WORLD FUTURE FUEL SUMMIT & EXPO

International Conference & Exhibition on Future Fuel

"Sustainable Future Fuel for Global Green Climate"

Global Hydrogen Energy Update

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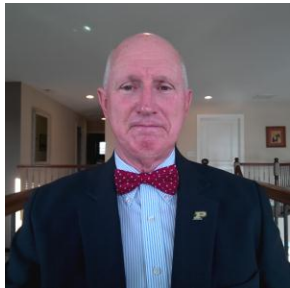
PURDUE UNIVERSITY

15-17 February – New Delhi, INDIA

Global Hydrogen Energy Update

John W. Sheffield

My career in hydrogen energy began in 1976 when working for Pratt and Whitney Aircraft in West Palm Beach, Florida. Specifically, we were developing the technologies for high-power, continuous wave hydrogen fluoride and deuterium fluoride chemical lasers. Later working at the University of Miami, California Institute of Technology, the Missouri University of Science and Technology and now at Purdue University in West Lafayette, Indiana.



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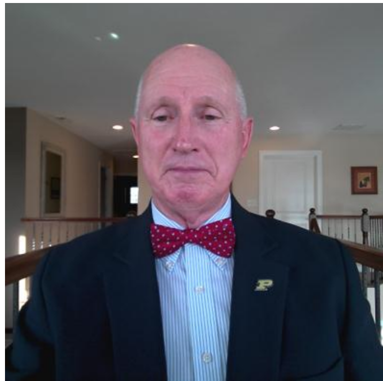
Global Hydrogen Energy Update

John W. Sheffield

I serve as the President of the International Association for Hydrogen Energy and I have served as an editor of the International Journal of Hydrogen Energy since 1978.

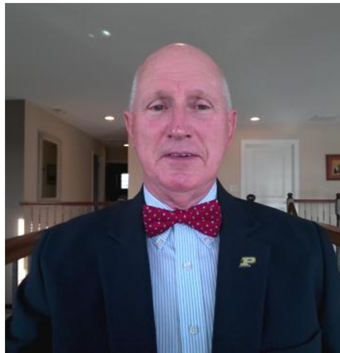
I am excited to share with you some of my personal insights on …

A Global Update on Hydrogen Energy



Why ...Hydrogen?

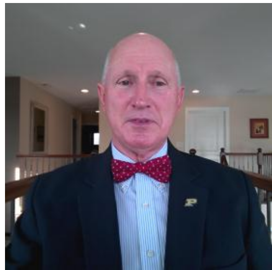
Hydrogen offers a unique cross-system opportunity for fundamental changes in the energy industry.



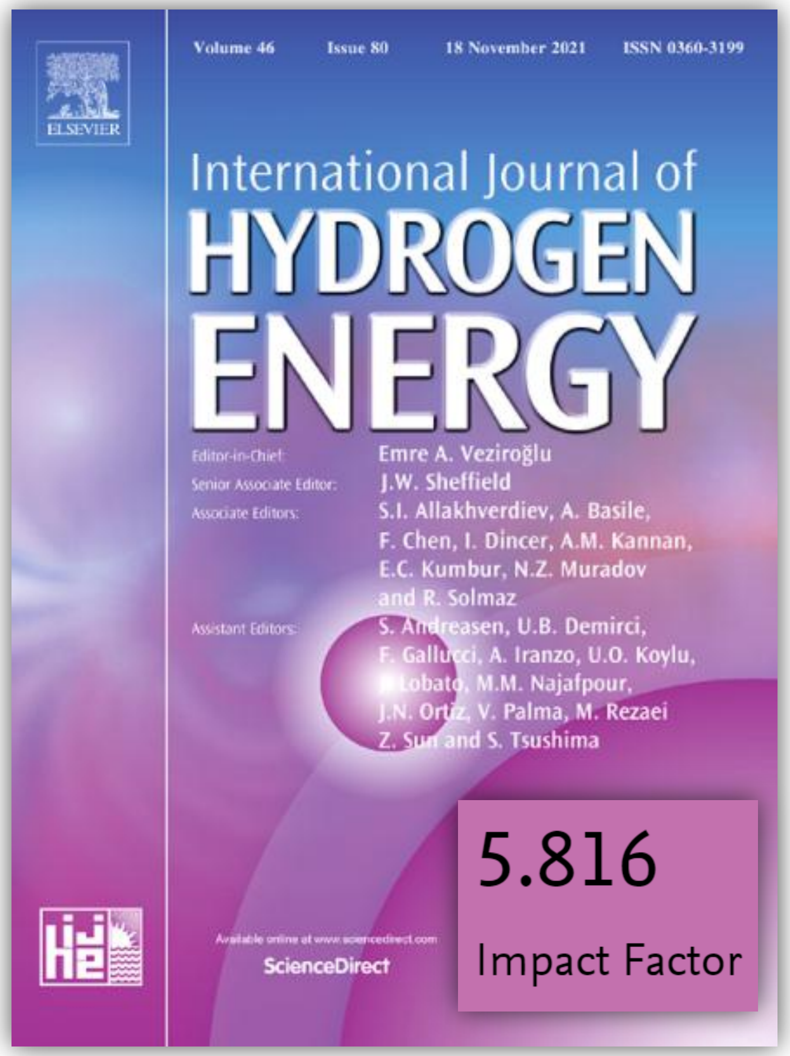
Global Hydrogen Energy Update

WHAT ARE THE THREE KEY OBJECTIVES for the global focus on the progress, prospects & markets of hydrogen energy technologies?

1. **CHANGE IN MINDSET:** *Because of the global shift of the mindset of regulators, investors, and consumers toward decarbonization, hydrogen projects are receiving unprecedented investments.*
2. **TOTAL COST OF OWNERSHIP ANALYSIS**: *Total Cost of Ownership analysis shows cost competitiveness of large-scale applications of hydrogen energy technologies.*
3. **GW SCALE WITH CORRECT REGULATORY FRAMEWORK:** *At-scale deployment of renewable hydrogen will require the development of GW-scale hydrogen production projects, for example by permitting an overbuilding of renewable energy supply with green hydrogen production capacity via electrolysis*.

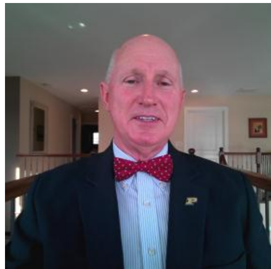


International Journal of Hydrogen Energy



The International Journal of Hydrogen Energy is published by Elsevier and is our official journal of the *International Association for Hydrogen Energy* and was established in 1976. I joined two years later as the first Assistant Editor. Four years later it became monthly, biweekly in 2008, weekly in 2015 and 80 issues in 2021.

We published 40,312 pages in 80 issues in 2021.



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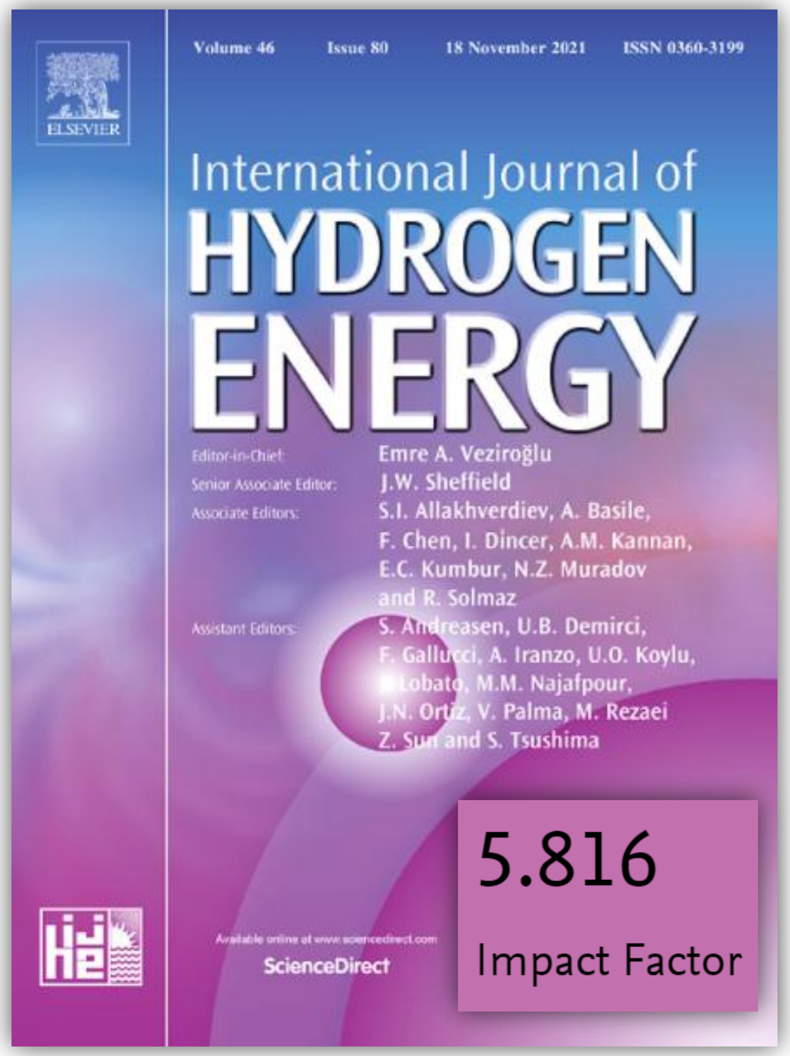
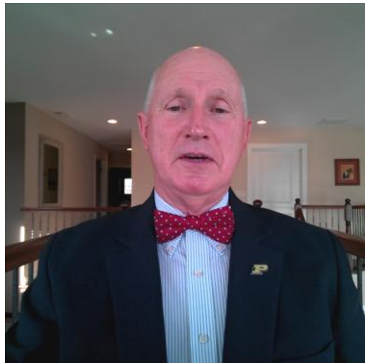


Journal metrics provide valuable insight into three aspects of the journal: *IMPACT, SPEED and REACH.*

These metrics help authors select the "best" journal for the publication of their research findings.



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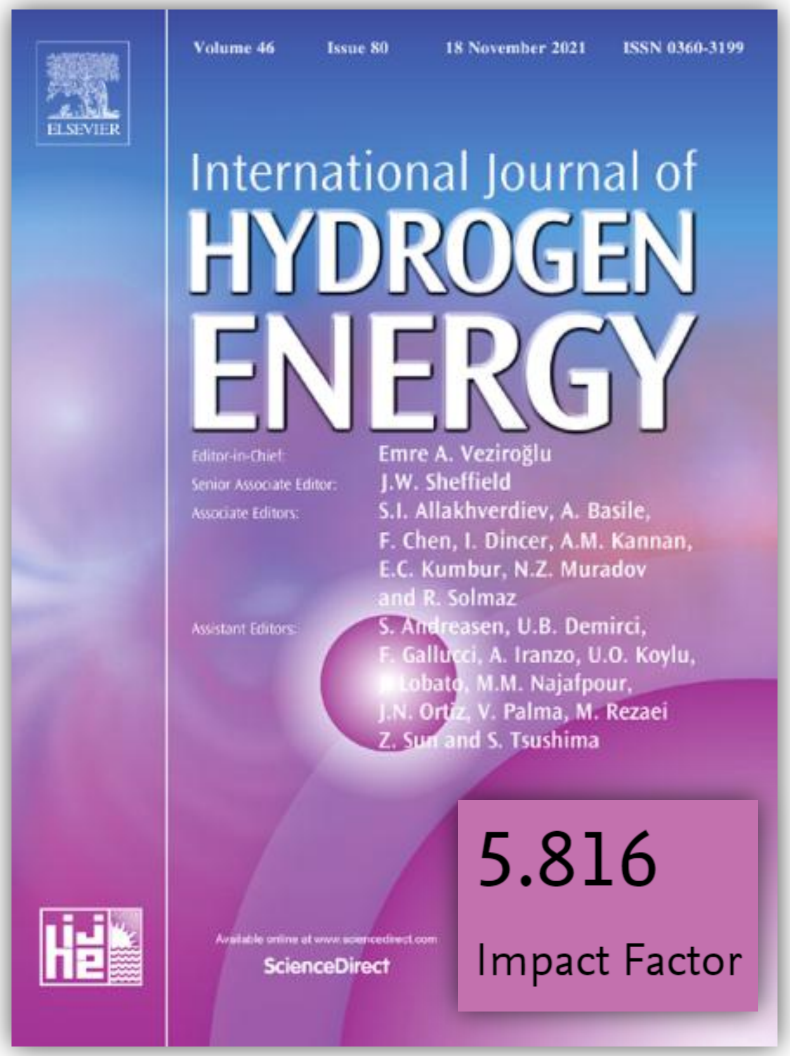

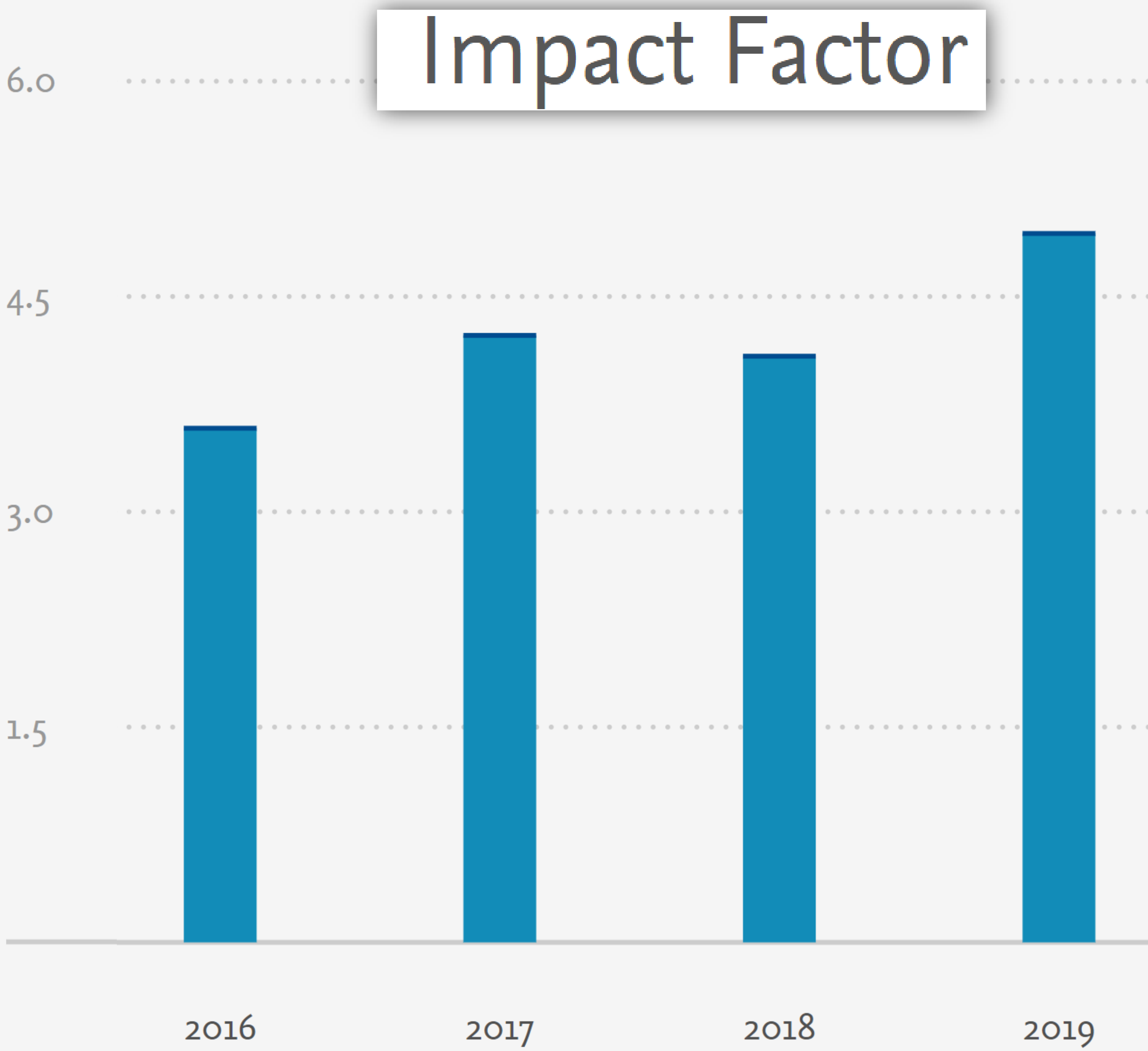

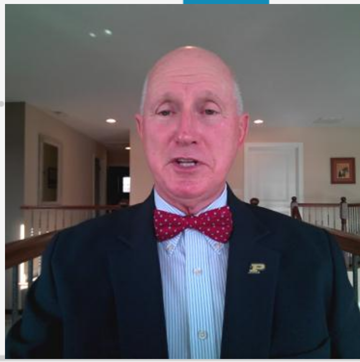

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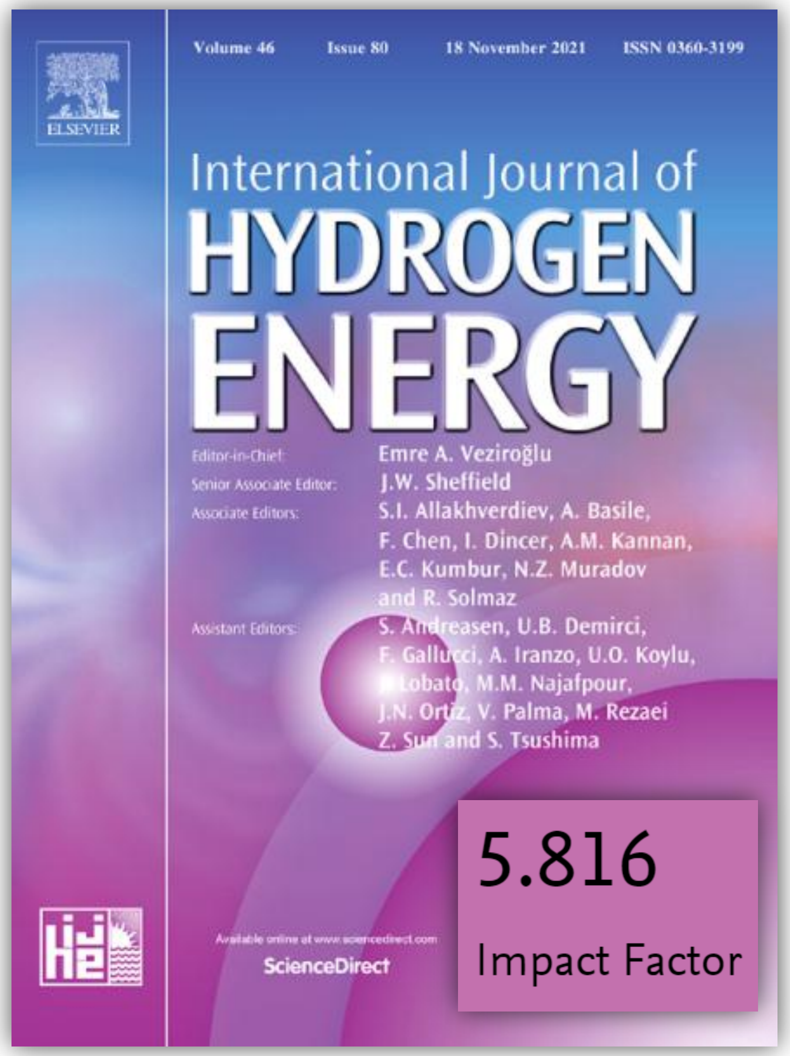
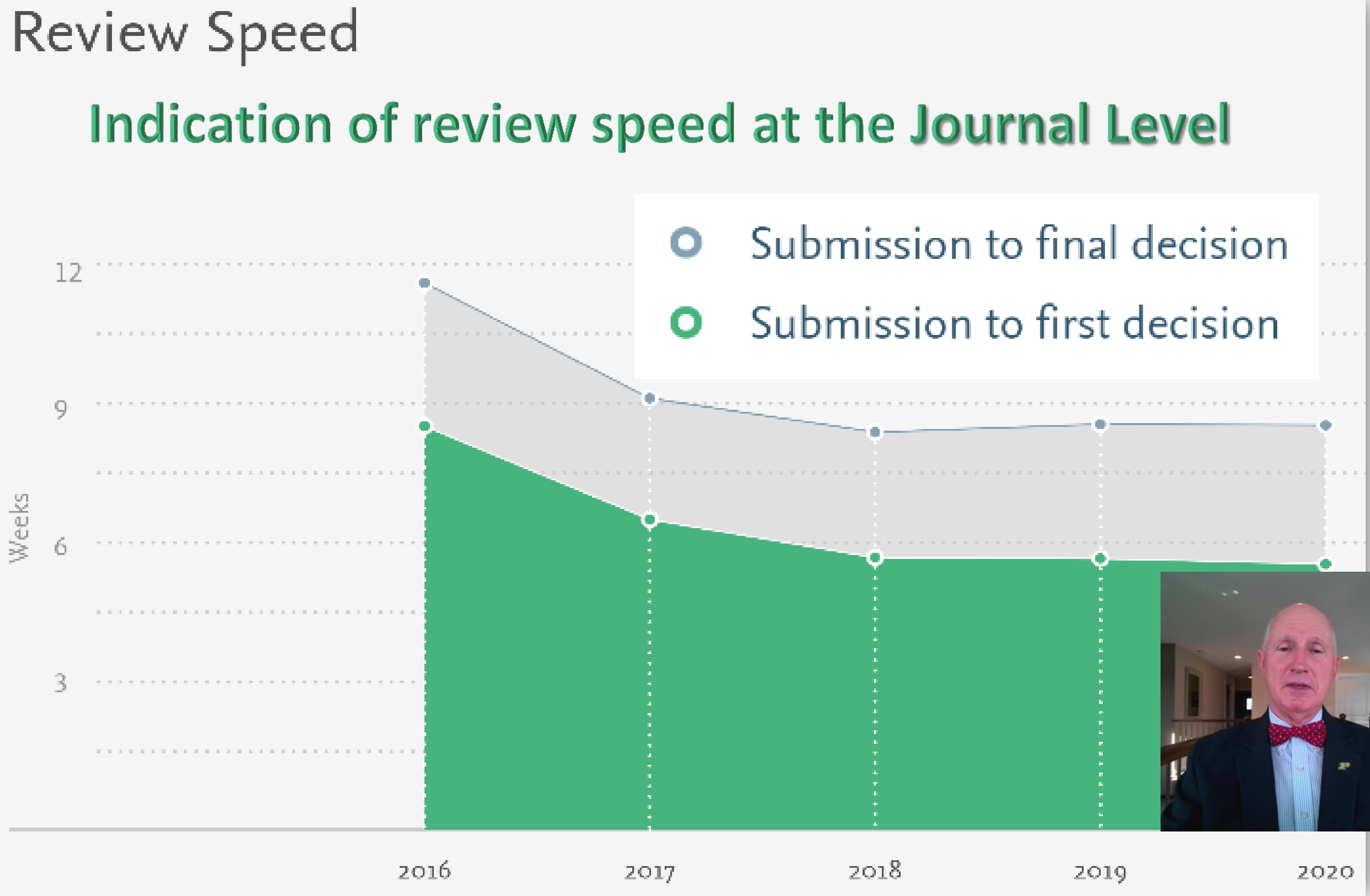
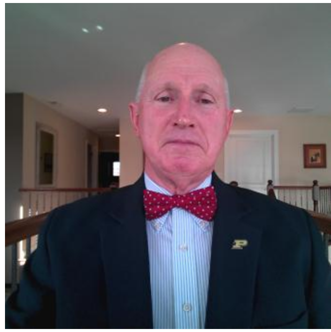




Hydrogen Council

The Hydrogen Council is a global CEO-led initiative of leading companies with a united vision and long-term ambition: for hydrogen to foster the clean energy transition for a better, more resilient future. Using its global reach to promote collaboration between governments, industry and investors, the Council provides guidance on accelerating the deployment of H_2 solutions around the world. It also acts as a business marketplace, bringing together a diverse group of 120+ companies based in 20+ countries and across the entire H_2 value chain, including large multinationals, innovative enterprises, and investors.



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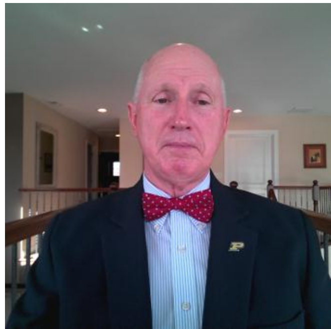
CEO COALITION TO COP26 LEADERS: HYDROGEN TO CONTRIBUTE OVER 20% OF GLOBAL CARBON ABATEMENT BY 2050– STRONG PUBLIC-PRIVATE COLLABORATION REQUIRED TO MAKE IT A REALITY

November 3, 2021 Articles, News, Press Releases



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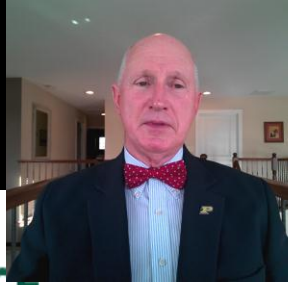

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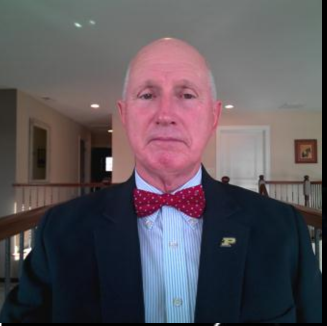

Global Hydrogen Energy Update

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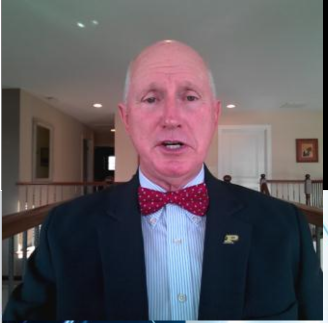

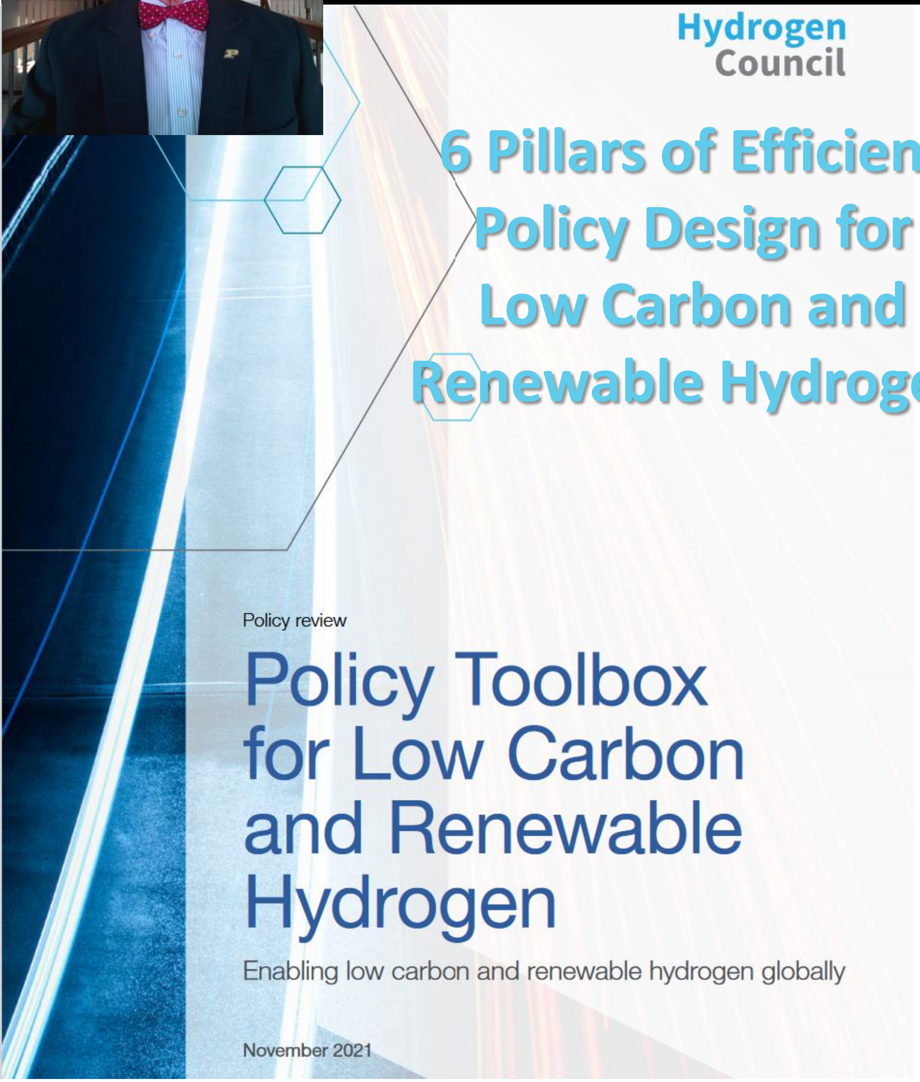

6 Pillars of Efficient Policy Design for Low Carbon and Renewable Hydrogen

1 Make use of local strengths & benefit from cross-border cooperation

Leveraging local strengths is an important starting point in policy design, which should be complemented by cross-border cooperation and trade to unlock efficiency gains.

2 Create certainty through targets and commitment

To drive down cost and attract investment, governments can create certainty through legislation, reducing policy risks and market uncertainty.

3 Provide hydrogen-specific support across the value chain

To catalyze and grow new markets, hydrogen-specific support is required across production, midstream infrastructure, and end-use sectors like industry and transport.

4 Support robust carbon pricing

Robust regional carbon pricing mechanisms should be built up from existing schemes, and work together with hydrogen-specific support to drive efficient and effective uptake in the longer term, whilst mitigating carbon leakage.

5 Adopt harmonized certification schemes

International standards and robust certification systems play a crucial role in the development of the hydrogen economy, enabling cross-border trade in hydrogen.

6 Factor in societal value and values

Societal value and values can be factored into policy decisions. Well-designed hydrogen policies can make a positive contribution to several UN Sustainability Development Goals.

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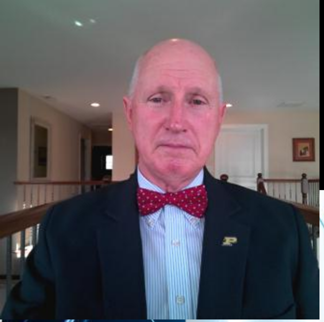

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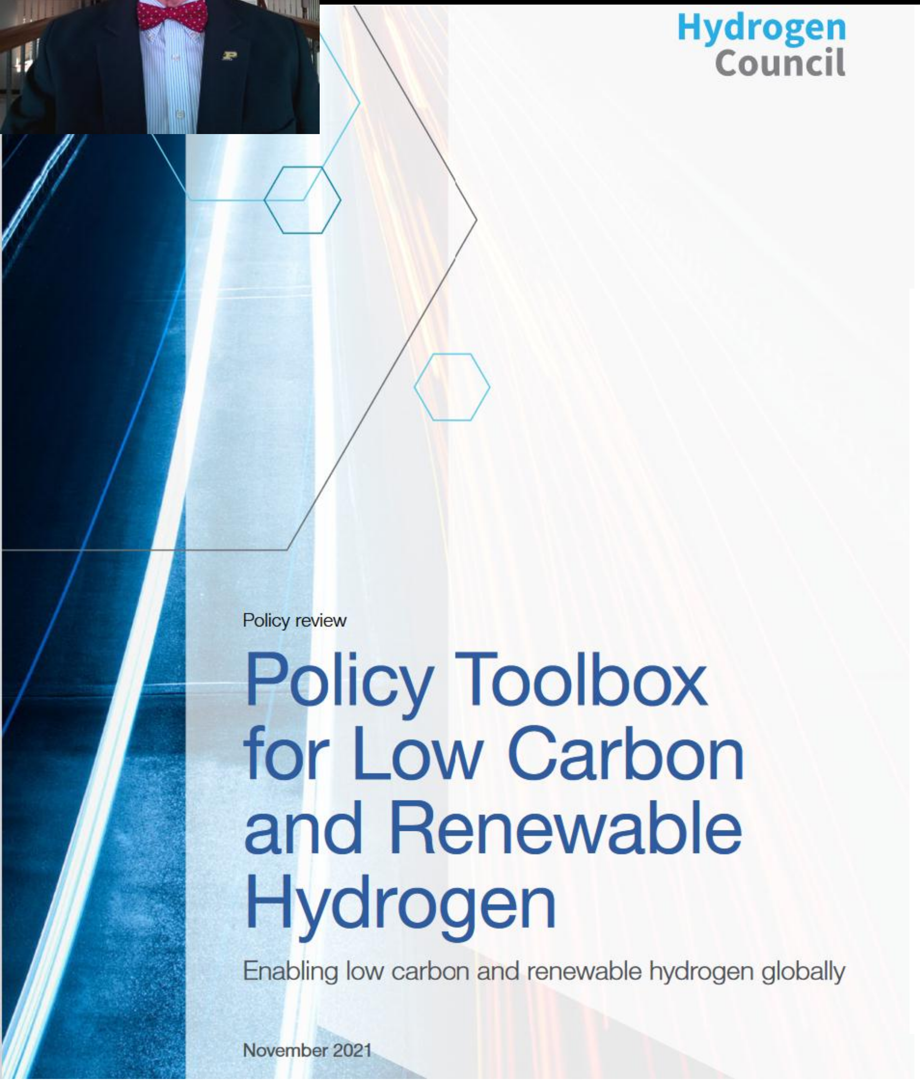

The Deployment & Financing Barriers are Concentrated in the First Two Market Maturity Phases

Time/maturity

H_2 value chain	Market cretation	Market growth	Market maturity
Enabling policies	A.1.1 Limited research, development, demonstration and deployment specific funding		
	A.1.2 Lack of standard methodologies and regulatory body to qualify[1] H_2 as renewable or low carbon, and certification systems to support the development of the H_2 market at international level		
	A.1.3 Lack of a regulatory/legal framework defining standards for H_2 technologies, applications, and H_2-derived products		
	A.1.4 Lack of H_2 strategy and societal acceptance as part of broader decarbonisation efforts resulting in uncertainties around future direction/low sectoral collaboration		

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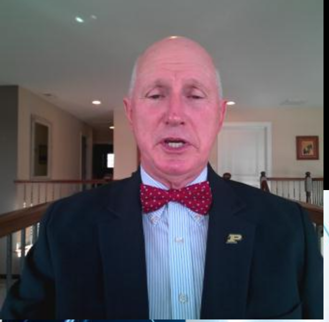

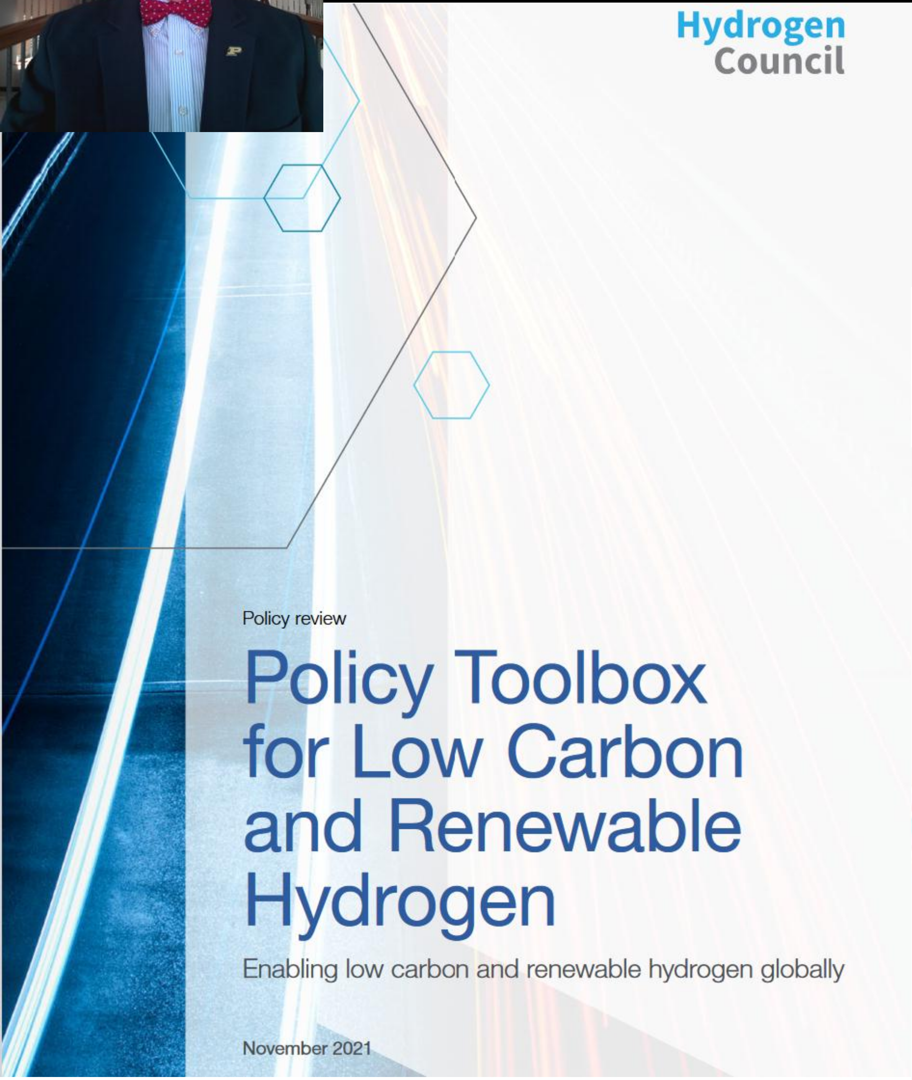
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Policy review

Policy Toolbox for Low Carbon and Renewable Hydrogen

Enabling low carbon and renewable hydrogen globally

November 2021

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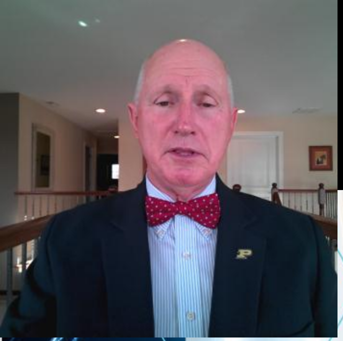
The Deployment & Financing Barriers are Concentrated in the First Two Market Maturity Phases

Time/maturity

H_2 value chain	Market cretation	Market growth	Market maturity
A Upstream supply	B.1.1 Locked-in to existing assets and fossil fuels (e.g., using coal/oil)	B.2.1 Inefficient subsidisation of unabated fossil fuels that encourages supply, e.g., carbon pricing	B.3.1. Unstable network and supply, including insufficient access to renewable energy and carbon capture and storage
	B.1.2 Limited physical access to required inputs, e.g., renewable electricity installations	B.2.2 Limited ability to recoup production costs, e.g., uncertain volumes and price	
	B.1.3 Low deployment of technology, e.g., electrolysers, carbon capture and storage	B.2.3 Low availability and high cost of capital	
	B.1.4 Limited investment due to long payback period and high risk		



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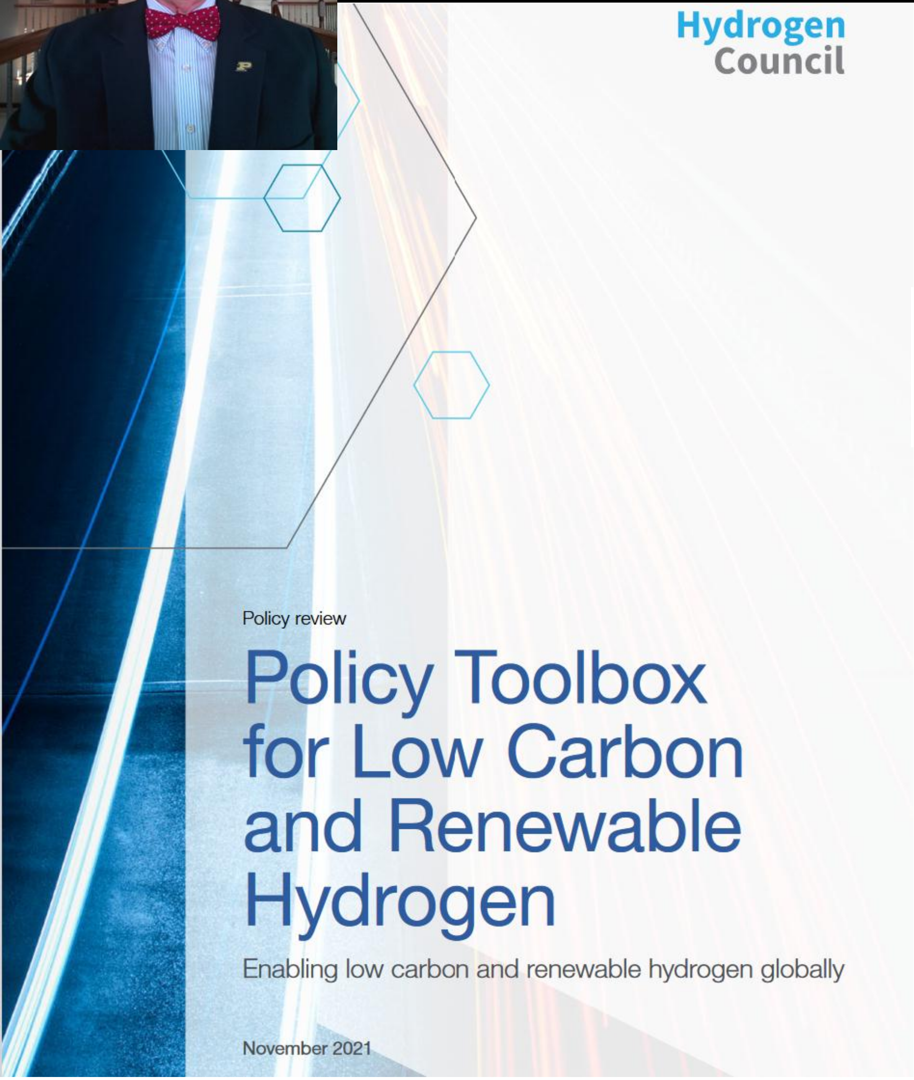

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The Deployment & Financing Barriers are Concentrated in the First Two Market Maturity Phases

Time/maturity

H_2 value chain	Market cretation	Market growth	Market maturity
B **Midstream transmission, distribution, and storage infrastructure**	C.1.1 Immature and/or inefficient storage options and development (incl. liability issues)	C.2.1 Lack of repurposing, retrofitting or building new infrastructure, e.g., pipeline, refueling stations, port facilities	C.3.1 Lack of reliable infrastructure, incl. last mile distribution infrastructure
	C.1.2 Lack of planning of H_2 infrastructure (e.g., transport, storage, HRS) resulting in delay in investment decision		C.3.2 Lack of monetisation of the flexibility (e.g., buffering, storage) that hydrogen will provide to the energy system
C **Downstream demand**	D.1.1 Locked-in to existing assets that do not use H_2, e.g., fleet	D.2.1 Limited demand-pull and uptake of H_2 in end-use sectors, e.g., industry, transport, buildings	
	D.1.2 Low availability, and technical and commercial viability of end use appliance for H_2, e.g., boilers	D.2.2 Lack of H_2 familiarity for offtakers, causes reluctance to adopt or need long lead time and cannot reach minimum viable scale	

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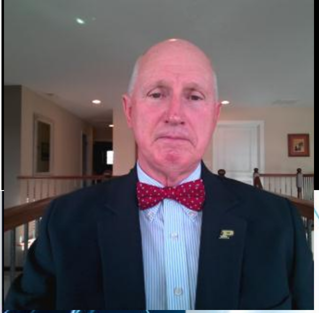

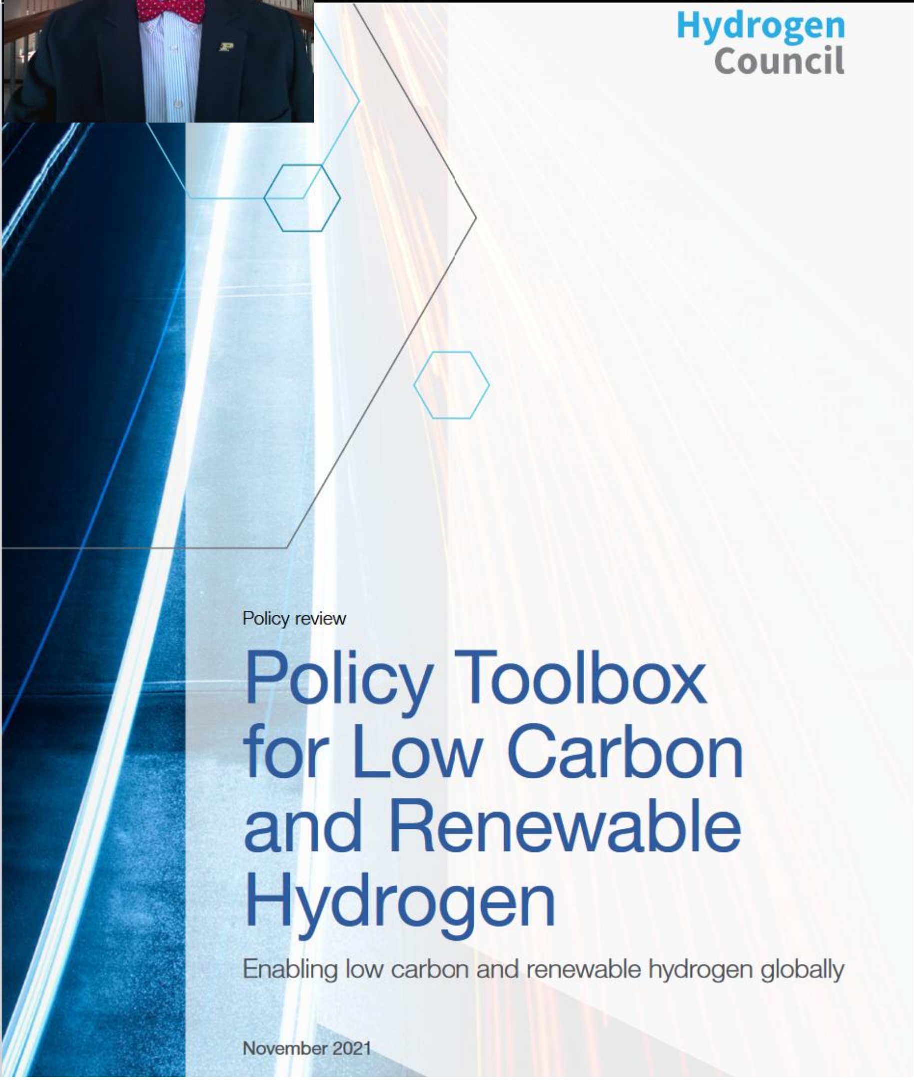

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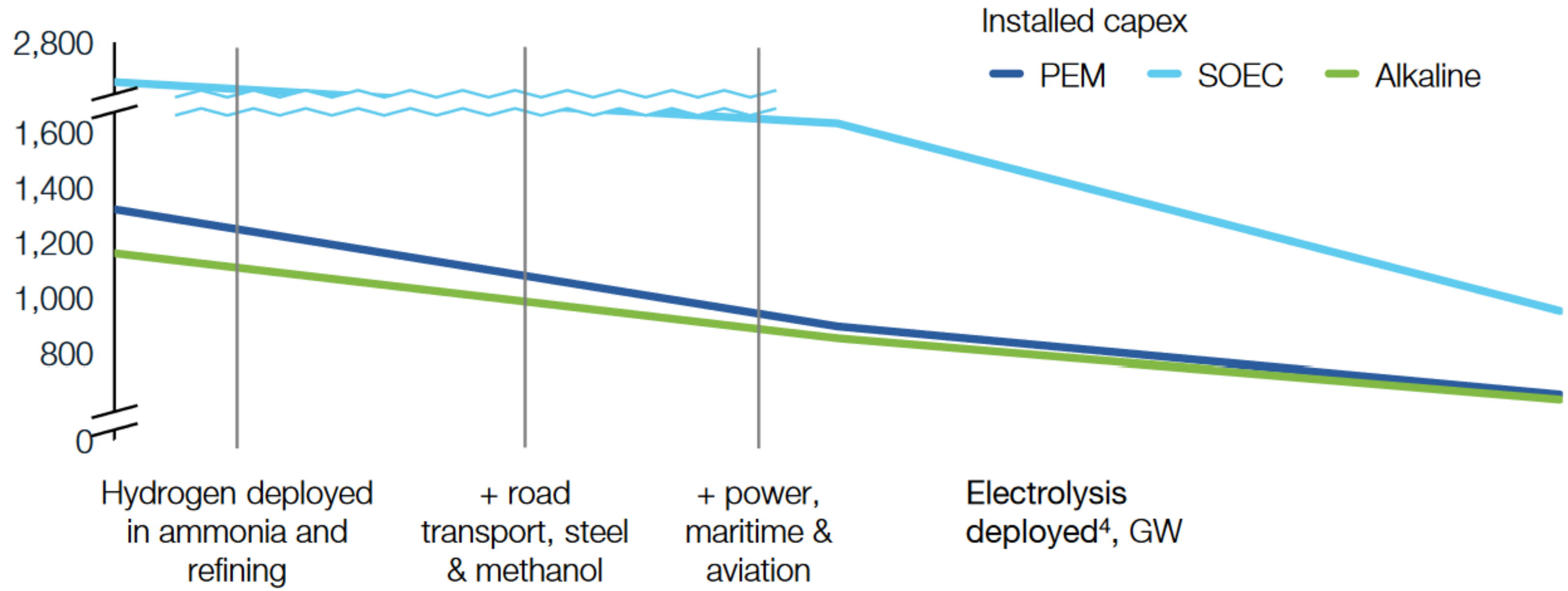
Electrolyzer CapEx[1] and Demand by Sector, USD/kW[2]



1. 2020-2030 modelled
2. USD/kW of hydrogen produced
3. Medium electrolysers (4000 Nm^3/h). Electrolyser CapEx defined as sum of: indirect costs, building CAapEx transportation to site, installation and assembly CapEx, system CapEx
4. Equivalent global demand

Source: ***Hydrogen Insights Project and Investment***

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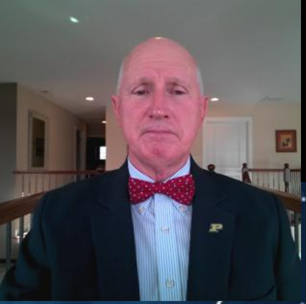

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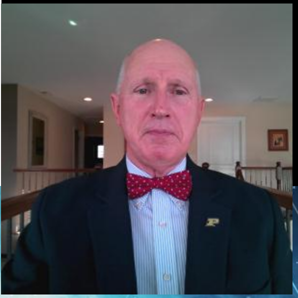

Hydrogen has a central role in helping the world reach net-zero emissions by 2050 and limit global warming to 1.5 °C. Complementing renewable energy technologies and enhanced energy efficiency improvements, clean H_2 offers the only long-term, scalable, and cost-effective option for deep decarbonization in sectors such as steel, maritime, aviation, and ammonia.

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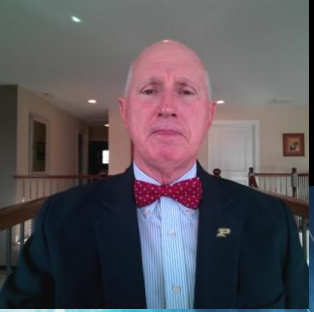

SCALING THROUGH 2030 IS CRITICAL FOR MEETING LONG-TERM TARGETS AND UNLOCKING COST-EFFICIENT DECARBONIZATION OPPORTUNITIES

Setting our energy system on a trajectory to net-zero requires firm commitment and rapid acceleration. It is estimated the deployment of 75 million metric tons of clean hydrogen is needed by 2030 – an ambitious, yet achievable target.

Hydrogen for Net-Zero
Hydrogen Council, McKinsey & Company

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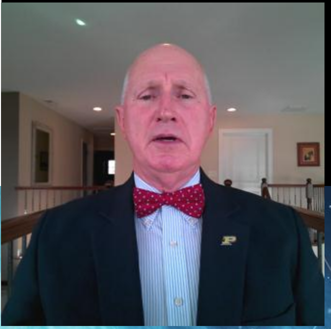

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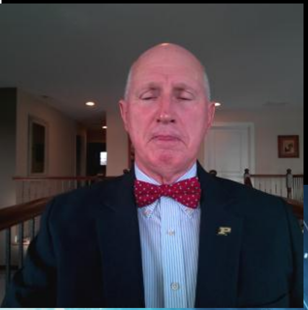
STRONG MOMENTUM,
BUT A $540 BILLION CAPITAL GAP REMAINS UNTIL 2030

The hydrogen industry shows strong momentum around the globe, with more than 520 projects announced in 2021, up 100% compared to 2020. These projects will produce 18 million metric tons of clean hydrogen supply, infrastructure and end-uses. Considering investments to achieve government targets and support equipment value chains, the total sum of estimated spending will grow to more than USD 600 billion by 2030.

Hydrogen for Net-Zero
Hydrogen Council, McKinsey & Company



Global Hydrogen Energy Update

Framing for 'Hydrogen for Net-Zero'

Focus

Hydrogen for Net Zero…

- Hydrogen demand and CO_2 abatement
- Current momentum
- Investments required & gap

Perspective on the role hydrogen can play in a Net Zero world 2050, and **highlight** (realistic) **steps that must be taken in the coming decade**

… is developing a ambitious, yet realistic, path to Net Zero in 2050

Current trajectory (BAU)	Hydrogen for Net Zero	Net Zero (Unconstrained)
Continuation of current trajectory and trends, with limited emission reduction - **we fail to meet the Paris targets**	**Ambitious, yet realistic, perspective** on hydrogen's role on the pathway to Net Zero in 2050 **in line with the Paris Accord**	**Techno-economic optimum** for 'what would need to happen', that is **unconstrained** by policy framework, supply chain limitations, and investments required

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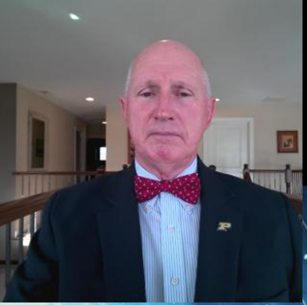
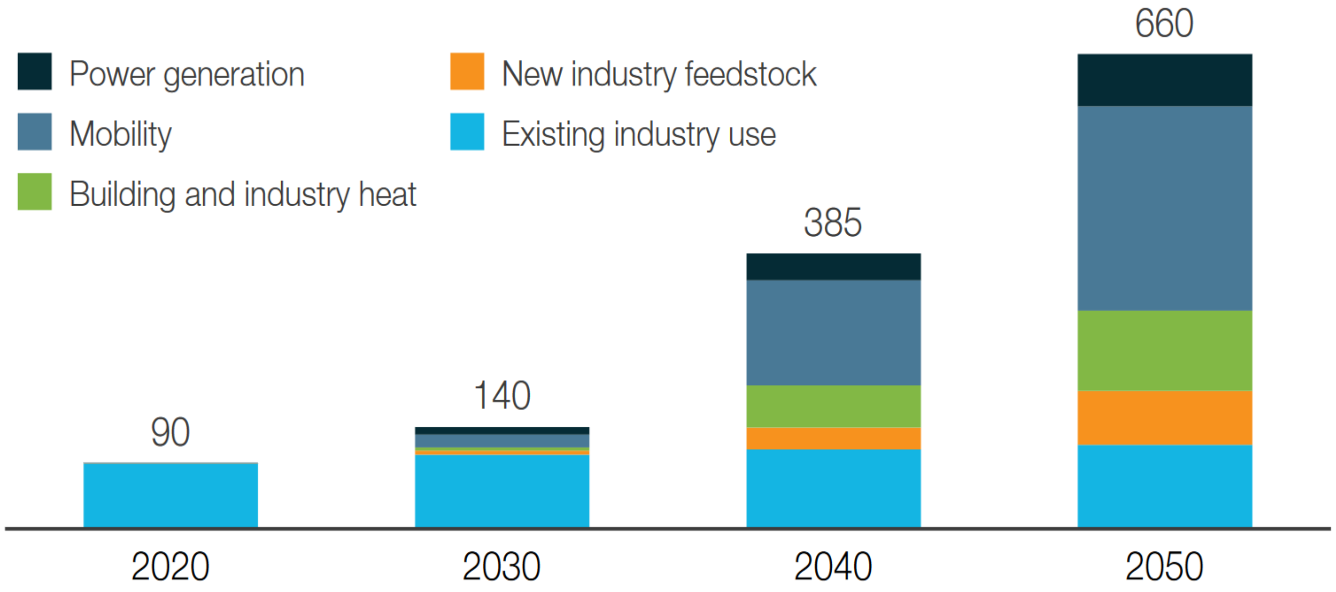


GLOBAL HYDROGEN DEMAND BY SEGMENT UNTIL 2050



660 MT
hydrogen required p.a. in 2050 for net-zero

22%
of global final energy demand[1]

Clean hydrogen is either renewable or low-carbon hydrogen.
Renewable hydrogen is produced from water electrolysis with renewable electricity.
Low-carbon hydrogen is produced from fossil fuel with carbon capture and storage.

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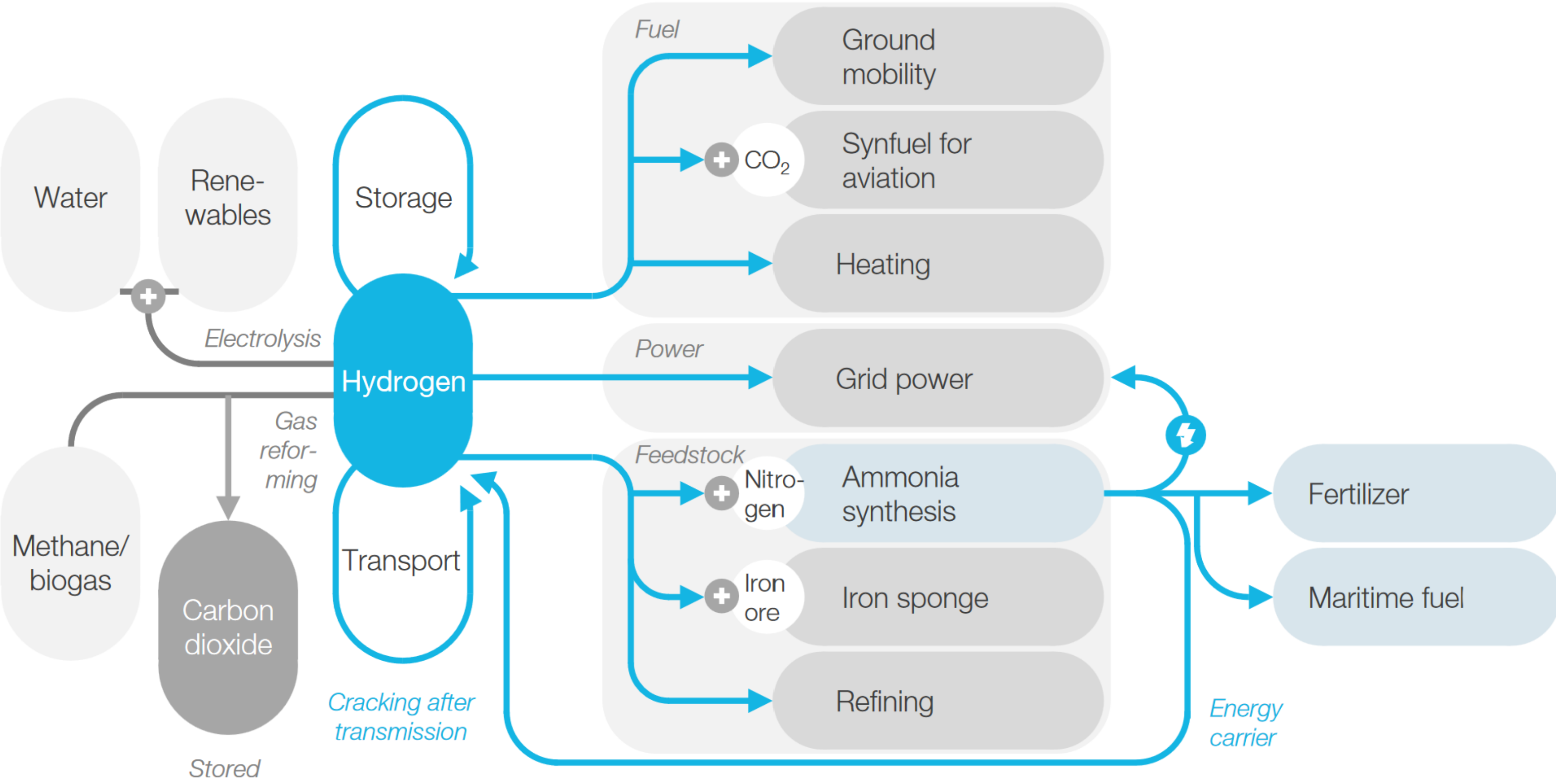
HYDROGEN PATHWAYS IN THE ENERGY SYSTEM: *SECTOR COUPLING*



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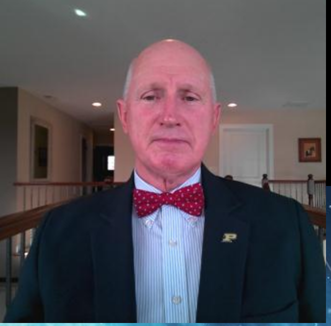

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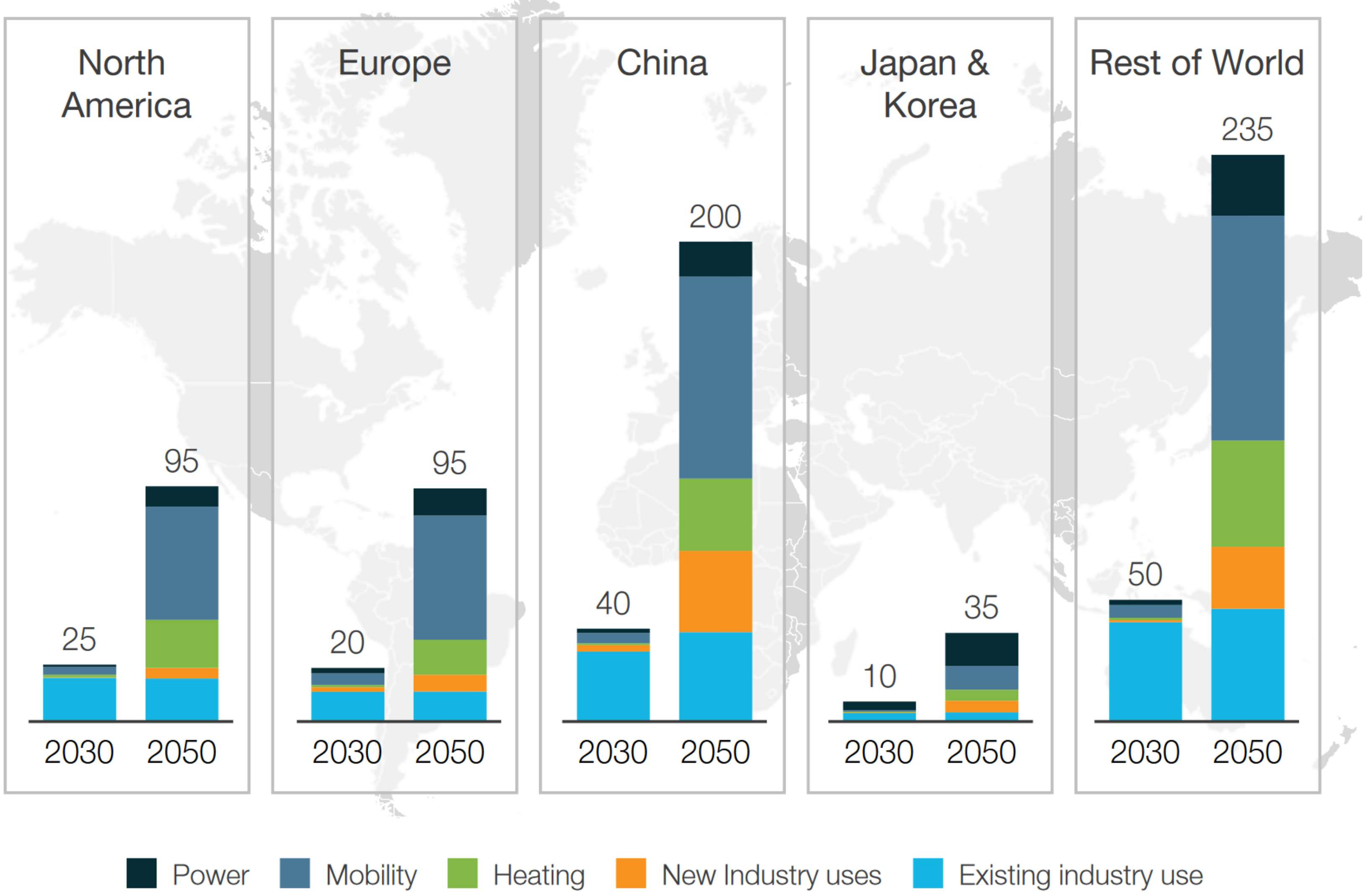
HYDROGEN END-USE DEMAND BY REGION (MT)



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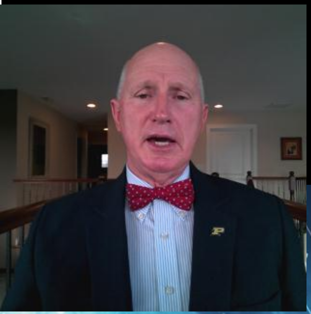
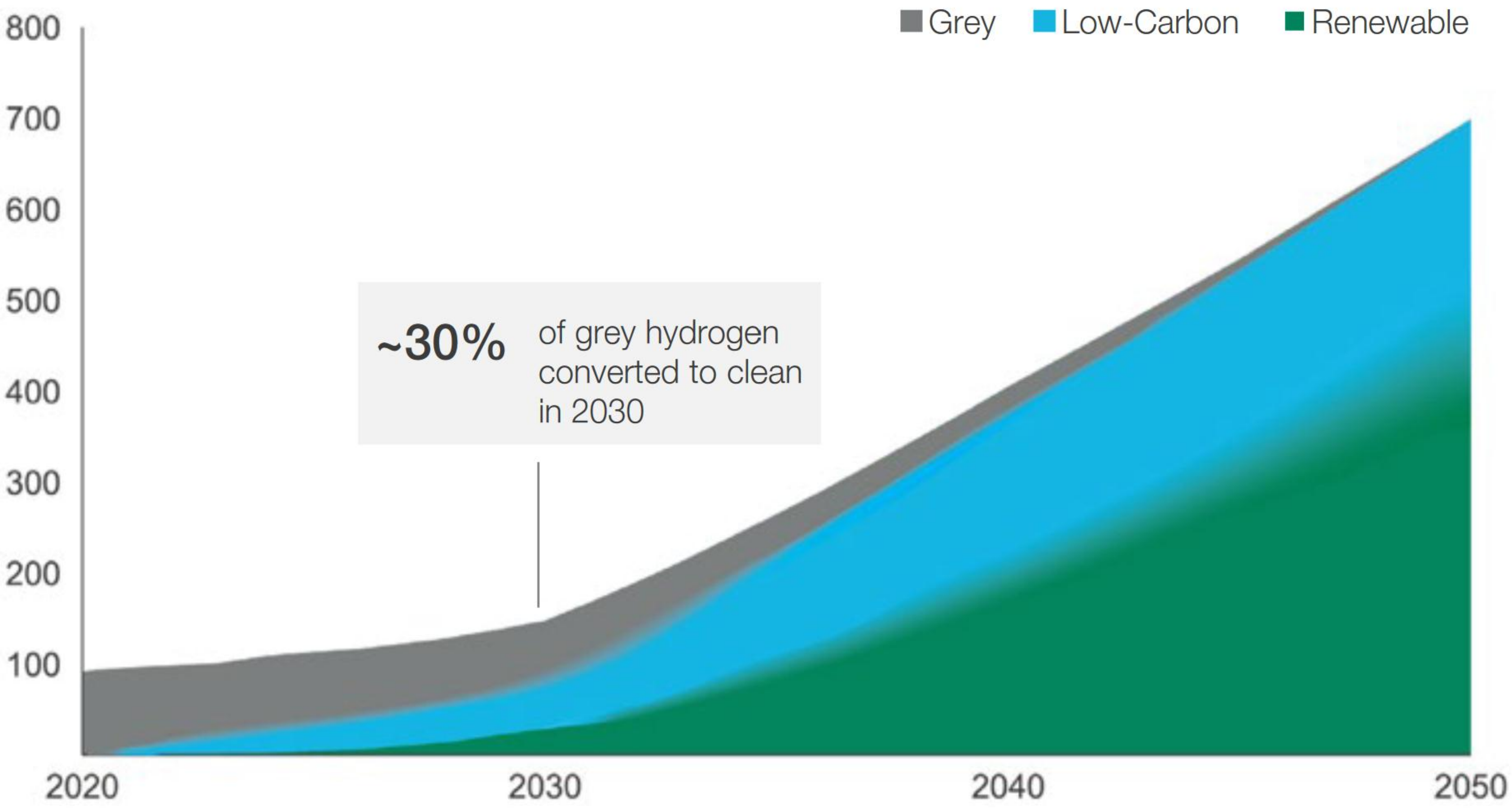


HYDROGEN SUPPLY MIX BY PRODUCTION METHOD (MT)



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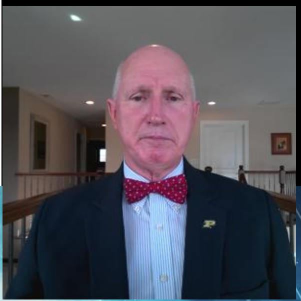

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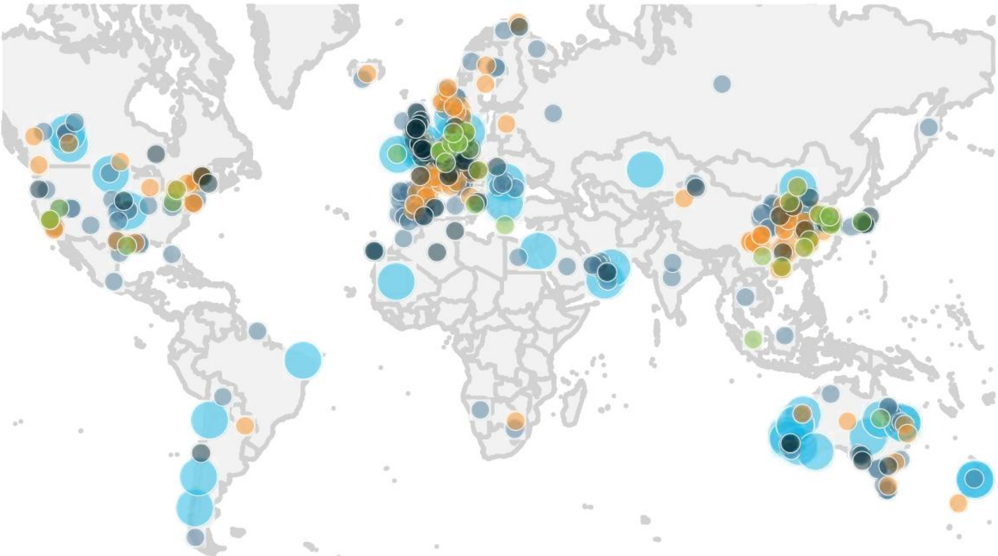
HYDROGEN PROJECT ANNOUNCEMENTS



50-100% increase since last January report

100+% increase since last January report

522	Announced MW-scale projects[1]
261	Europe
121	Asia and China
67	North America
43	Oceania
10	Latin America
20	Middle East and Africa

43 – Giga-scale production: Renewable hydrogen projects >1 GW, low-carbon hydrogen projects >200 ktpa

221 – Large-scale industrial usage: Refinery, ammonia, methanol, steel, and industry feedstock

133 – Transport: Trains, ships, trucks, cars and other hydrogen mobility applications

74 – Integrated hydrogen economy: Cross-industry, and projects with different types of end-uses

51 – Infrastructure projects[2]: Hydrogen distribution, transportation, conversion, and storage

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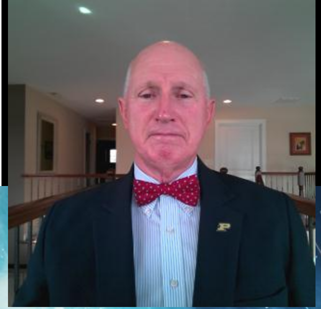

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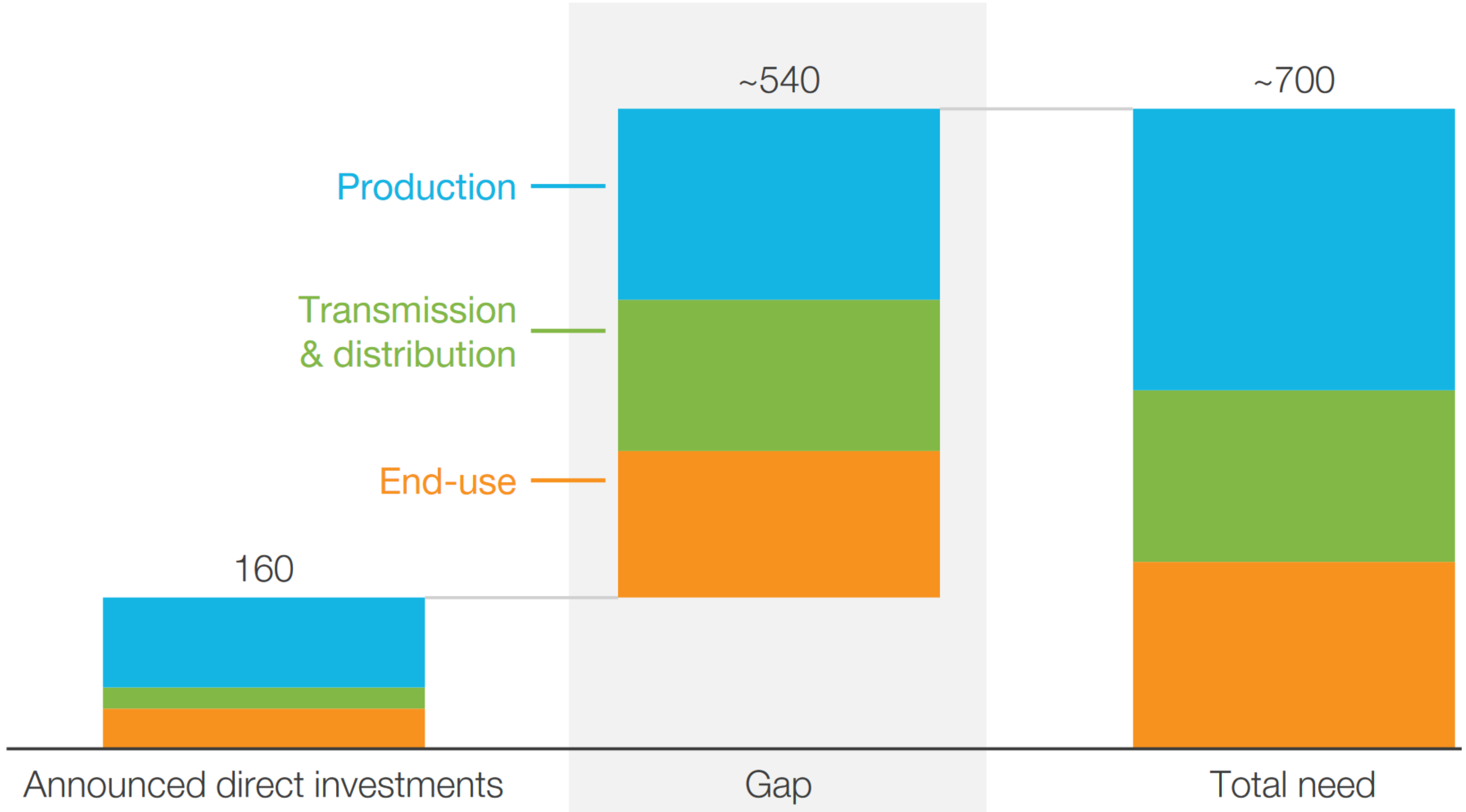
INVESTMENT GAP IN HYDROGEN VALUE CHAIN

Announced and required direct investments into hydrogen
USD billion until 2030



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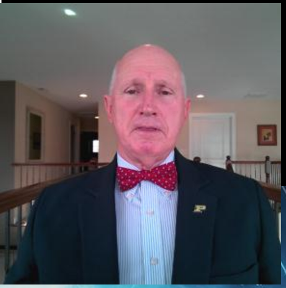

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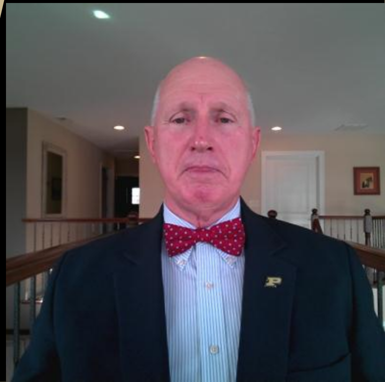
HYDROGEN MUST BE UNLOCKED AND SCALED

Create demand
Incentivize decarbonization through clean hydrogen

Ensure access
Make hydrogen accessible through the right infrastructure

Lower cost
Create economies of scale to reduce cost and open new markets

Thank you



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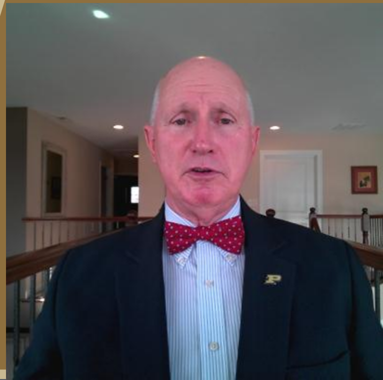

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