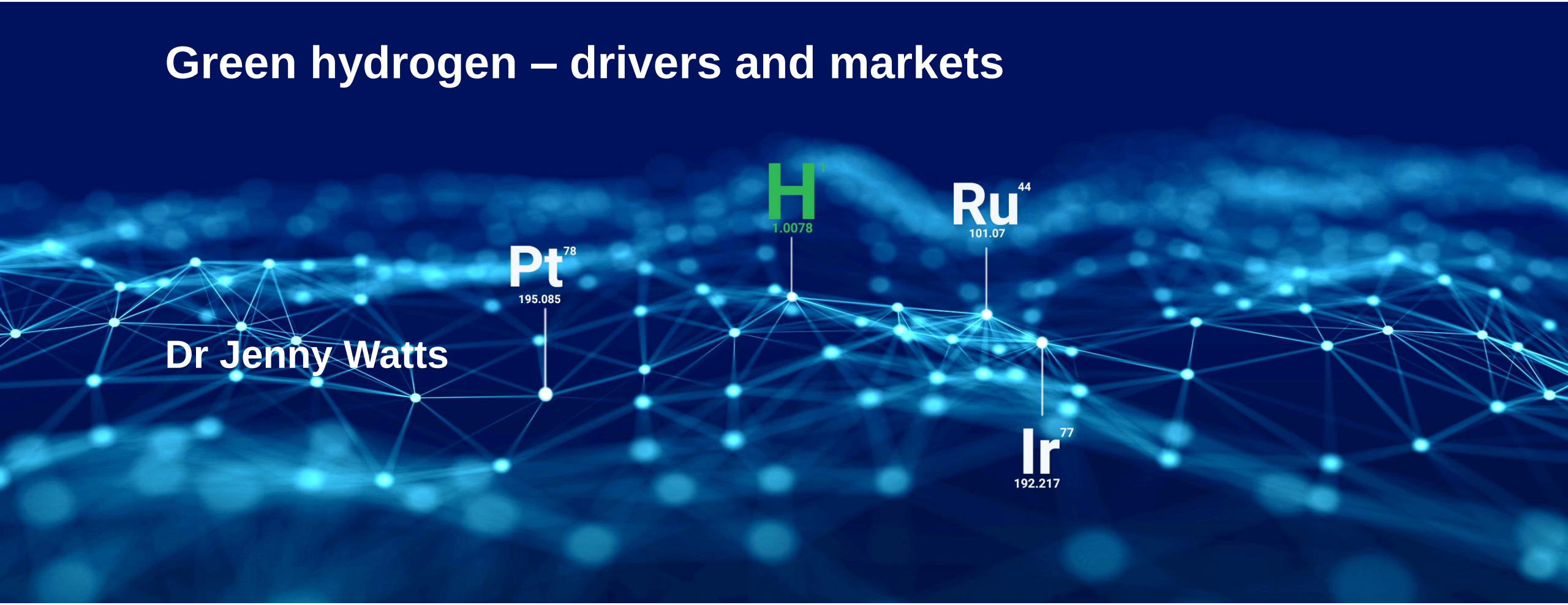
Green hydrogen – drivers and markets



Dr Jenny Watts

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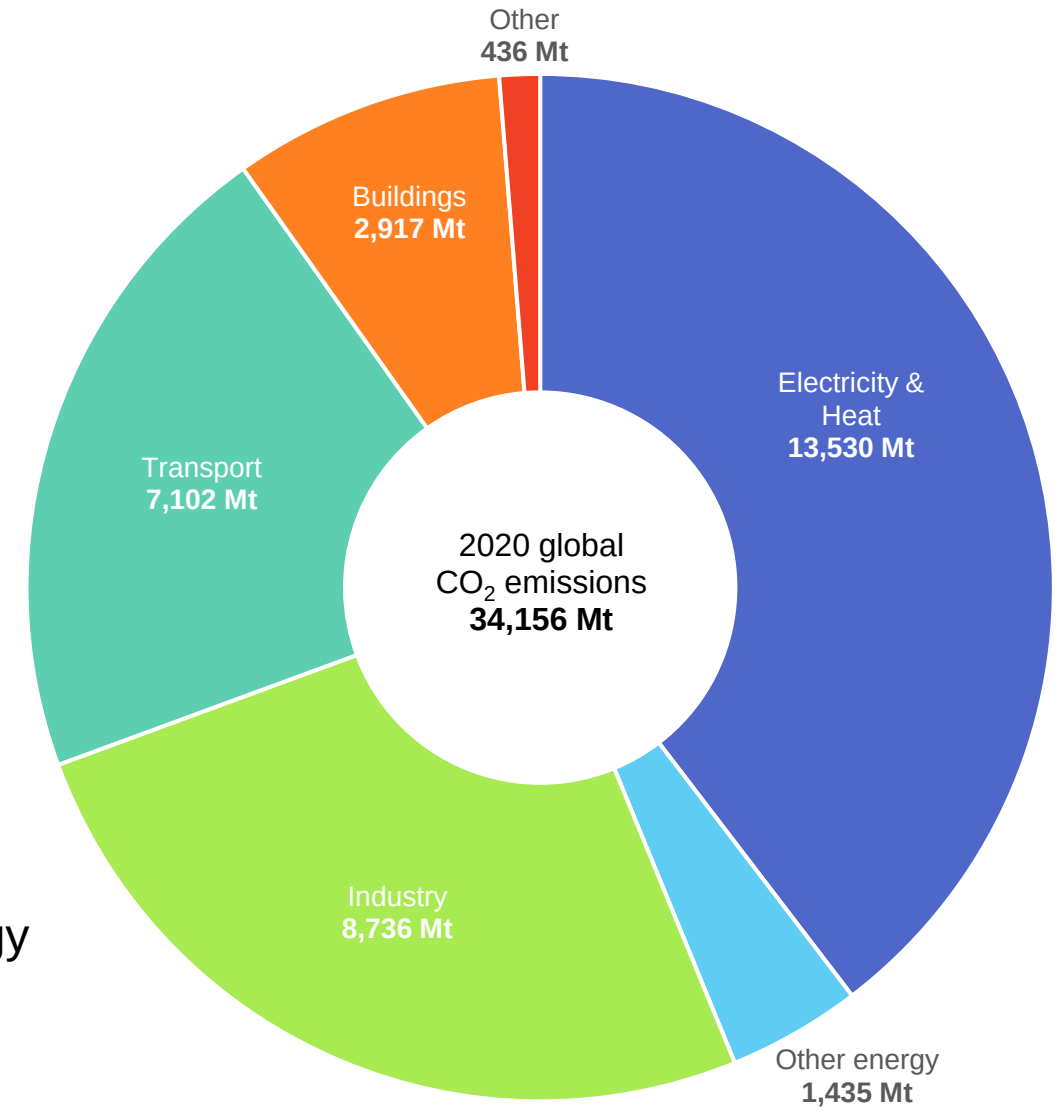
Decarbonisation – hydrogen's leading role

- ✓ World aims to limit global warming
- ✓ No more than 1.5°C above pre-industrial levels
- ✓ Cut greenhouse gas emissions by >30 Gt p.a. by 2030
- ✓ Focus on 6 main sectors
- ✓ Target the quickest and biggest win sectors…
- ✓ …energy, industry, transport
- ✓ Hydrogen as the 'new oil'
- ✓ Green hydrogen goes hand-in-hand with renewable energy



Source: IEA, World Energy Outlook October 2021

Most hydrogen today has a high carbon footprint

Route	Carbon footprint
Grey from steam methane reforming (SMR) of oil, gas or coal	**High**
Turquoise from methane pyrolysis producing solid carbon as a by-product	**Low**
Blue from SMR but with the CO_2 emissions captured and stored (CCS)	**Low**
Pink from electrolysis from nuclear energy	**Low**
Green from electrolysis from renewable wind or solar energy	**Zero**

Source: SFA (Oxford)

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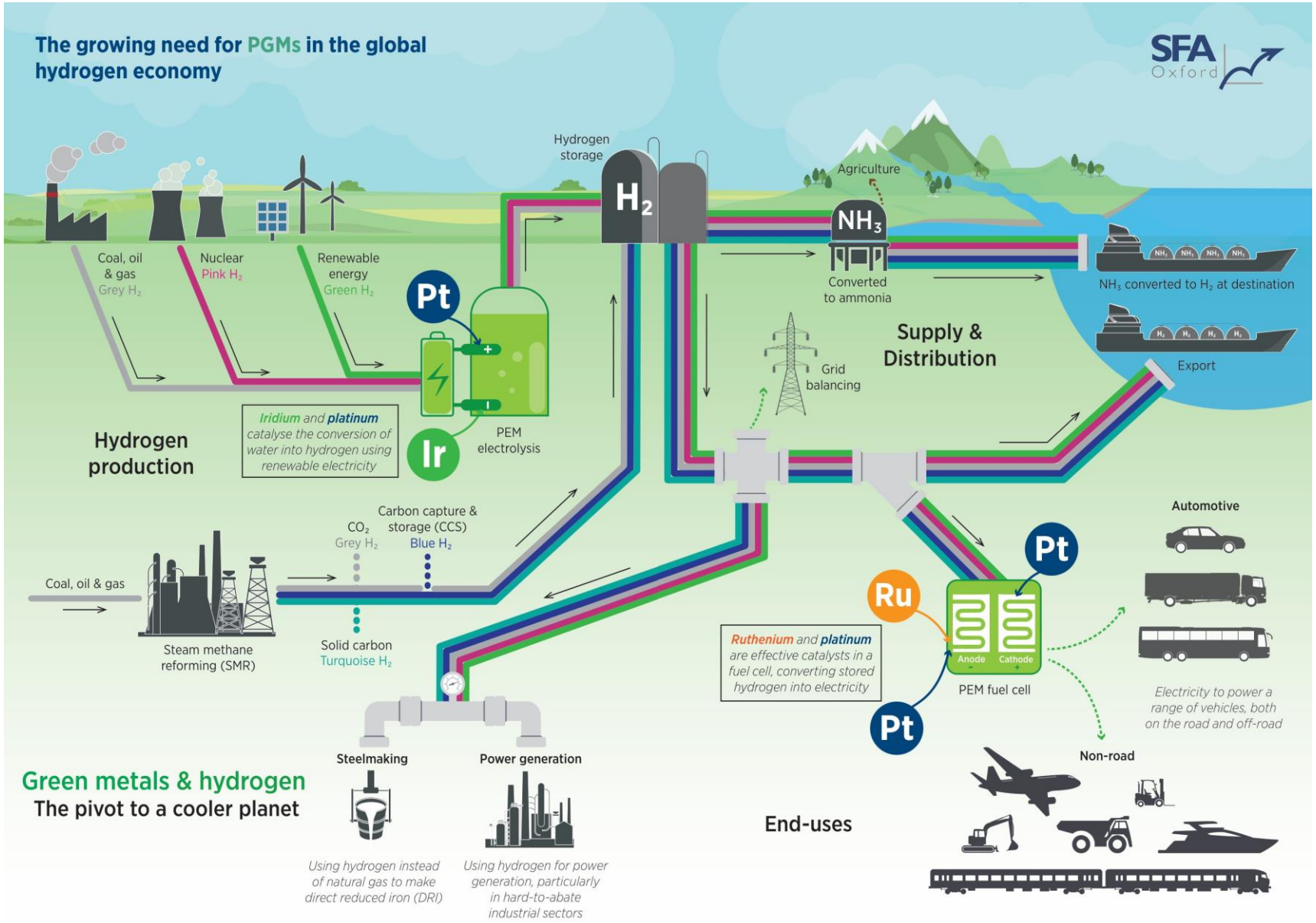
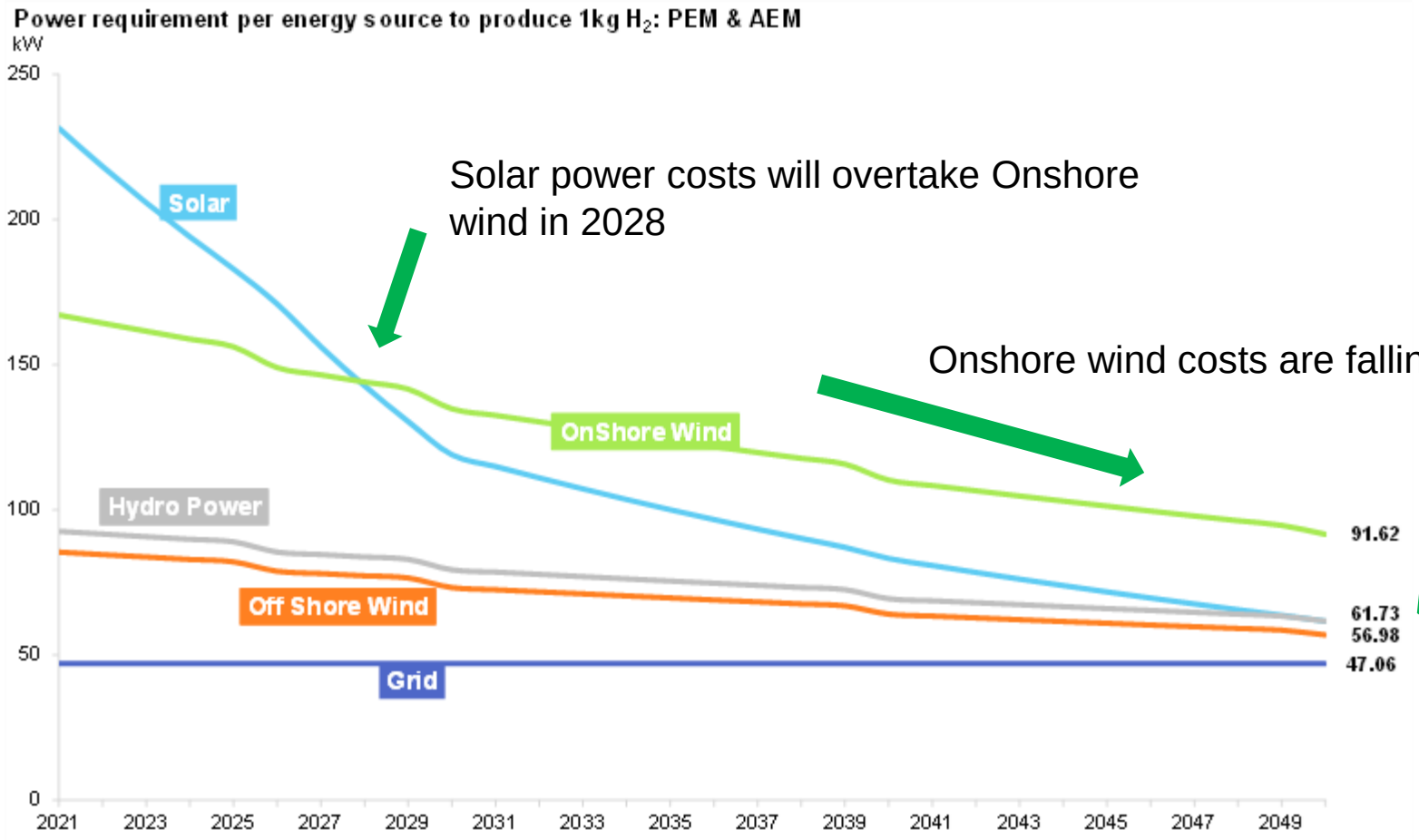
Where do the PGMs fit in?



Source: SFA (Oxford)

Green hydrogen increasingly competitive as renewable energy costs fall

Power requirements for H_2 production are falling in all renewable cases as sources reach maturity



Solar power costs will overtake Onshore wind in 2028

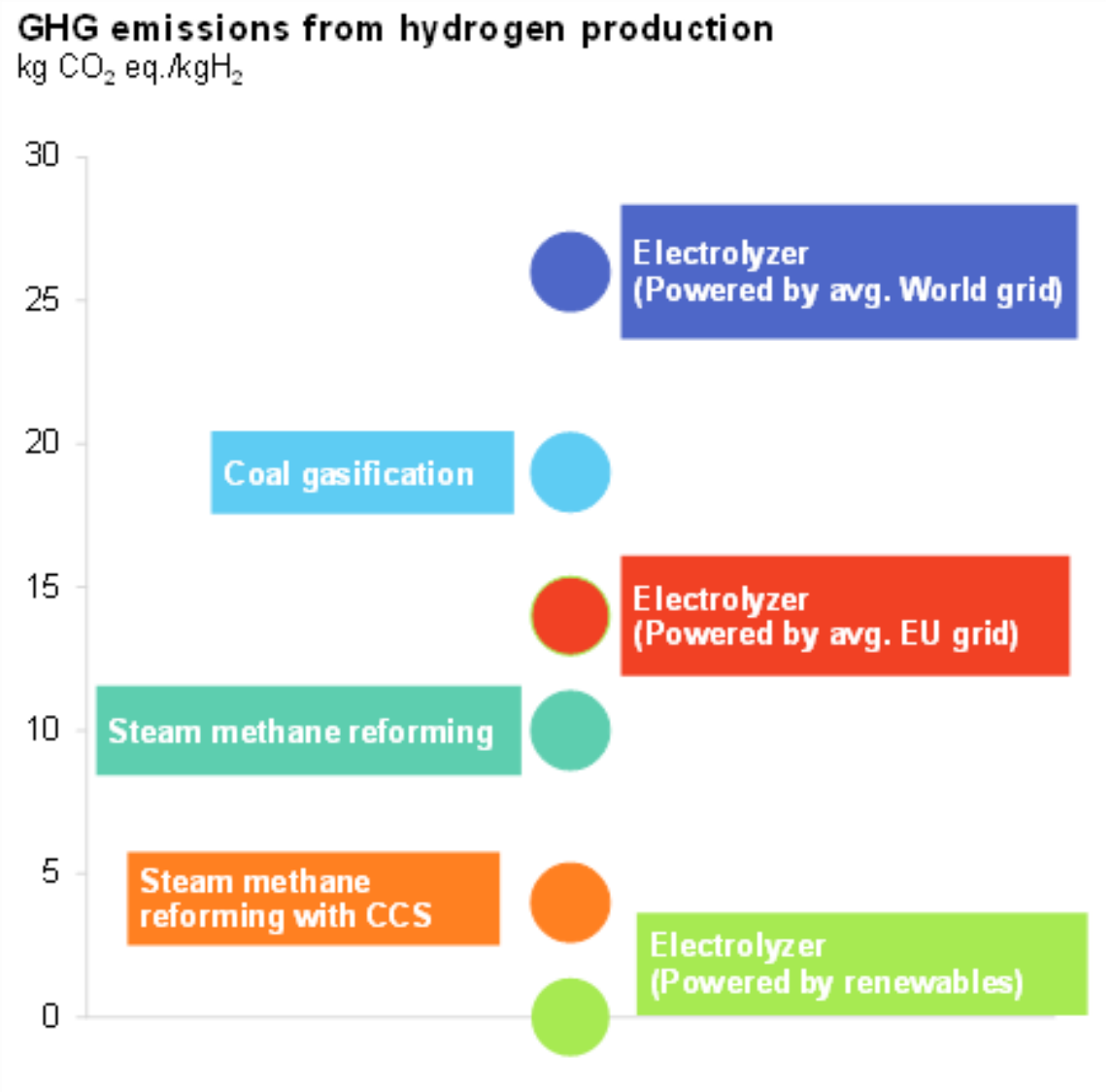
Onshore wind costs are falling steadily

By 2050, solar power could converge with hydropower

Source: SFA (Oxford)

Legislation and collaboration are vital!

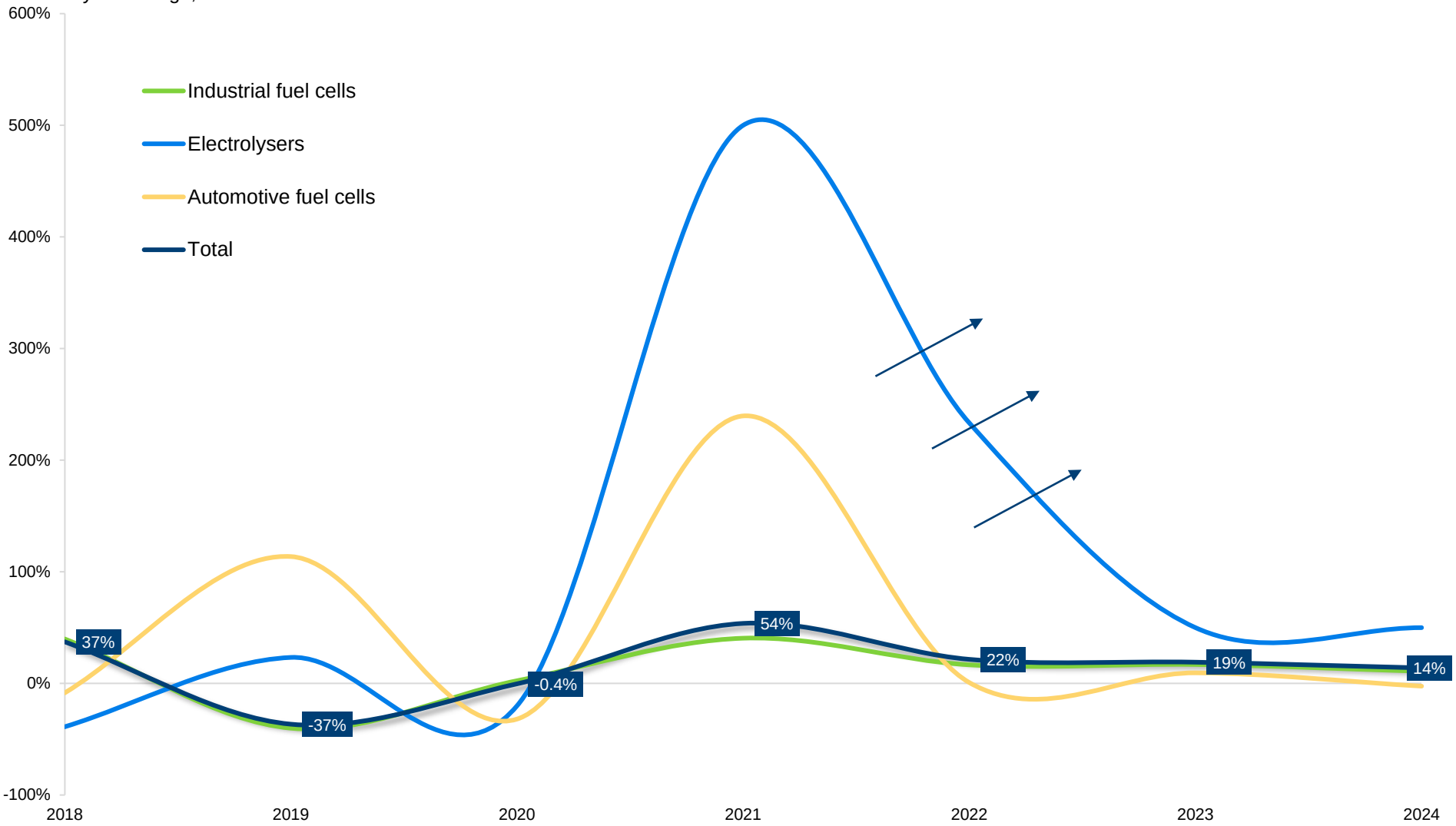
- ✓ CO_2 emissions mitigated in the various industrial processes available to produce hydrogen
- ✓ Maximising hydrogen's potential will require
  - ✓ governments to set the right legislation
  - ✓ industry collaboration & partnerships



Source: SFA (Oxford), Siemens Gamesa & Siemens Energy

Electrolyser growth *now* underpins green hydrogen *future*

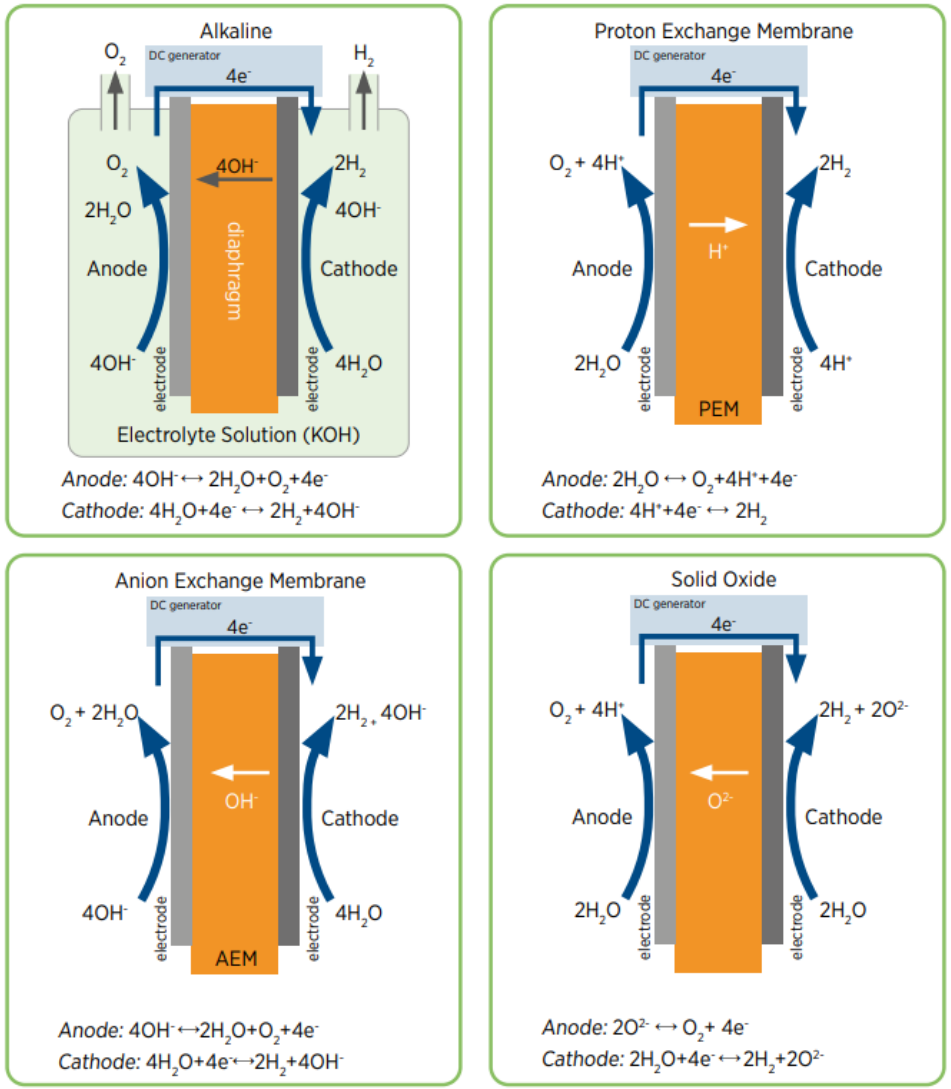
Hydrogen: PGM demand
Year-on-year change, %



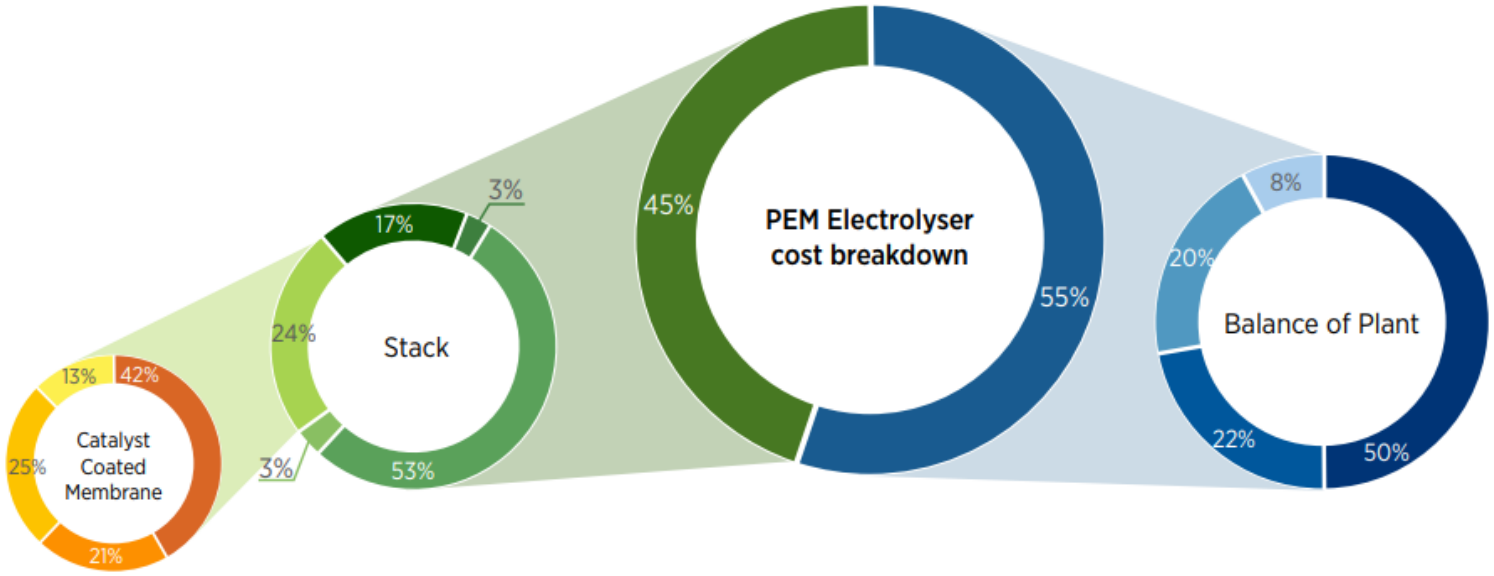
Source: SFA (Oxford)

Importance of Ir and Pt in electrolysis

Commercial water electrolysis technologies



Cost breakdown for a 1 MW PEM electrolyser, moving from full system, to stack, to CCM

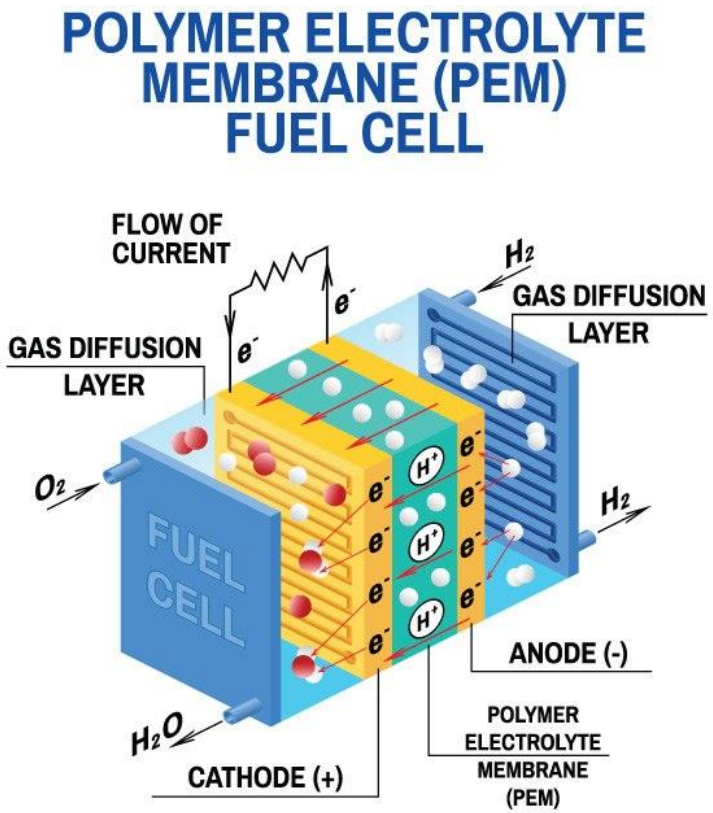


- Manufacturing
- PFSA Membrane
- Iridium
- Platinum
- Porous Transport Layer (PLTs)
- Small parts (sealing, frames)
- Bipolar Plates (BPSs)
- Stack assembly and end plates
- Catalyst Coated Membrane
- Protective coating BPs
- Balance of Plant
- Stack components incl. CCM
- Power Supply
- Deionised Water Circulation
- Hydrogen Processing
- Cooling

Source: IRENA

Importance of Pt and Ru in fuel cell technologies

Scalable and modular from this …



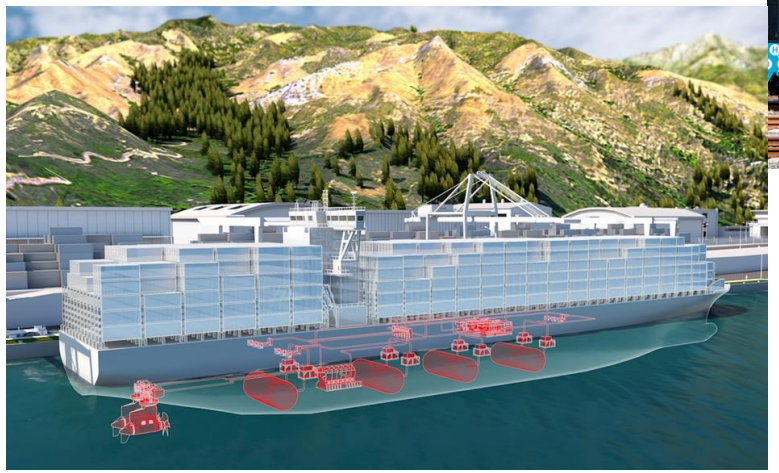
Source: sigmaaldrich.com

…via this…

Source: Foshan Feichi fuel cell bus manufacturing facility

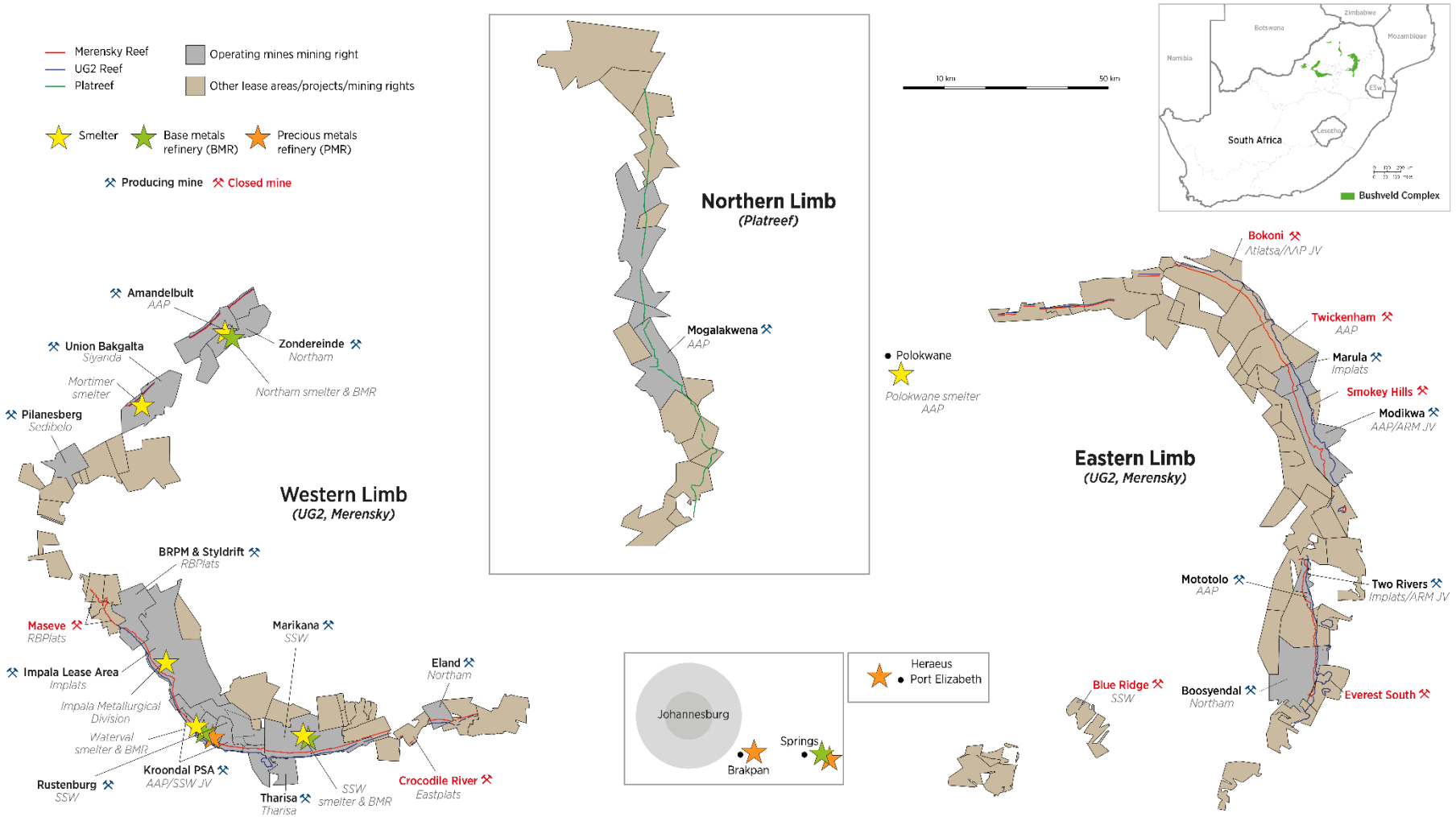
…to this

Source: Alstom



Source: ABB

South Africa – the world's hydrogen metals basket

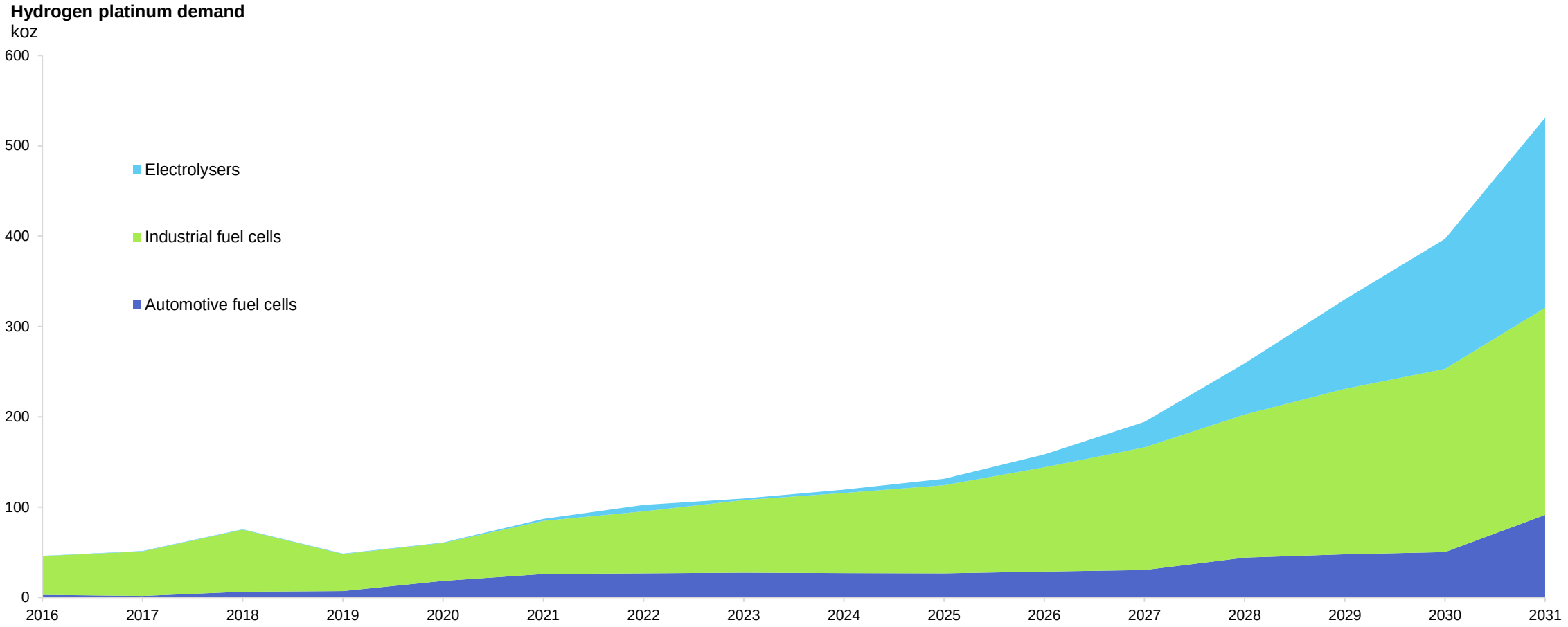


A secure supply chain for the hydrogen metals:

- ✓ 16 operating PGM mines plus various other sources (e.g. chrome mining and tailings reprocessing)
- ✓ fully capitalised
- ✓ huge resource base with several active projects
- ✓ known geology
- ✓ established, skilled labour force
- ✓ extraction technology refined over many decades
- ✓ mine-to-market routes in place

Source: SFA (Oxford)

The hydrogen economy needs iridium, ruthenium and platinum…and those metals need hydrogen



Source: SFA (Oxford)

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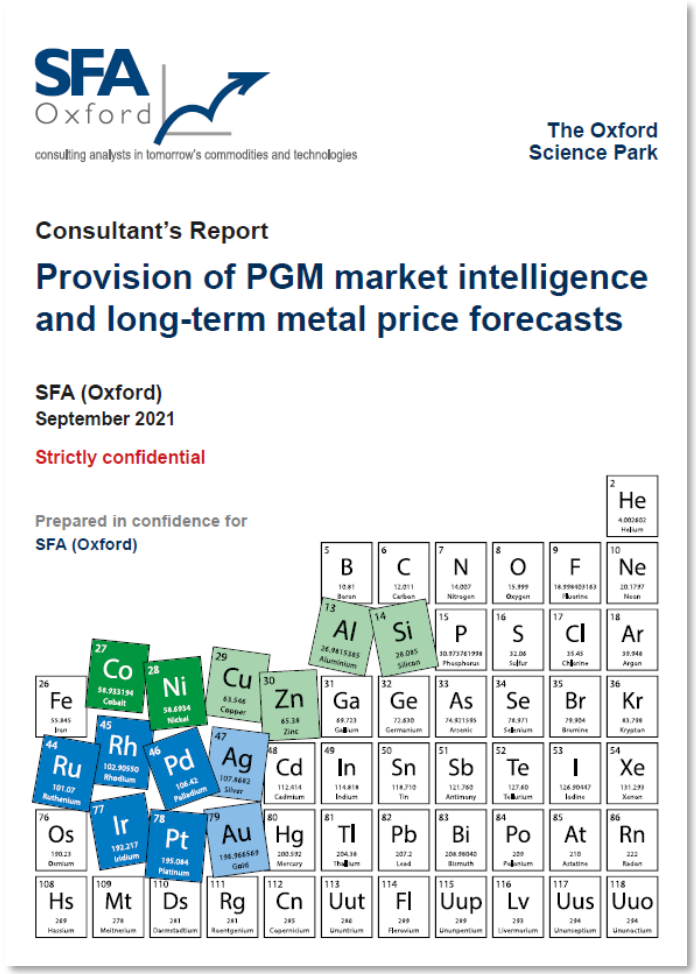

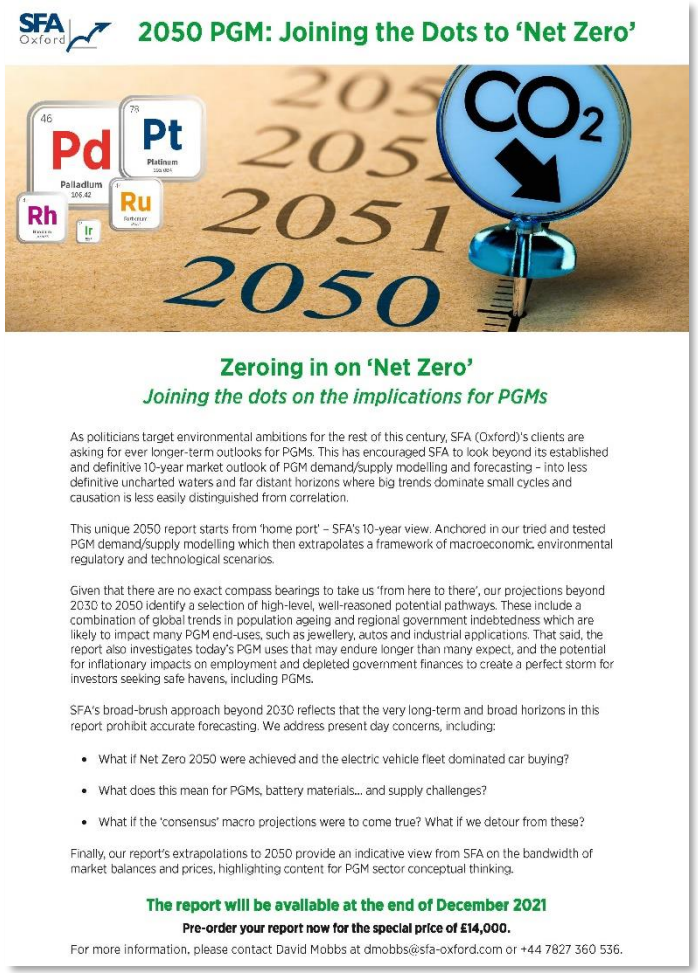

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