



HEC Hydrogen Sessions

Producing Hydrogen with Electrolysis

June 11, 2021

Brad Bradshaw
President, Velerity
President, Hydrogen Energy Center
brad@velerity.com

Agenda

Hydrogen Energy Center

Velerity

Clean Hydrogen Demand

Electrolyzer Demand

Types of Electrolyzers

Electrolyzer Economics

Gigawatt Factory Announcements

Illustrative Product Offerings

Hydrogen Energy Center

HEC is a nonprofit professional society focused on accelerating the hydrogen as an enabling solution for renewable energy

HEC provides public forums, conducts research and implements projects focused on accelerating the clean energy future

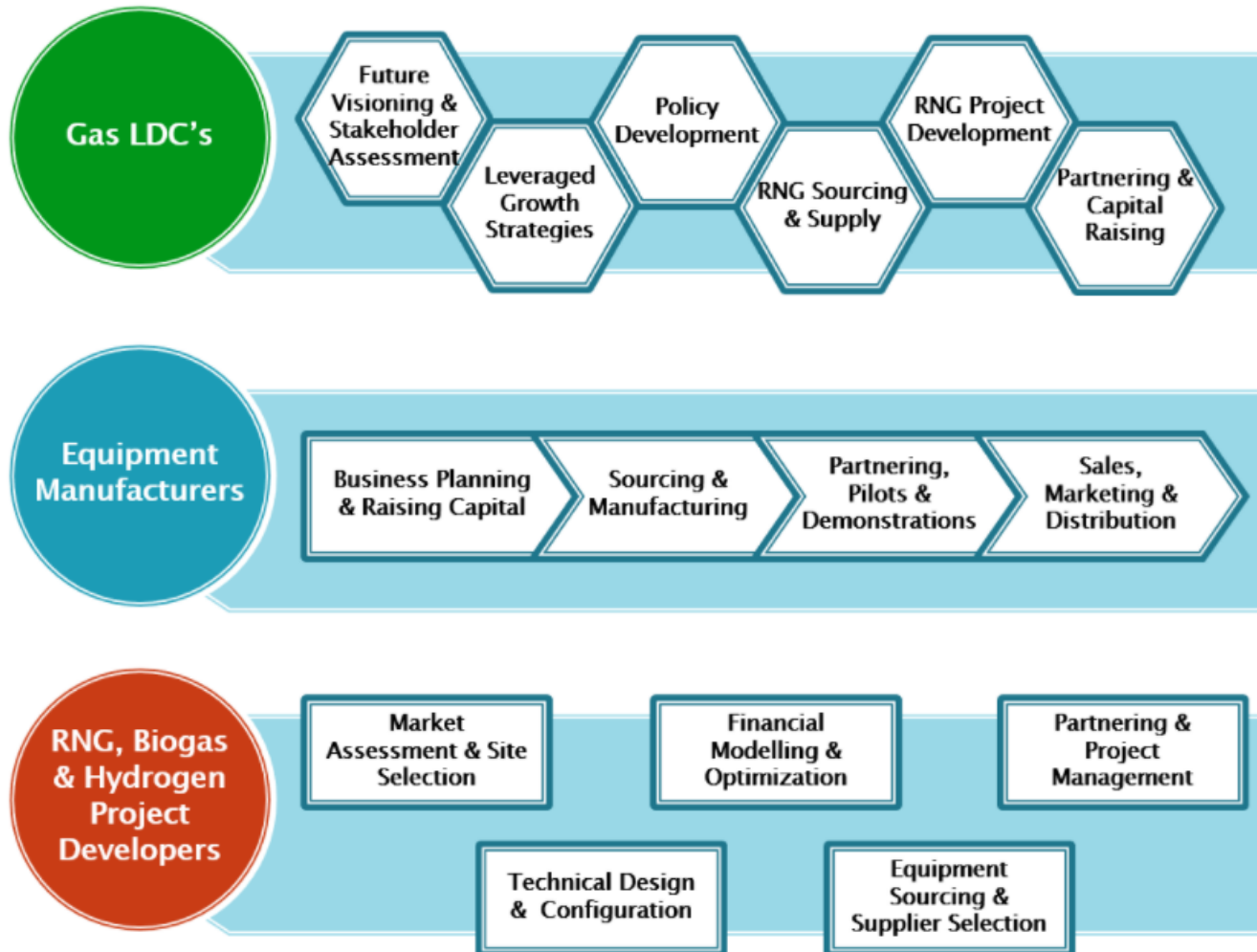
Consider supporting this important effort by becoming a member:

- Influence the course of renewable hydrogen energy technology and policy.
- Be a part of projects that really build hydrogen solutions.
- Have full access to white papers, technical reports, and meeting minutes from our projects and from other organizations.
- Immerse yourself in the hydrogen "goings-on" by connecting with developments & networking with people who are collectively driving the hydrogen "bus".

Upcoming Hydrogen Sessions

- ▶ June 11, 2021 Sources of Hydrogen: Electrolysis
- ▶ June 25, 2021 Hydrogen Production with Carbon Separation
- ▶ July 2, 2021 Wind to Hydrogen

Velerity Services



Velerity – Illustrative Clients



Future hydrogen demand

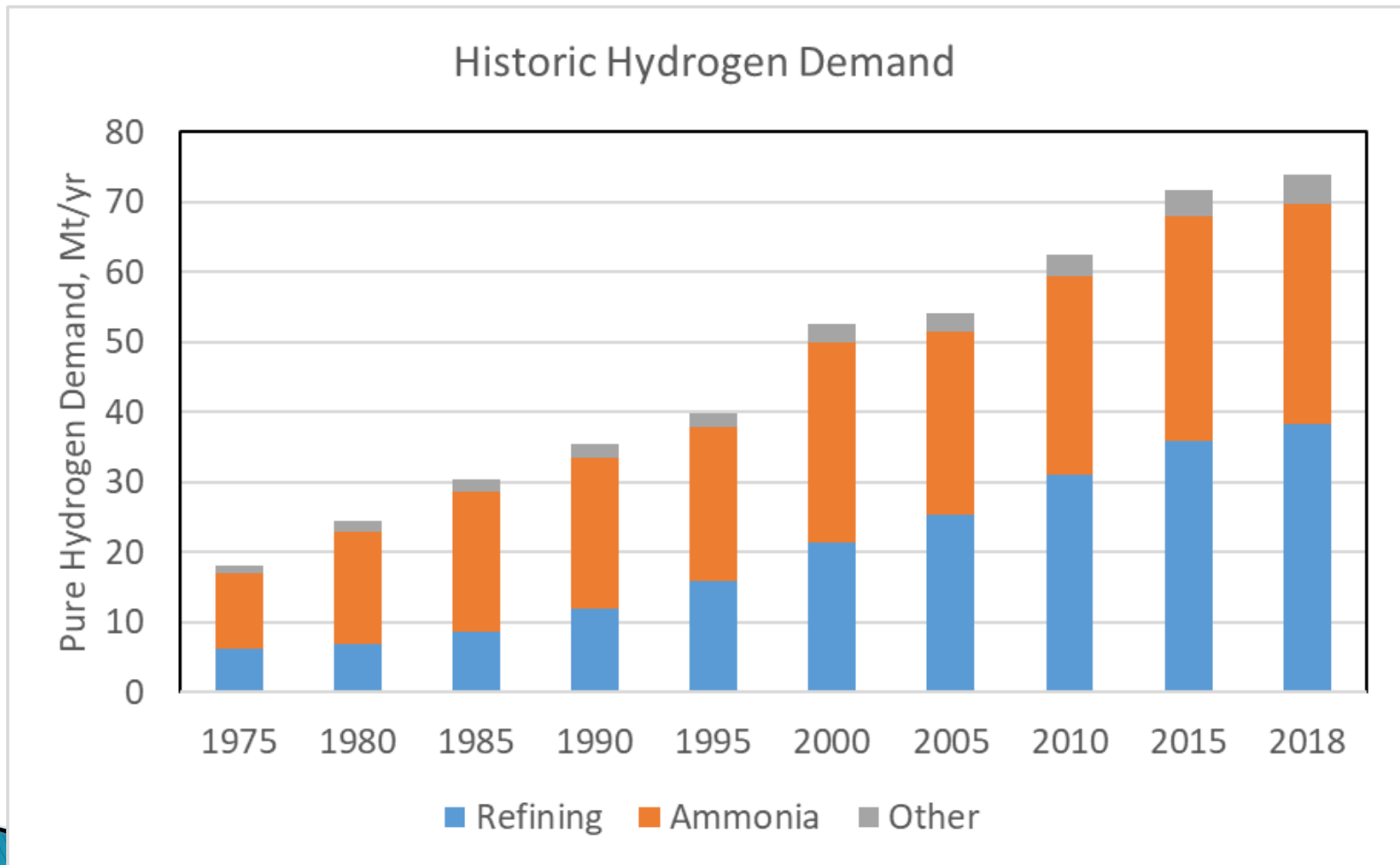
Demand for hydrogen in the US could reach as much as 41 million mt/year by 2050, a four-fold increase compared with the present - NREL

Hydrogen is going to take 25% of all oil demand by 2050 - Bank of America

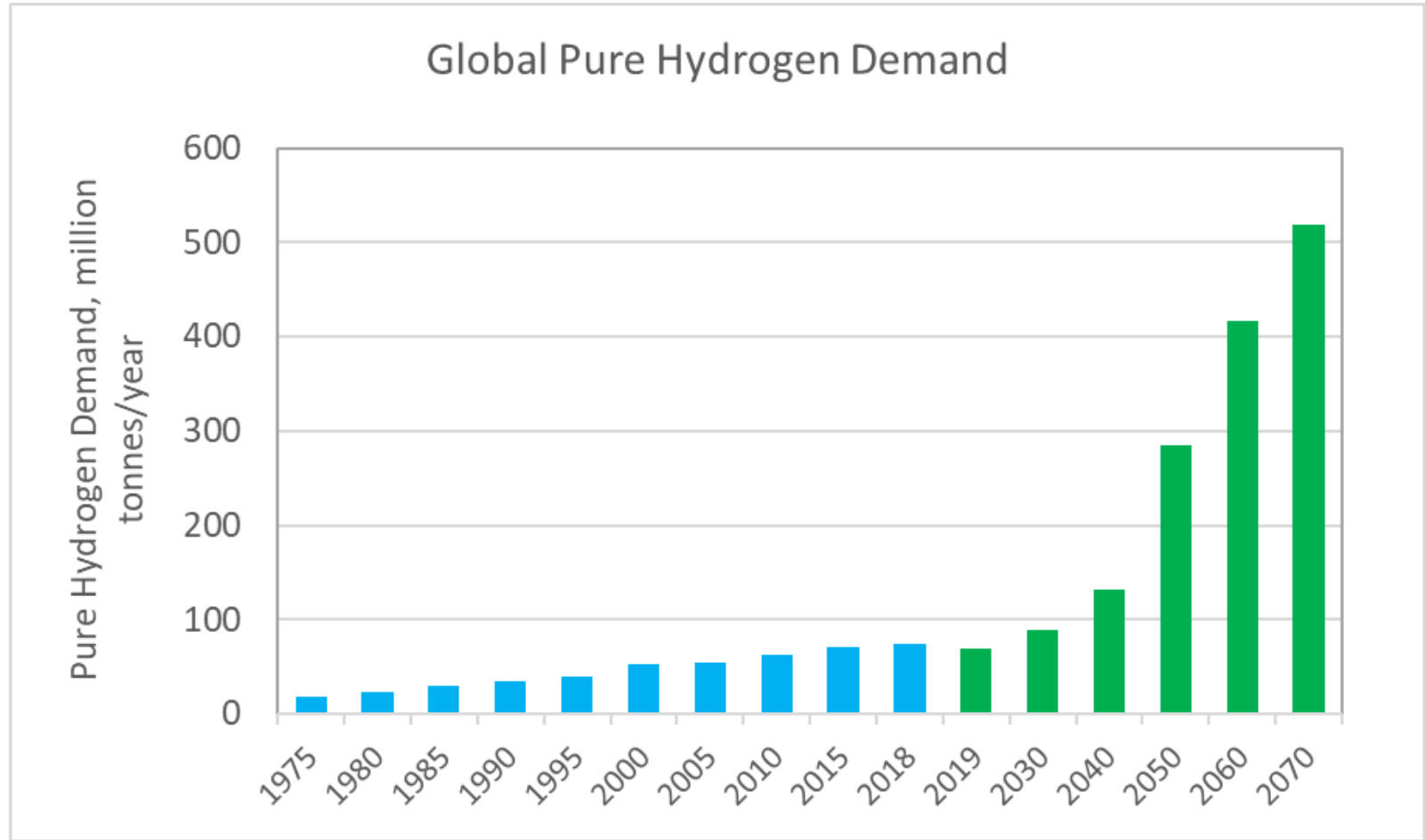
The EU has laid out plans to install 40 gigawatts of renewable hydrogen electrolyzers and produce as much as 10 million metric tons of renewable hydrogen by the year 2030 - European Commission

Global Green Hydrogen Production Set to Reach 5.7 Million Tons by 2030. a compound annual growth rate (CAGR) of 57% between 2019 and 2030, rising from 40,000 tons to 5.7 million tons - Frost & Sullivan

Historic Hydrogen Demand

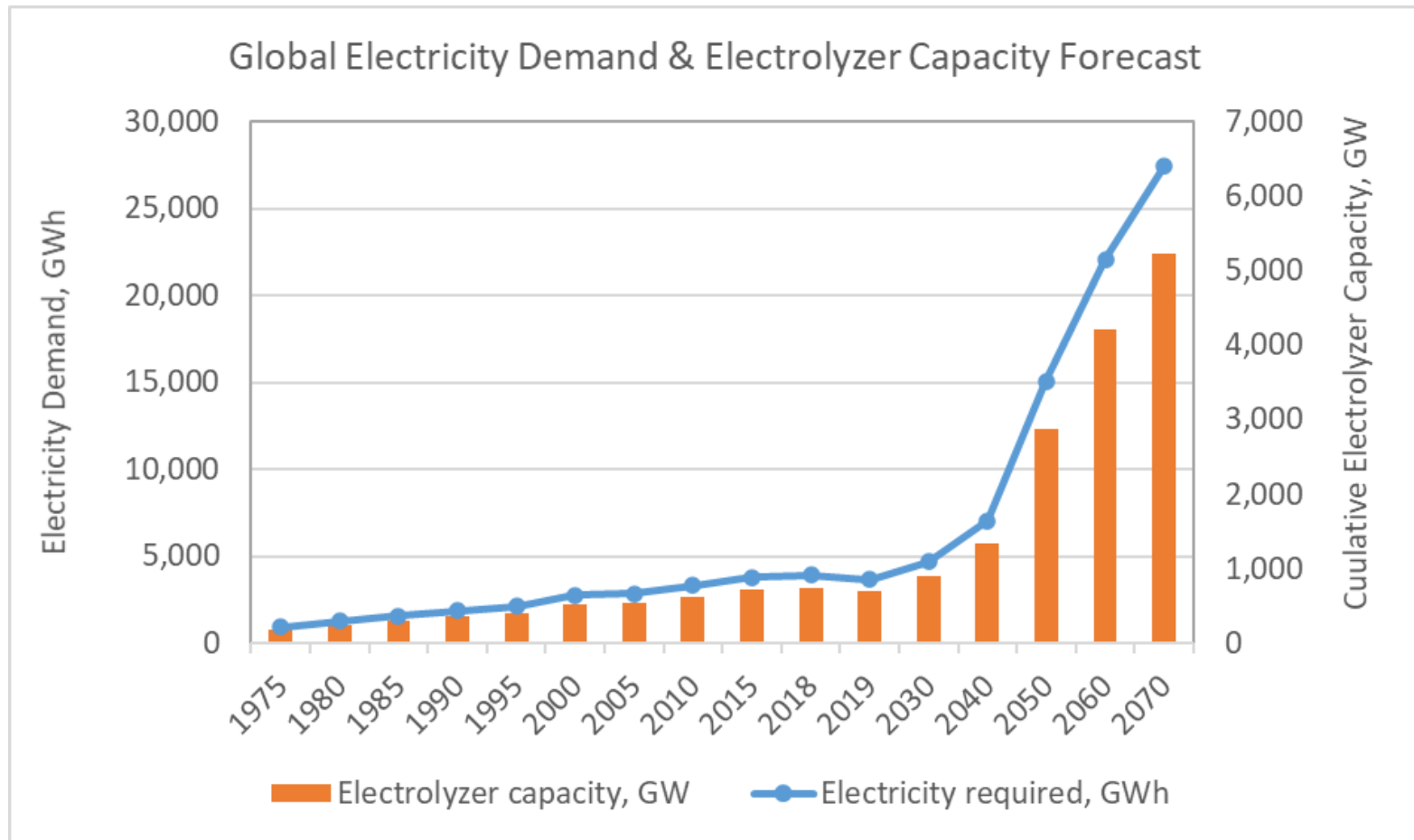


Future clean hydrogen demand dwarfs historic demand of all industrial hydrogen sales



Source: Energy Technology Perspectives 2020, IEA

Expansion of clean hydrogen is going to drive extraordinary demand for electrolyzers



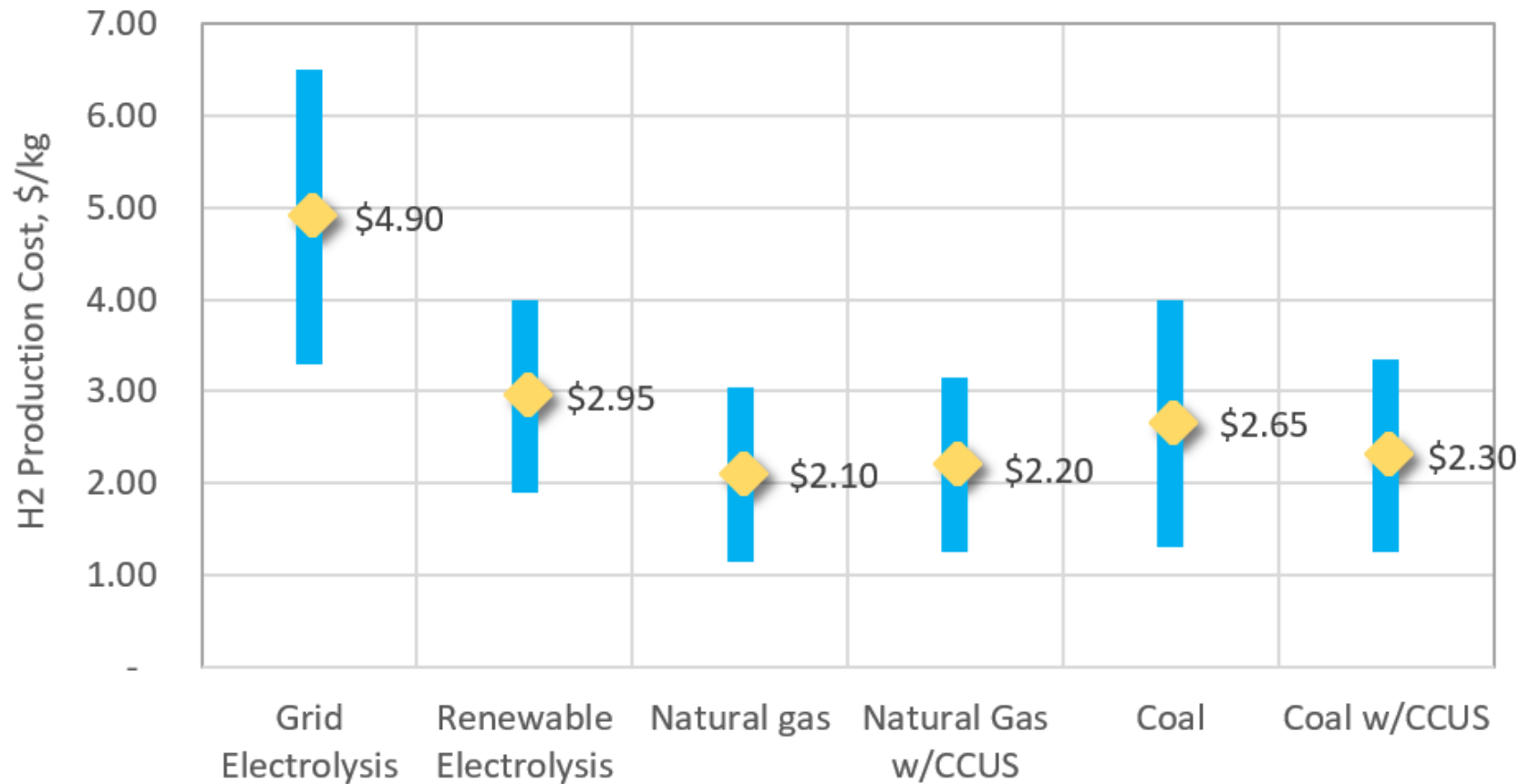
Types and Characteristics of Electrolyzers

| | Alkaline | PEM | Solid Oxide |
|----------------------------------|-----------|-------------|-------------|
| Electrical Efficiency | | | |
| 2020 | 63-70% | 56-60% | 74-81% |
| 2030 | 65-71% | 63-68% | 77-84% |
| Long Term | 70-80% | 67-74% | 77-90% |
| Operating Temperature, °C | 60-80 | 50-80 | 650-1,000 |
| Cap Ex, \$/kW | | | |
| 2020 | 500-1,400 | 1,100-1,800 | 2,800-5,600 |
| 2030 | 400-850 | 650-1,500 | 800-2,800 |
| Long Term | 200-700 | 200-900 | 500-1,000 |

Source: The Future of Hydrogen, IEA, June 2019

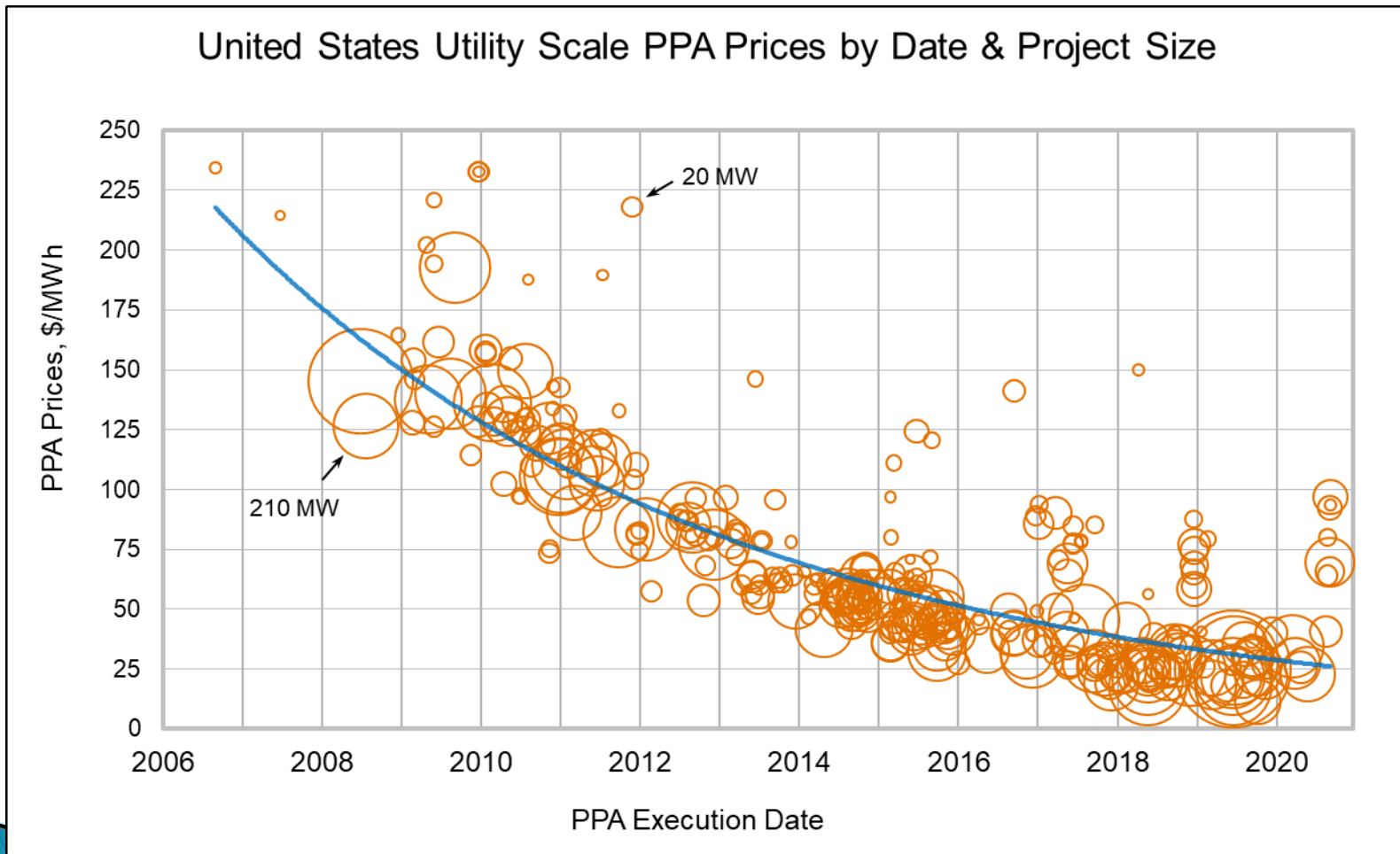
Hydrogen costs using different production methods

Fully Loaded Hydrogen Production Costs

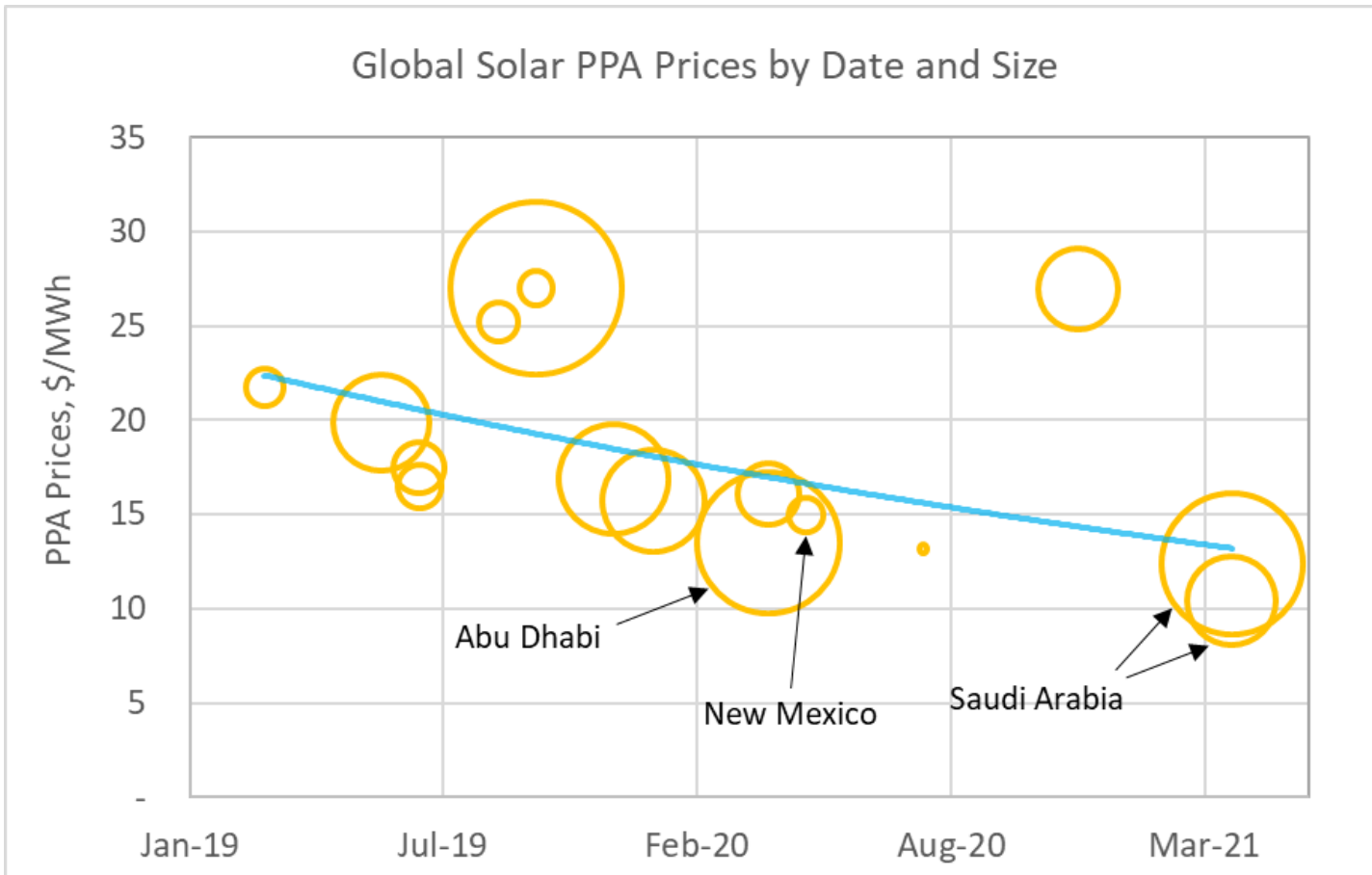


Source: The Future of Hydrogen, IEA

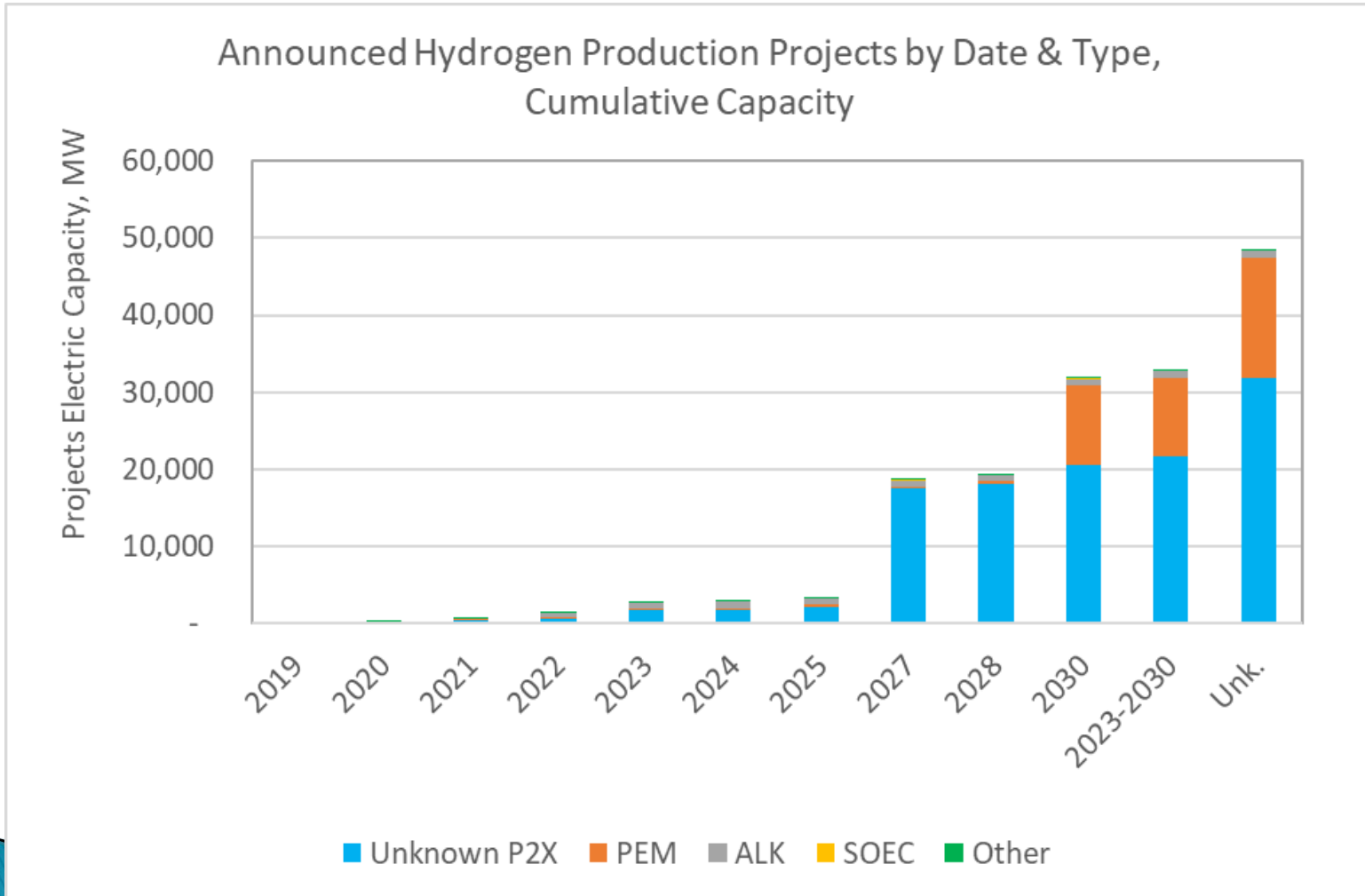
A fundamental driver creating an opportunity for hydrogen is the extraordinary drop in PPA prices



Globally, PPA prices for solar are nearing 1 cent per kWh, implying marginal cost of hydrogen production at 50 cents per kilogram



Electrolyzer project announcements



Major Electrolyzer Factory Announcements

Nel ASA

- ▶ Porsgrunn, Norway
- ▶ Alkaline
- ▶ 360 MW/year
- ▶ Later upgraded to 1,000 MW/year

Haldor Topsoe

- ▶ Lyngby, Denmark
- ▶ Solid Oxide
- ▶ 500 MW/year – expand to 5 GW/year

ITM Power

- ▶ Sheffield, England
- ▶ PEM
- ▶ Operational at up to 1,000 MW/year
- ▶ Second gigawatt factory fully funded

Rotterdam

- ▶ Castilla-La Mancha, Spain
- ▶ PEM
- ▶ 500 MW/year scalable to more than 1 GW/year

Nel ASA – Electrolyzer Products

▶ Background

- Founded in 1927
- 3,500 electrolyzers installed around the world

| Product | Type | Production | Efficiency |
|----------|----------|-------------------|-------------|
| A Series | Alkaline | Up 8 tons per day | 3.8 kWh/NM3 |
| M Series | PEM | Up to 4,000 NM3/h | |
| C Series | PEM | Up to 30 NM3/h | |
| H Series | PEM | Up to 6 NM3/h | |

ITM Power – Electrolyzer Products

| Product | Type | Stacks | Production | Capacity |
|---------|------|--------|----------------|----------|
| HGasXMW | PEM | 15 | 4,050 kg/24 hr | 10.07 MW |
| HGas3SP | PEM | 3 | 36 kg/h | 2.35 MW |
| HGas2SP | PEM | 2 | 22 kg/h | 1.39 MW |
| HGas1SP | PEM | 1 | 11 kg/h | 0.7 MW |

Cummins – Electrolyzer Products

| Product | Type | Production | Capacity | Efficiency |
|------------------|----------|------------------------|----------|-------------------------------|
| HySTAT 60-10 | Alkaline | 60 Nm ³ /h | 300 kW | 5.0 – 5.4 kWh/Nm ³ |
| HySTAT-100-10 | Alkaline | 100 Nm ³ /h | 500 kW | 5.0 – 5.4 kWh/Nm ³ |
| HyLYZER-1,000-30 | PEM | 1,000 Nm ³ | 5 MW | 4.4 – 4.8 kWh/Nm ³ |
| HyLYZER-5,000-30 | PEM | 5,000 Nm ³ | 25 MW | 4.4 – 4.8 kWh/Nm ³ |

MAN Energy Solutions – H-TEC – Electrolyzer Products

| Product | Type | Production | Capacity | Efficiency |
|-----------------------|------|--------------------------------|--------------|-------------------------|
| Series-S | PEM | 0.22 – 1.10 Nm ³ /h | 1 – 5 kW | |
| Series-ME ME 100/350 | PEM | 13 – 66 Nm ³ /h | 40 – 330 kW | 4.9 kWh/Nm ³ |
| Series-ME ME 450/1400 | PEM | 25 – 210 Nm ³ | 0.2 – 1.4 MW | 4.9 kWh/Nm ³ |