Beyond Power:
Opportunities and Challenges for Green Hydrogen

GREEN HYDROGEN COALITION

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CEO, Strategen
Founder and President
Green Hydrogen Coalition
October 2020

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YOUR PARTNER IN THE ENERGY TRANSITION

- Low Carbon System Planning
- Clean Technologies Expertise
- Regulatory & Policy Design
- Stakeholder Management
- Value Proposition Design
- Modeling & Analytics

CESA
CALIFORNIA ENERGY STORAGE ALLIANCE

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VGIC
VEHICLE-GRID INTEGRATION COUNCIL

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"Climate change is the defining issue of our time
and we are at a defining moment."
Antonio Guterres
United Nations Secretary General
Photo credit: Associated Press, September 18, 2020


Green Hydrogen is a super gamechanger
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HYDROGEN
COALITION

About Green Hydrogen Coalition

MISSION:

Facilitate policies and practices to advance the production and use of Green Hydrogen in all sectors where it will accelerate a carbon free energy future

APPROACH:

Prioritize Green Hydrogen project deployment at scale; leverage multi-sector opportunities to simultaneously scale supply and demand

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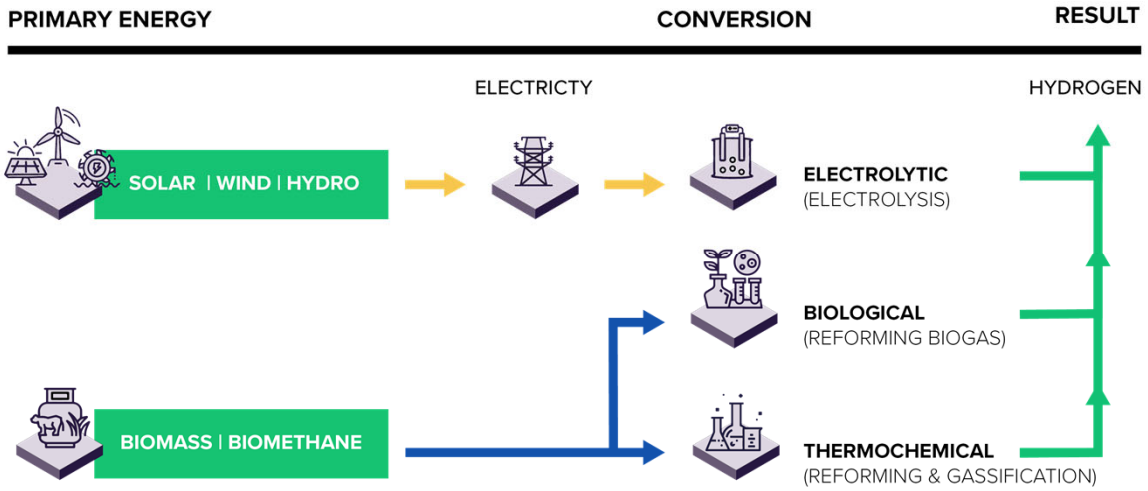
6

There are many ways to make Green Hydrogen...



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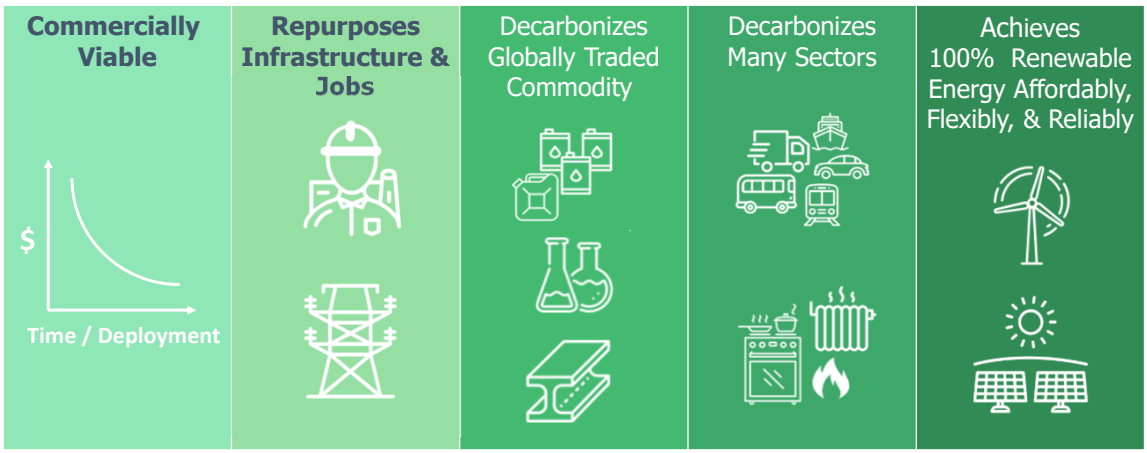
...which are zero net emission

7

Why Green Hydrogen is a Super Gamechanger



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Decarbonizes Traded Commodity

Green H_2 can decarbonize today's global hydrogen commodity markets…

Today's Global Hydrogen Value Chains

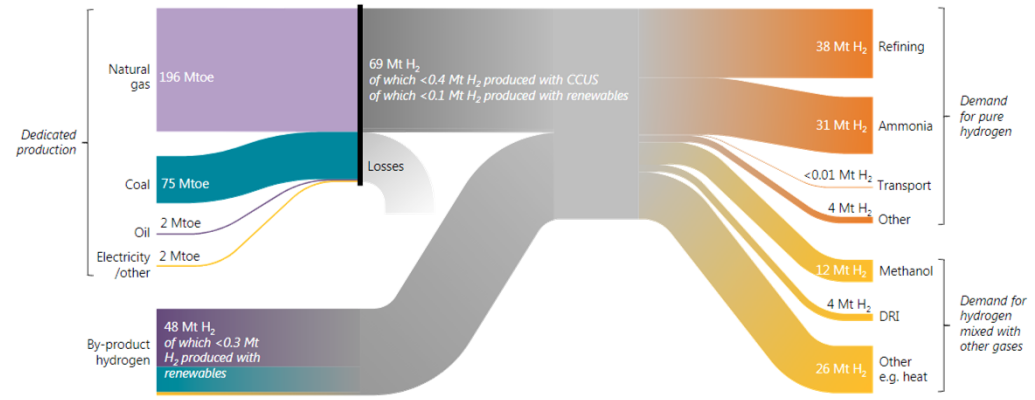

Image from "The Future of Hydrogen: Seizing today's opportunities" report prepared by IEA for the G20, Japan.
Mtoe=million tons of oil equivalent. Mt=million tons

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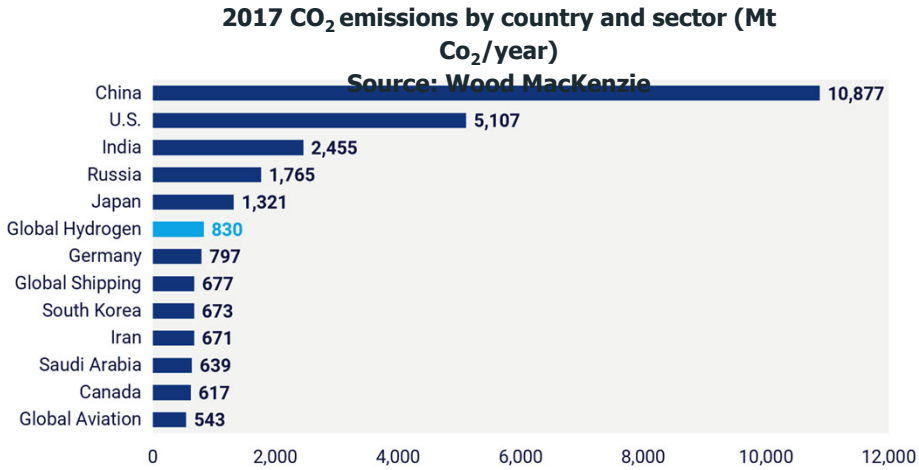
>99% is made from fossil fuels

9

Decarbonizes Traded Commodity

GHG Emissions From Global Hydrogen Production Ranks Higher than Germany



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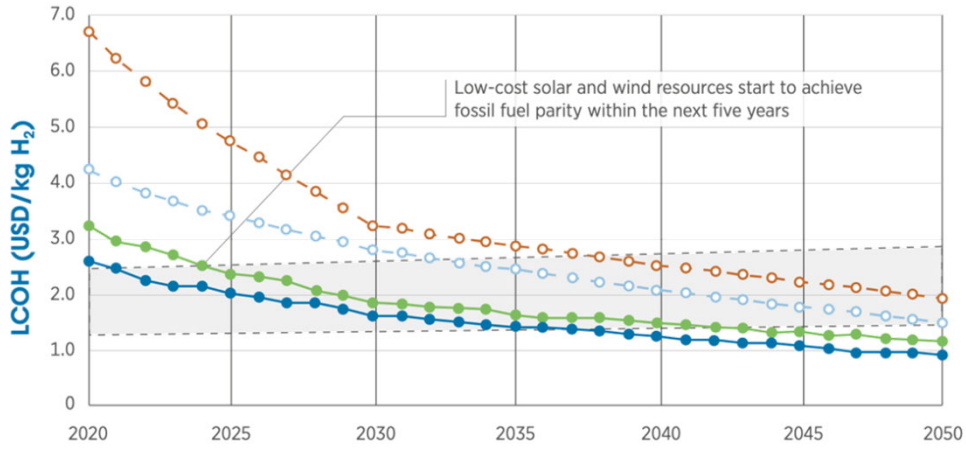
Commercially Viable

Green H_2 is commercially viable; on trajectory for lowest cost



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11

•*IRENA, 2019*: Dolf Gielen, Emanuele Taibi and Raul Miranda, 2019. *Hydrogen: A Renewable Energy Perspective.* International Renewable Energy Agency (IRENA). Report.

Repurposes Infrastructure & Jobs

Green Hydrogen (H_2) can repurpose existing infrastructure …

Source: LADWP

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…Enabling an affordable & responsible transition

12

Decarbonize Many Sectors

Green H_2 with fuel cells can be used as a clean alternative to diesel and gas backup generators today

Photo Credit: Altergy

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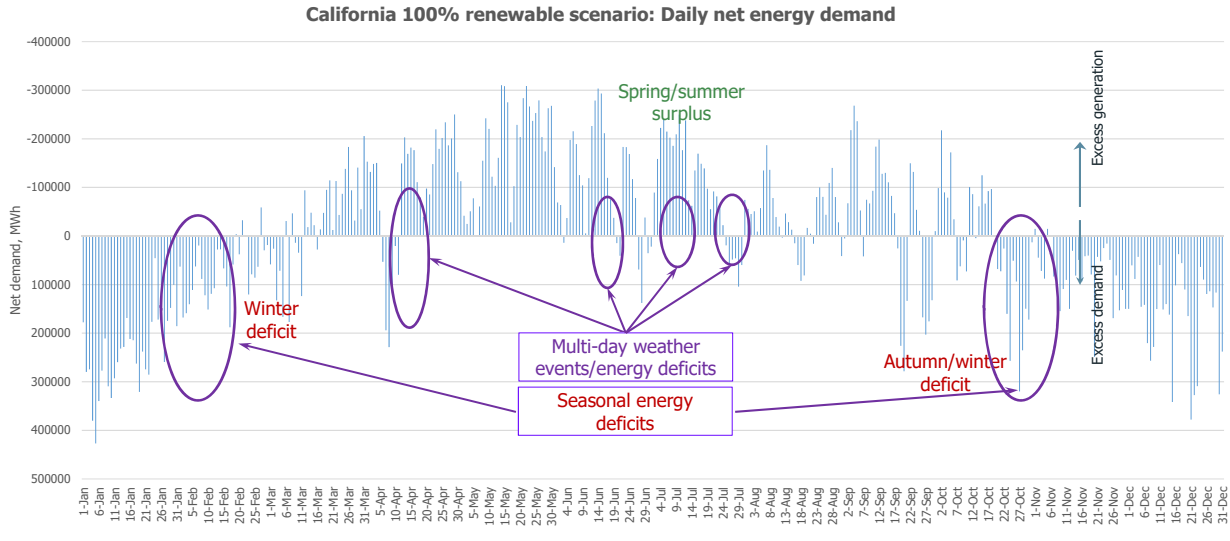
13

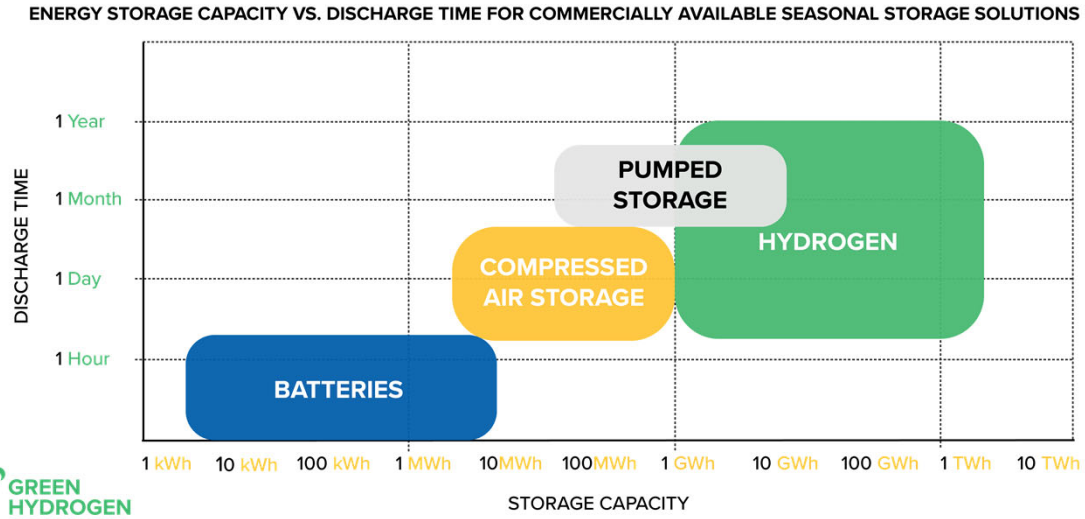
Achieves 100% Renewables

Green H_2 can integrate low cost seasonal renewable energy



Achieves 100% Renewables

Green H_2 is the only commercially viable seasonal storage solution available today



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Green Hydrogen has versatile applications

TRANSPORT POWER INDUSTRY CHEMICAL AGRICULTURE

Hydrogen has the potential to decarbonize multiple sectors, including hard-to-abate applications like aviation and shipping

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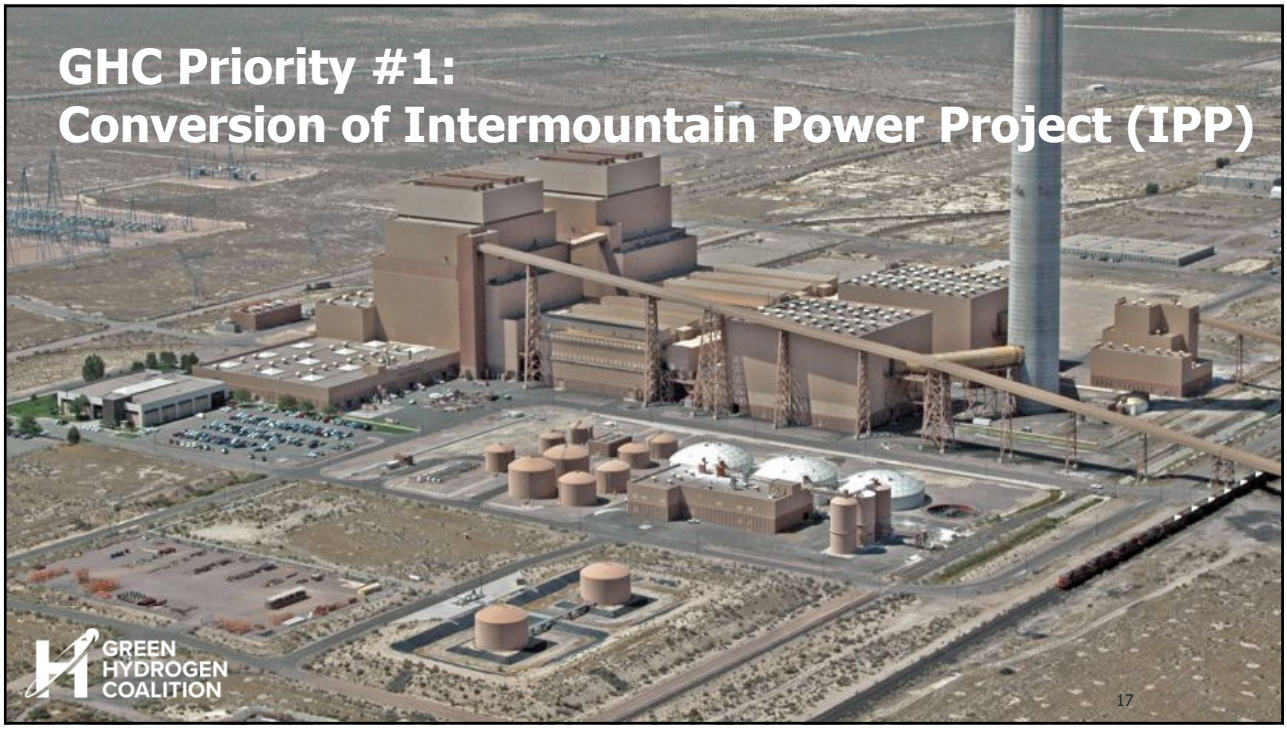
GHC Priority #1:
Conversion of Intermountain Power Project (IPP)
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Unlocking IPP Green H_2 Potential
RENEWABLES
TRANSMISSION
LAND & WATER
SALT DOME
PEOPLE

Practical Solutions to Key Barriers

Barrier	Solution
• Projects to date have been too small to drive down green H2 production cost	• Aggregate demand across applications & sectors within a specific geography – start with electric generation and storage
• High cost of green H2 transport and storage	• Aggregate demand across applications & sectors within a specific geography – start with electric generation and storage • Consider alternate uses for natural gas storage and pipelines
• Not modeled as a solution in integrated resources planning process	• Consider green H2 production and use as part of ongoing integrated resources planning processes
• Access to wholesale renewable tariffs for green H2 production from electrolysis	• Consider new tariffs, prioritizing high value applications – fueling stations, alternative to diesel for fuel cell backup in resilient microgrid

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Commercial opportunities exist today – requires broad ecosystem participation

20

Pathways for Collaboration

Objective	Pathway for Collaboration
• Shape market design for green hydrogen project development, obtain latest news, information and global best practices about green hydrogen market development	• Donate to the GHC!
• Non profit and government organizational collaboration – information sharing, messaging, events and networking	• Become a GHC Supporting Partner
• Learn about green hydrogen pathways and innovation. Stay informed, at a high, level on green hydrogen news and market developments	• Attend GHC events, sign up for newsletter

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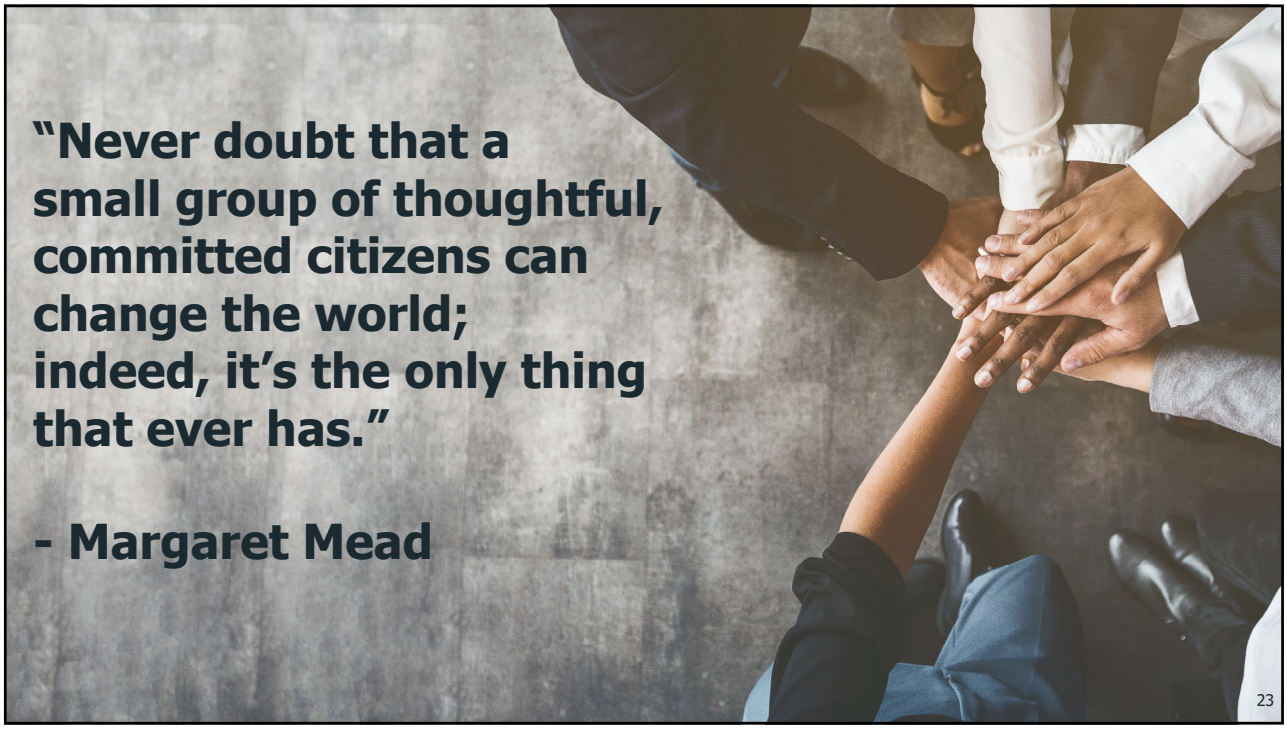
Goal: Efficient collaboration to accelerate progress and momentum for green hydrogen

21

You're Invited! GHC VIRTUAL EVENTS

FREE WEBINARS ON DEMAND

Air, Land, Earth: Multi-Sectoral Decarbonization with Green Hydrogen
Global Progress & Momentum for Green Hydrogen
Green Hydrogen Technology 101
Re-Imagining the Energy Ecosystem with Green Hydrogen



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24

STRATEGEN

Strategen is a mission-driven professional services firm dedicated to decarbonizing energy systems

ASSOCIATIONS

Strategen co-founded and manages the California Energy Storage Alliance (CESA) , the Vehicle-Grid Integration Council, and the Green Hydrogen Coalition. Through these organizations, Strategen policy work has been pivotal in building the energy storage industry in California, the US, and around the world.

CONSULTING

Since 2005, Strategen Consulting provides analysis and insight to governments, utilities, NGO's, and industry to help them achieve leading-edge market development and transformational clean energy strategies.

CONVENINGS

Strategen excels in stakeholder engagement, via customized small and large events. Strategen founded Energy Storage North America (ESNA), the largest grid-connected storage conference in North America. ESNA 2021 is affiliated with Intersolar North America.

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25

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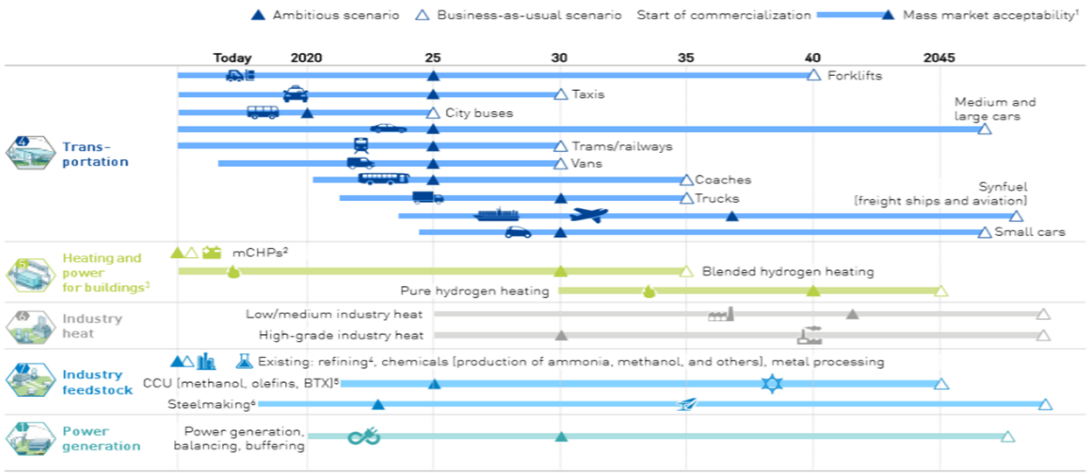
APPENDIX

- Global Drivers for Green Hydrogen
- Global Green Hydrogen Projects
- The Intermountain Power Project (IPP)

Global Drivers for Green Hydrogen:
A Roadmap to 100% Clean Energy

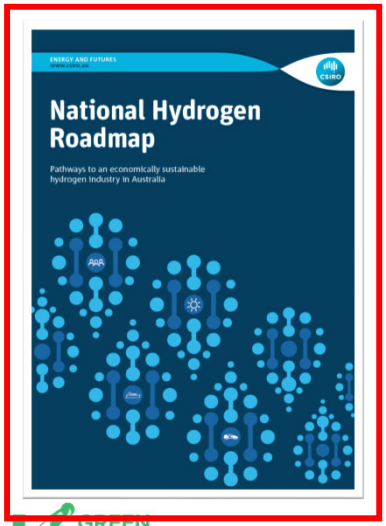
EXHIBIT 20: HYDROGEN TECHNOLOGY EXISTS AND IS READY FOR DEPLOYMENT

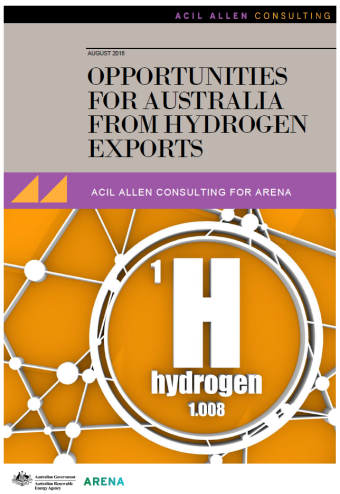


1 Defined as sales >1% within segment 2 mCHPs sales in EU independent of fuel type (NG or H_2) 3 Pure and blended H_2 refer to shares in total heating demand
4 Refining includes hydrocracking, hydrotreating, biorefinery 5 Market share refers to the amount of production that uses hydrogen and captured carbon to replace feedstock 6 CDA process and DRI with green H_2, iron reduction in blast furnaces, and other low-carbon steelmaking processes using H_2

Source: Hydrogen Roadmap Europe 2019

Global Drivers for Green Hydrogen:
Jobs and Economic Development Opportunity





Source: CSIRO Energy

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28

2018: Australia Green H2 Export Plan

- Description:
  - Use massive solar resources to generate electrolytic green hydrogen. Ship the hydrogen fuel to Japan, South Korea, Singapore and other energy resource-constrained Asian nations to power their economies.
- Project Plan:
  - In development
- Goal:
  - Establish the next "Great Export" for Australia

TABLE ES 2 PROJECTED GLOBAL DEMAND FOR HYDROGEN ('000 TONNES)

Country	2025			2030			2040		
	Low	Medium	High	Low	Medium	High	Low	Medium	High
Japan	88	516	1,338	875	1,761	3,858	1,896	4,131	9,573
Republic of Korea	74	223	493	373	728	1,562	1,001	2,175	5,304
Singapore	3	15	31	27	51	103	96	168	481
China	48	226	698	1,028	3,318	7,009	7,853	17,430	40,989
Rest of the World	98	448	1,170	1,053	2,678	5,729	4,958	10,927	25,758
Total	311	1,429	3,731	3,357	8,536	18,260	15,804	34,831	82,105

SOURCE: ACIL ALLEN ANALYSIS

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https://www.powerengineeringint.com/2019/11/19/worlds-largest-green-hydrogen-pilot-begins-operation-in-austria/

May 2019: Heide Oil Refinery in Germany - Westkust 100 700MW off-shore wind electrolysis project

Description:
- Green hydrogen production from offshore wind energy to produce aviation fuel

Project Plan:
- 2019 – Proposal to Federal Ministry of Economics
  - Initial: 30 MW electrolysis plant to gather information on operation, control
  - Scale-up: 700MW electrolysis plant

Goal:
- Continuous stream of green hydrogen for industrial use

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https://www.heiderefinery.com/en/press/press-detail/cross-sector-partnership-green-hydrogen-and-decarbonization-on-an-industrial-scale

November 2019: World's large green-hydrogen steel plant began operation in Austria - 6MW renewable electrolysis project

Description:
- Researching the industrial production of green hydrogen as a means of replacing fossil fuels in steel production over the long term.

Project Plan:
- Built in 2019, currently in operation

Goal:
- Test whether green hydrogen is suitable for industrial-scale use in the steel industry, refineries, and other industrial sectors requiring large volumes of hydrogen

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https://www.powerengineeringint.com/2019/11/19/worlds-largest-green-hydrogen-pilot-begins-operation-in-austria/

January 2020: Belgium, Port of Oostende 4 GW

Description:
- Plant that produces green hydrogen from the electricity produced at Belgium's offshore wind farms

Project Plan:
- 2020 – Demonstration phase with shore-based power, 2.26 GW wind
- 2025 – Commercial green hydrogen plant completed, 4MW off-shore wind

Goal:
- CO_2 reduction of 500,000-1,000,000 tons/year

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https://www.offshorewind.biz/2020/01/27/deme-oostende-port-and-pmv-launch-offshore-wind-to-hydrogen-project/

January 2020: Canada, Chetwynd Hydrogen 3% pipeline injection

Description:
- Coupled electrolysis plant and wind farm to produce green hydrogen to inject into natural gas pipelines at 3% concentration

Project Plan:
- Build dedicated wind farm as well as the electrolysis plant
- Negotiate agreement to inject hydrogen into natural gas pipeline

Goal:
- 22,000 tons green hydrogen produced/year

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https://fuelcellsworks.com/news/canada-macquarie-capital-to-finance-new-200-plus-million-renewable-hydrogen-plant-in-chetwynd/

February 2020: Netherlands NortH2 Project 10 GW

Description:
- Shell plans to have 10GW of turbines off the Netherlands coast to power green hydrogen production

Project Plan:
- 2027 – start with 3-4 GW
- 2040 – 10 GW target

Goal:
- 800,000 tons of green H2 produced/year

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https://www.rechargenews.com/wind/shell-unveils-worlds-largest-offshore-wind-plan-to-power-green-hydrogen/2-1-763610

34

May 2020: CEFC welcomes launch of new $300 million Advancing Hydrogen Fund

Description:
- Clean Energy Finance Corporation Investment Mandate (CEFC) will support the growth of a clean, innovative, safe and competitive Australian hydrogen industry.

Project Plan:
- Advance hydrogen production projects
- Develop export and domestic hydrogen supply chains, including hydrogen export industry infrastructure
- Establish hydrogen hubs
- Build demand for hydrogen

Goal
- Create a pathway for the decarbonisation of "hard-to-abate" sectors responsible for driving approximately 30 per cent of Australia's greenhouse gas emissions

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https://www.heiderefinery.com/en/press/press-detail/cross-sector-partnership-green-hydrogen-and-decarbonization-on-an-industrial-scale/

35

July 2020: Saudi Arabia: Future City of Neom 4 GW

- Description:
  - 4 GW facility, powered by wind and solar, is a collaboration by Air Products, Saudi Arabia's ACWA Power and Neom. It will be capable of producing 650 tons of green hydrogen per day-around enough to power 20,000 hydrogen buses.
- Project Plan:
  - Completion date is 2025
- Goal:
  - The hydrogen produced can be shipped globally as ammonia and then converted back to hydrogen.

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https://www.greentechmedia.com/articles/read/us-firm-unveils-worlds-largest-green-hydrogen-project

GHC Priority #1:
Conversion of Intermountain Power Project (IPP)

37

IPP History and Plan

- Located in Delta, Utah
- Two coal-fired units operating since 1986 with 1,800 MW net capacity
- Two Transmission Systems:
  - STS To Southern California 2400 MW HVDC System
  - NTS To Utah & Nevada
  - Interconnected to 370MW of Wind Generation
- 35 Project Participants, 6 from Southern California
- Coal Units to be retired by 2025; IPP conversion to 840 MW natural gas combined cycle gas facility
- Day 1: run on 30% blend of green hydrogen ramping up to 100% over time

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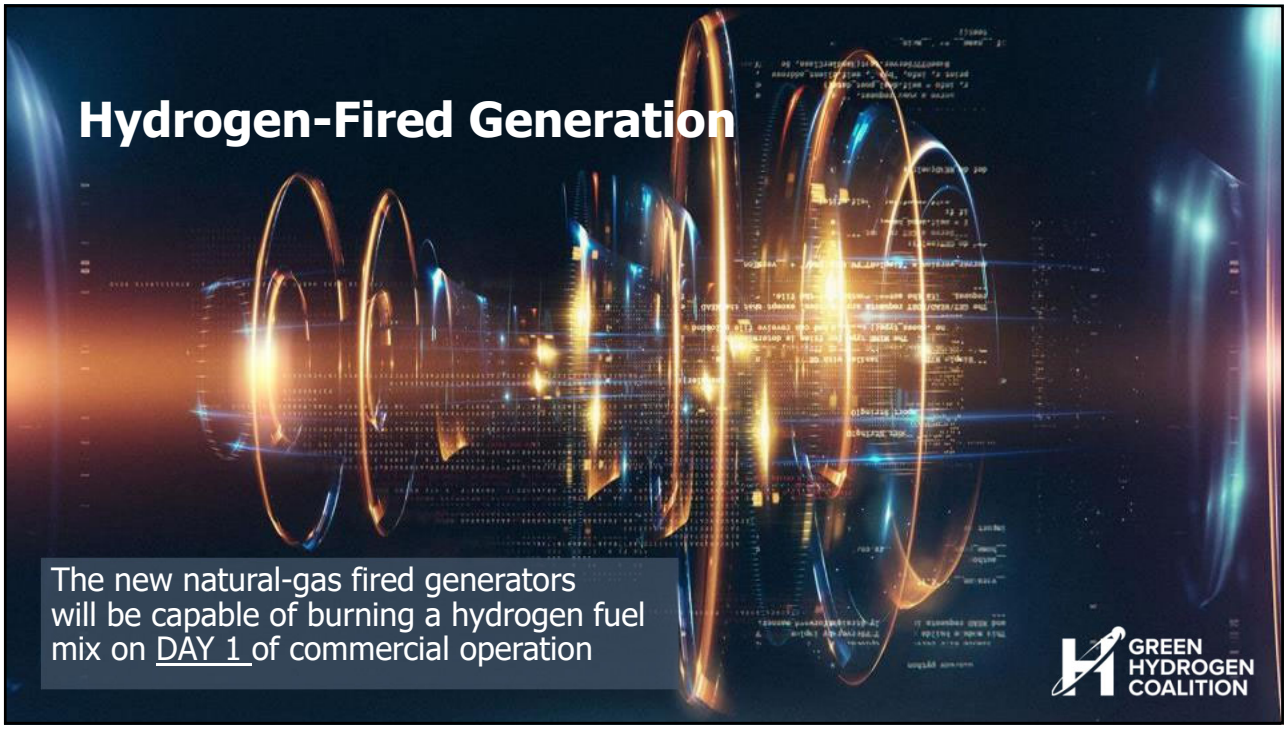
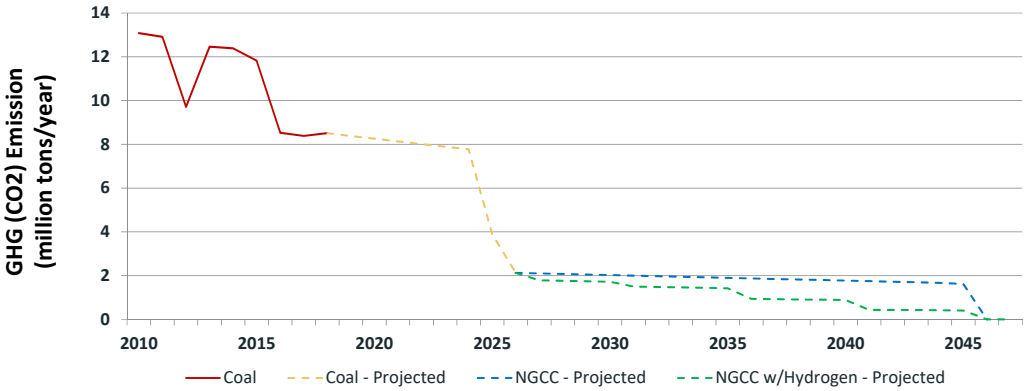
38



IPP Emissions Reduction Profile



%Hydrogen by Heat Rate	2026-2030	2031-2035	2036-2040	2041-2045	2046 -
	15%	25%	50%	75%	100%

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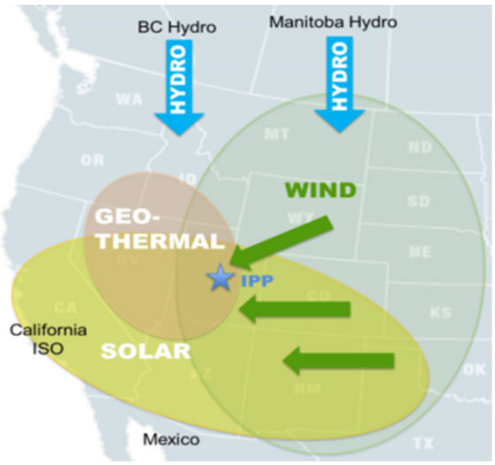
Utah's Renewable Hub

- IPP sits in a confluence of renewable resources
- Currently interconnected to 370 MW of wind generation
- Secondary Path for existing Geothermal Projects and potential for additional geothermal in the area
- 2,300 MW of current solar interconnection requests in queue
- 1500 MW of Wyoming wind interconnects currently being discussed



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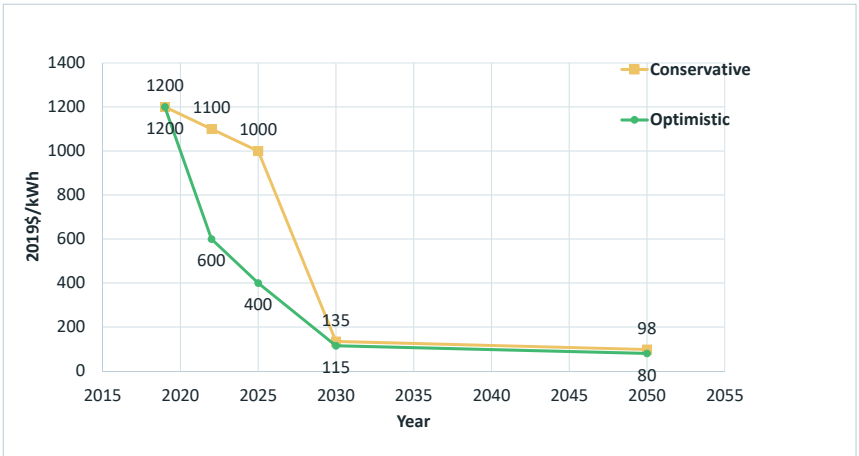
41

IPP Can Help Drive Global Reductions in Hydrogen Electrolyzer Capex & Operations



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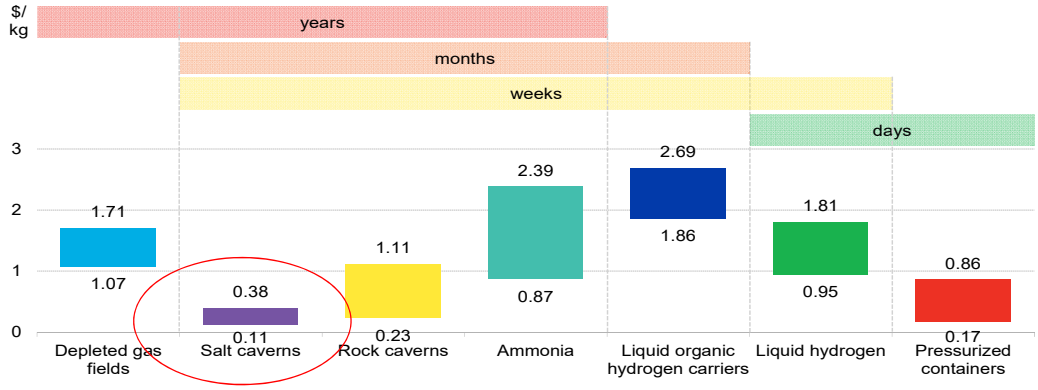
Source: BloombergNEF

42

Levelized Cost of Hydrogen Storage
FUTURE BEST CASE



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Source: BloombergNEF

43

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THANK YOU!

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