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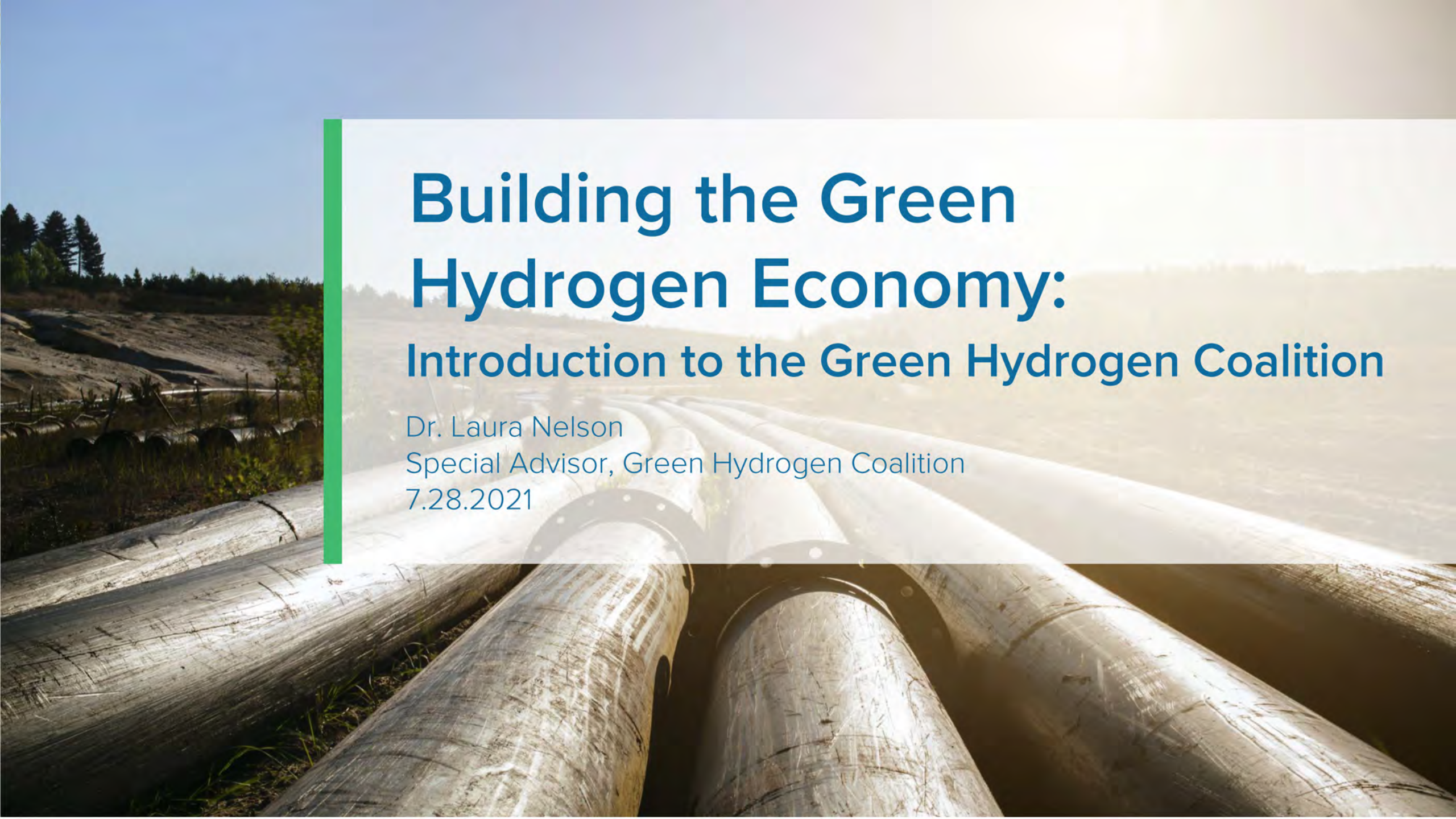

Building the Green Hydrogen Economy:

Introduction to the Green Hydrogen Coalition

Dr. Laura Nelson
Special Advisor, Green Hydrogen Coalition
7.28.2021

GREEN HYDROGEN COALITION

About the GHC

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

*The GHC is a 501(c)(3) Tax Exempt Nonprofit Organization

GHC Focus: Accelerating the green hydrogen economy

Core effort:
Coalition Building - The Intermountain Power Project

Establish appropriate legal and regulatory framework to enable an at-scale power-gas-power green hydrogen project: IPP
Link

Initiative 1:
Regional Collaboration - Western Green Hydrogen Initiative

Western Interstate Energy Board

NASEO
National Association of State Energy Officials

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Establish a regional green hydrogen strategy for the West by providing decision-makers with the information, tools, and policy support to realize commercialization of green hydrogen for reliability, diversity, and economic growth. Link

Initiative 2:
Commercialization - HyDeal North America

Aggregate multi sectoral demand and develop high-volume supply chain & infrastructure to achieve $1.50/kg delivered green hydrogen in strategically targeted locations.
Link

Is the hydrogen economy finally here?

2000

2020

BBC

New hydrogen buses hit the road

Three buses powered by H_2 are to be introduced on routes in central London as part of a two-year trial

The New York Times

Hydrogen cars join EV models in showrooms

Fuel Cells Power Up: Three Surprising Places Where Hydrogen Energy Is Working

Hydrogen may not be fueling many cars, but it is delivering clean power for warehouses, data centers, and Telcom towers.

PHYS.ORG

European nations plan to use more hydrogen for energy needs

Energy officials from 25 countries pledged Tuesday to increase research into hydrogen technology and accelerate its everyday use to power factories, drive cars and heat homes.

RTO Insider

Initiative Seeks to Fuel Use of Green Hydrogen in West

The push to develop green hydrogen got a boost with the announcement of a new program to hasten its development for use in the Western Interconnection

Lancaster, CA Becomes the First Hydrogen City in the US

CISION PR Newswire

UTILITY DIVE

Utility of the Year

NextEra Energy is investing in green hydrogen, solar energy and grid resilience,

riviera

Hydrogen and fuel cells will future-proof shipping

Future Proof Shipping is taking a pioneering step by retrofitting a vessel to run on hydrogen fuel cell propulsion

TechCrunch

GM and Honda partner to mass produce hydrogen fuel cells in Michigan

CNN BUSINESS

Toyota is pushing ahead with hydrogen-powered cars

Doubling down on its bet that fuel cells will help secure Toyota's future as the industry comes under enormous pressure to slash carbon emissions

Air Products Plans $5 Billion Green Fuel Plant in Saudi Arabia

Bloomberg Green

Air Products signed an accord with Saudi-based ACWA Power International and the kingdom's planned futuristic city of Neom to develop a $5 billion hydrogen-based ammonia plant powered by renewable energy

gtm: A Wood Mackenzie Business

Coalition Aims for 25GW of Green Hydrogen by 2026

Seven firms join forces for fiftyfold scale-up of global hydrogen production capacity.

reNEWS.BIZ

Vestas backs world's first commercial green ammonia plant

Enel teams up on US green hydrogen project

Hydrogen-powered flight

Is the time now ripe for planes to run on hydrogen?

The Economist

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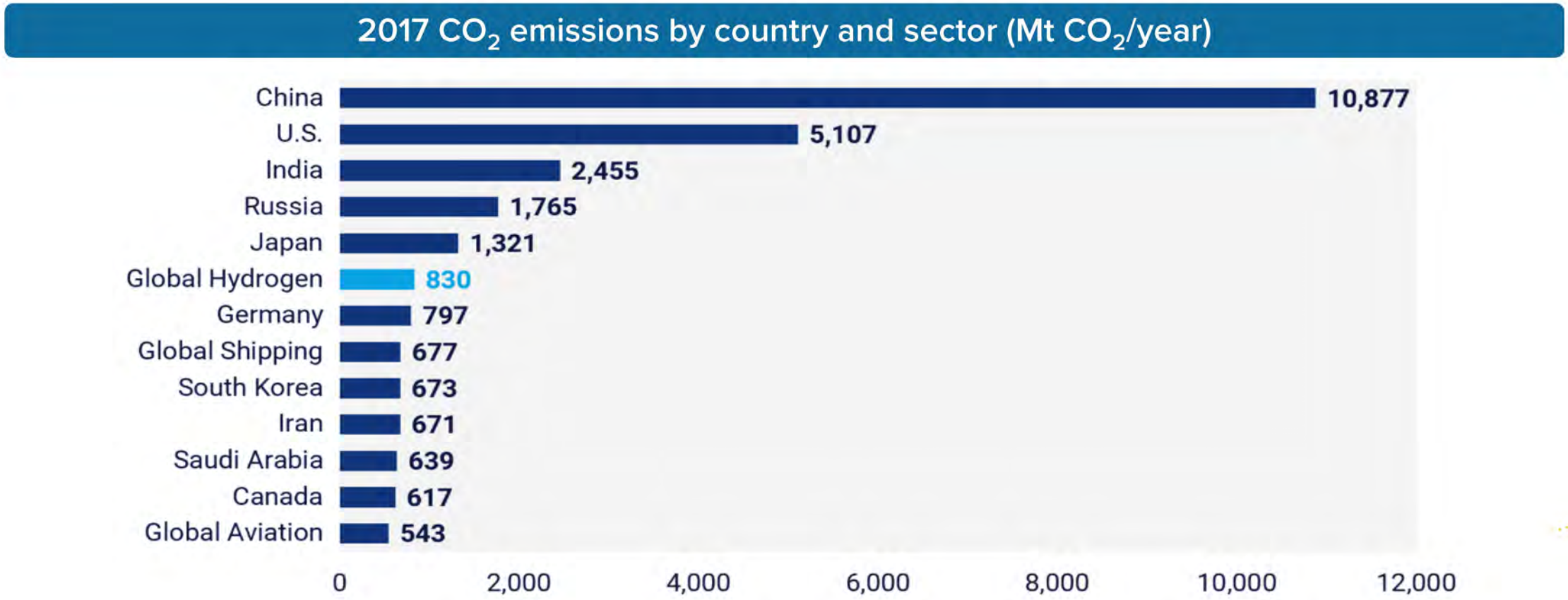
Global hydrogen production accounts for 832 Mt CO2/year...more than the emissions of Germany



Source: Wood Mackenzie, 2019. "CO_2 and other Greenhouse Gas Emissions"

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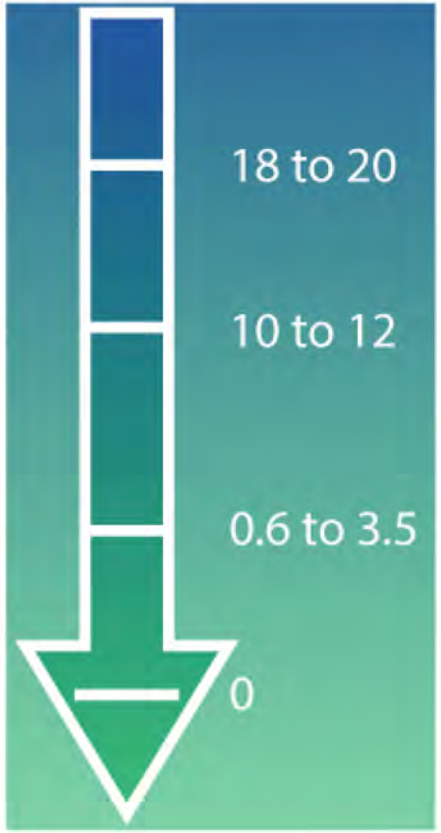
The colors of hydrogen

Color	Primary Feedstock	Primary Energy Source	Primary Poduction Process	Carbon Impact (kg CO_2/kg H_2)
Brown	Coal or Lignite	Chemical Energy in Feedstock	Gasification & Reformation	18 to 20
Gray	Natural Gas	Chemical Energy in Feedstock	Gasification (SMR)	10 to 12
Blue	Coal, Lignite, or Natural Gas	Chemical Energy in Feedstock	Gasification with Carbon Capture and Sequestration	0.6 to 3.5
Green	Biomass or Biogas	Chemical Energy in Feedstock	Gasification and Reformation	
	Water	Zero Carbon Electricity	Electrolysis	0



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Green hydrogen can transform how we power our world and create vibrant clean energy economies with sustainable local jobs

Agriculture

Industrial applications

Natural Gas

Power

Transportation

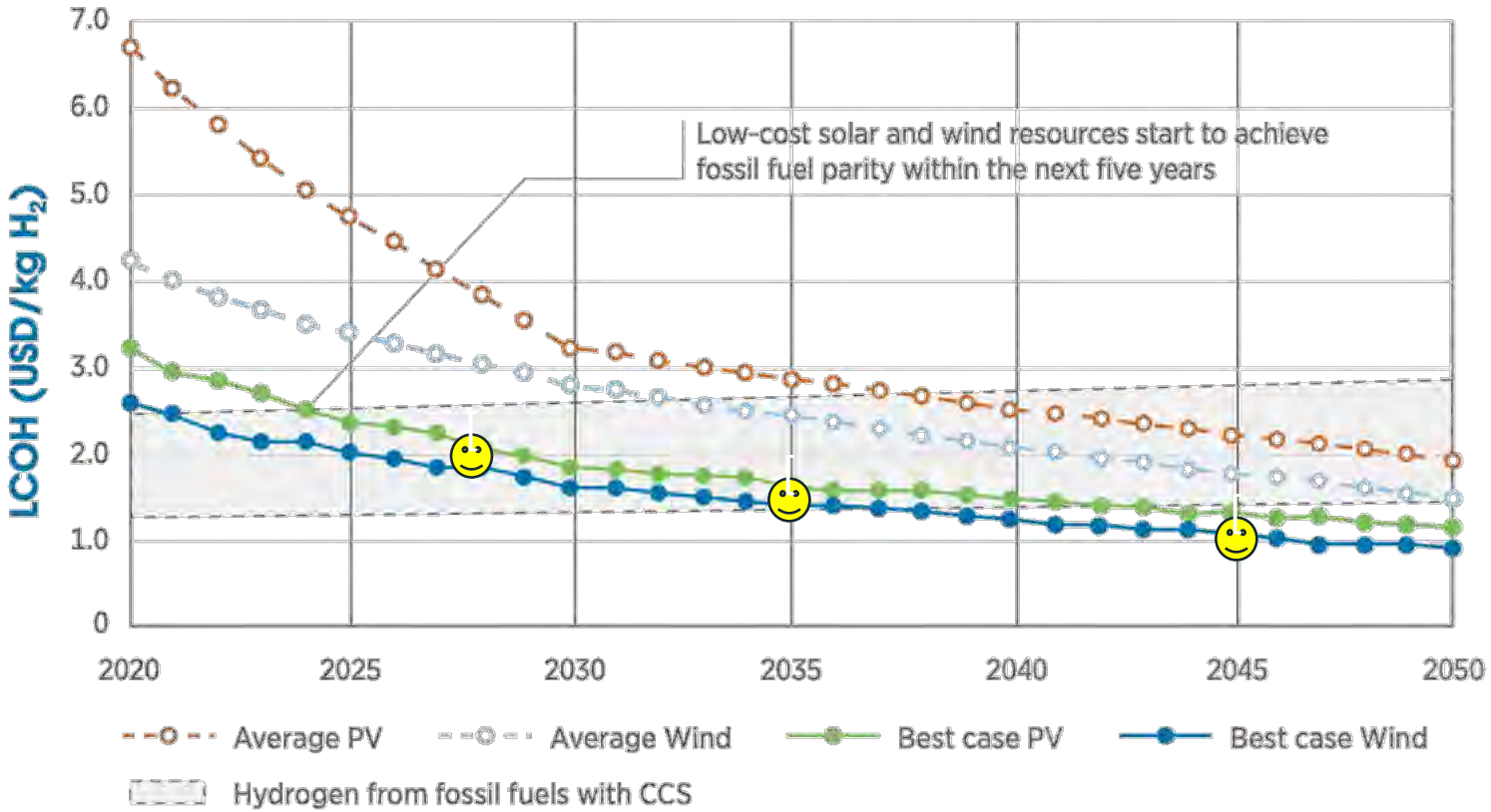
Mining

Energy Storage

GREEN HYDROGEN COALITION

Green hydrogen is commercially viable now and on trajectory for lowest cost

Hydrogen production costs from solar and wind vs. fossil fuels



Source: IRENA, 2019. Hydrogen: A Renewable Energy Perspective. International Renewable Energy Agency (IRENA). Report.

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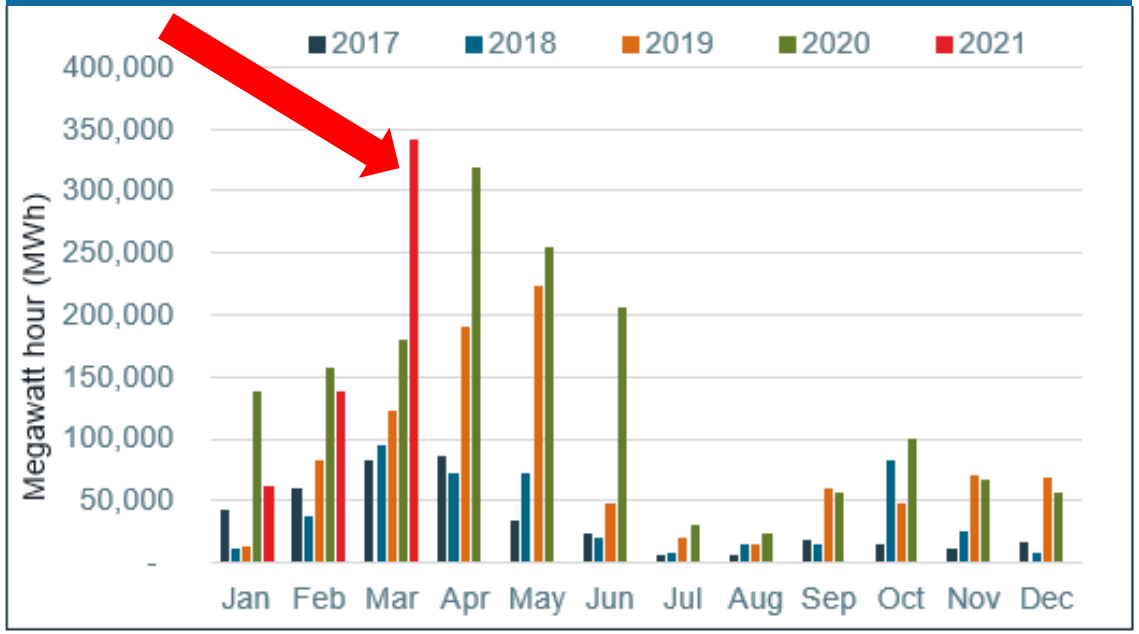
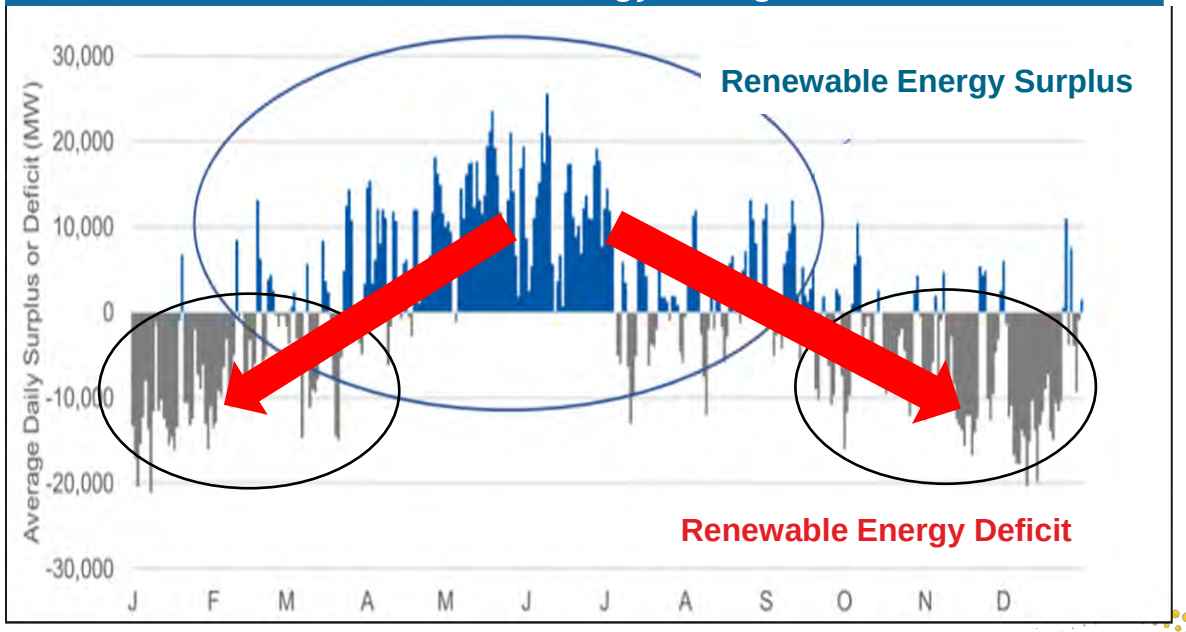
Why is green hydrogen important now for California?

California Wind and Solar Curtailments Hit Record High in March 2021



Data Source: CAISO, Compiled April 2021

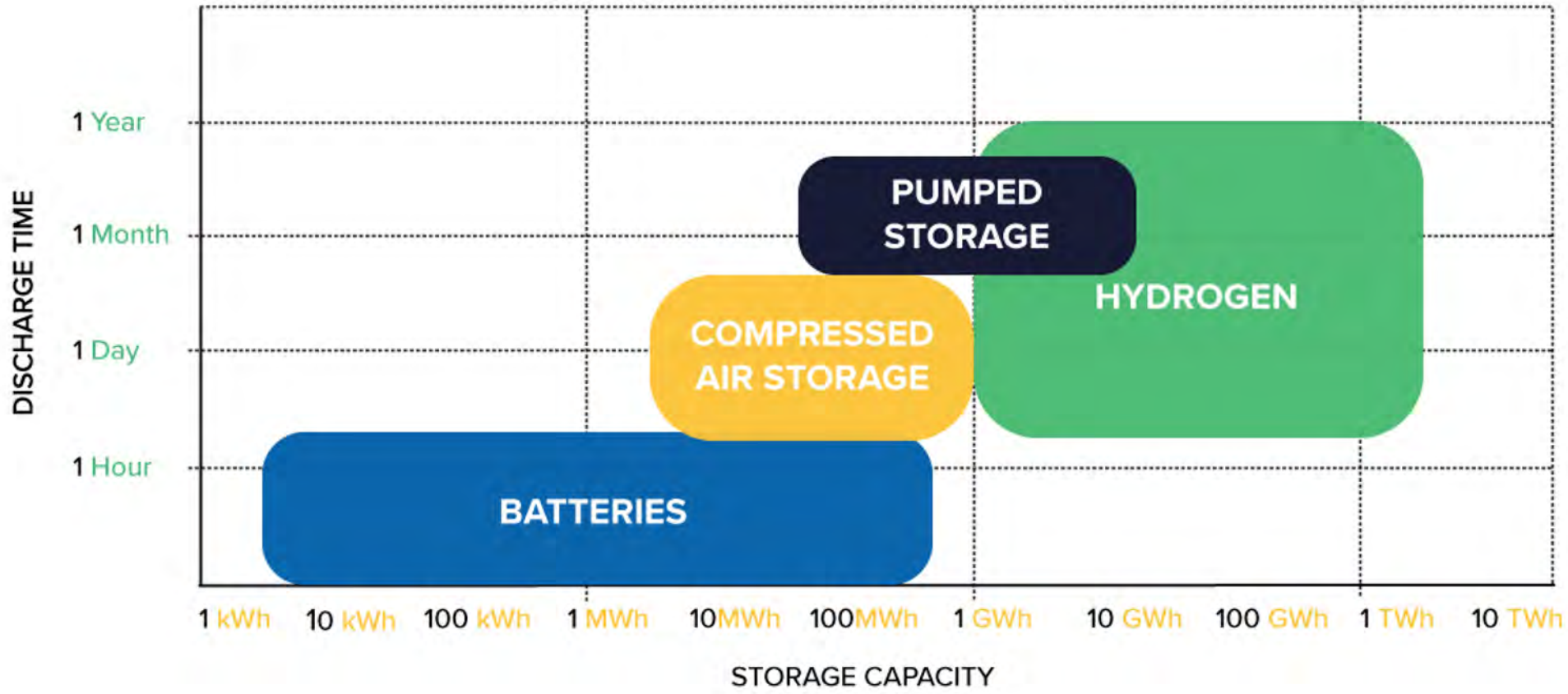
100% Renewable Energy Scenario in California Signals a Need for Seasonal Energy Storage



Data Source: Armonk Cohen Testimony

Information Source: Mitsubishi Power Americas

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



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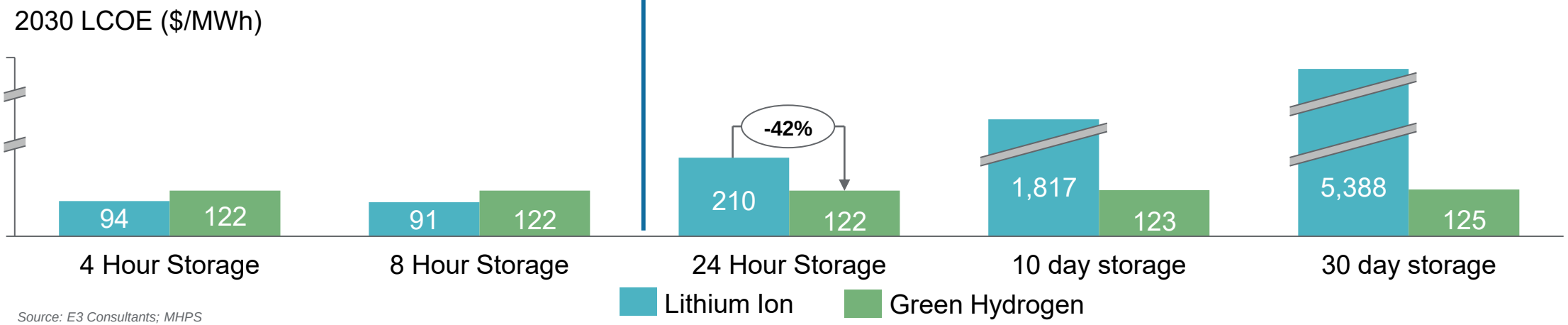
Renewable Energy Storage Alternatives

Intra-Day Shifting vs. Inter-Day and Seasonal Shifting

Lithium Ion Suitable for "Intra-Day Shifting"

H_2 Storage clear solution for "Inter-Day" and longer duration



Source: E3 Consultants; MHPS

Assumptions

- Battery roundtrip efficiency impacted as duration need extends beyond 1-day
- Gas turbine capacity factor: 40%
- MHPS 2019 electrolyzer and H_2 storage cost with learning curve + CCGT
- LCOE includes solar cost

Information Source: Mitsubishi Power Americas

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Green Hydrogen can repurpose existing infrastructure & jobs

Source: DNV GL

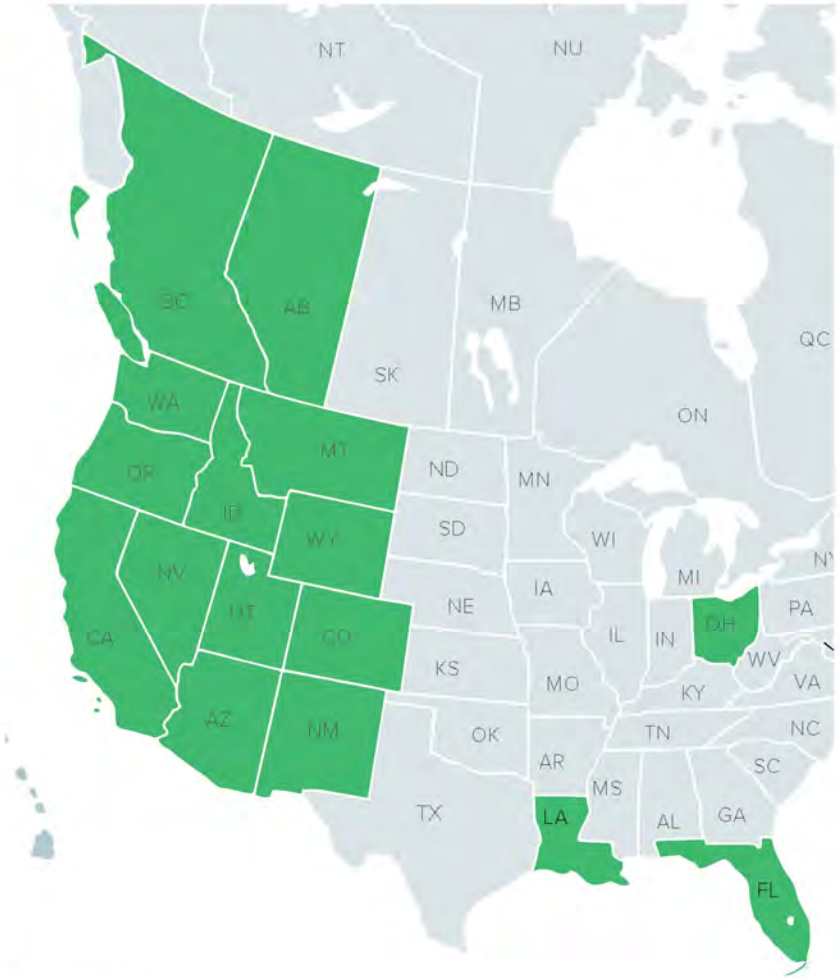
Source: LADWP

Enabling an affordable & responsible transition

Green hydrogen is a reliable, easily dispatchable, zero-carbon fuel that can reduce the need for fossil fuels in gas turbine plants

Making it the solution to maintain energy sector jobs and clean the air in disadvantaged communities

Western Green Hydrogen Initiative (WGHI): Fostering Regional Green Hydrogen Collaboration



It is the mission of the WGHI to help policymakers evaluate and understand the potential for hydrogen in achieving energy resilience and creating economic development opportunities for the West.

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WGHI State Leads

Dan Lloyd, Chair

Bureau Chief of the Montana Department of Environmental Quality

David Bobzien, Chair

Director of the Nevada Governor's Office of Energy for Governor Steve Sisolak

Andrew McAllister, Vice-Chair

Commissioner of the California Energy Commission

John Chatburn, Vice-Chair

Administrator at the Idaho Governor's Office of Energy and Mineral Resources

HyDeal LA goal: Establish America's first green hydrogen industrial hub at scale

LA will be the first in North America to...

Achieve 100% renewable electricity affordably and reliably

Decarbonize fuel refining and move to renewable fuels

Provide green ammonia fueling to maritime goods movement (and for fertilizer production)

Demonstrate green hydrogen fuel cell passenger flight (Long Beach Airport to Sacramento)

Export low-cost green hydrogen at scale

GREEN HYDROGEN COALITION

HyDeal LA Project Team Leverages Experience from HyDeal Europe and Ongoing GHC California Policy/Regulatory Work

CONTRACTS	INDUSTRIAL PLAN & ECONOMICS	FUNDING	POLICY & REGULATORY	PROJECT MANAGEMENT
CLIFFORD CHANCE	CVA Corporate Value Associates	MARATHON CAPITAL	STRATEGEN	GREEN HYDROGEN COALITION
SheppardMullin	STRATEGEN	Cranmore Partners	SheppardMullin	STRATEGEN
	ENERGEIA	SheppardMullin	CLIFFORD CHANCE	
		CLIFFORD CHANCE		

HyDeal Los Angeles Advisors & Supporting Partners

Advisors

Tyson Eckerle
California Gov's Office of Business & Economic Development

Jack Brouwer
National Fuel Cell Research Center, UC Irvine

Rachel Fakhry
Natural Resources Defense Council

Keith Wipke
National Renewable Energy Laboratory

Michael Colvin
Environmental Defense Fund

Jeffery Preece
Electric Power Research Institute

Supporting Partners

California Governor's Office of Business and Economic Development

California Stationary Fuel Cell Collaborative CaSFCC

California Hydrogen Business Council

CESA California Energy Storage Alliance

Colorado Hydrogen Network

EPRI Electric Power Research Institute

Advanced Power & Energy Program University of California, Irvine

M-RETS Renewable Electricity

Green Hydrogen Coalition

HyDeal Phase 1 Approach

Leverage existing pipeline infrastructure to bring low-cost green hydrogen to the basin

- Utilize existing natural gas pipeline through injection
- Utilize pipeline right of ways for new, exclusively hydrogen pipelines
- Repurpose existing natural gas pipelines

Leverage existing transmission infrastructure and capacity to produce green hydrogen locally through electrolysis

- Utilize excess transmission capacity to import low-cost renewable electricity for electrolysis
- Maximize local rooftop solar

Create green hydrogen locally through gasification (Ph2)

- Divert organic municipal solid waste and non-recyclable paper and ocean plastic from landfills to thermochemically produce green and low carbon hydrogen in the LA basin

High-Level Regulatory and Policy Roadmap
Work needs to start NOW to resolve issues for ALL pathways

2020-2025
Electric Transmission Pathway

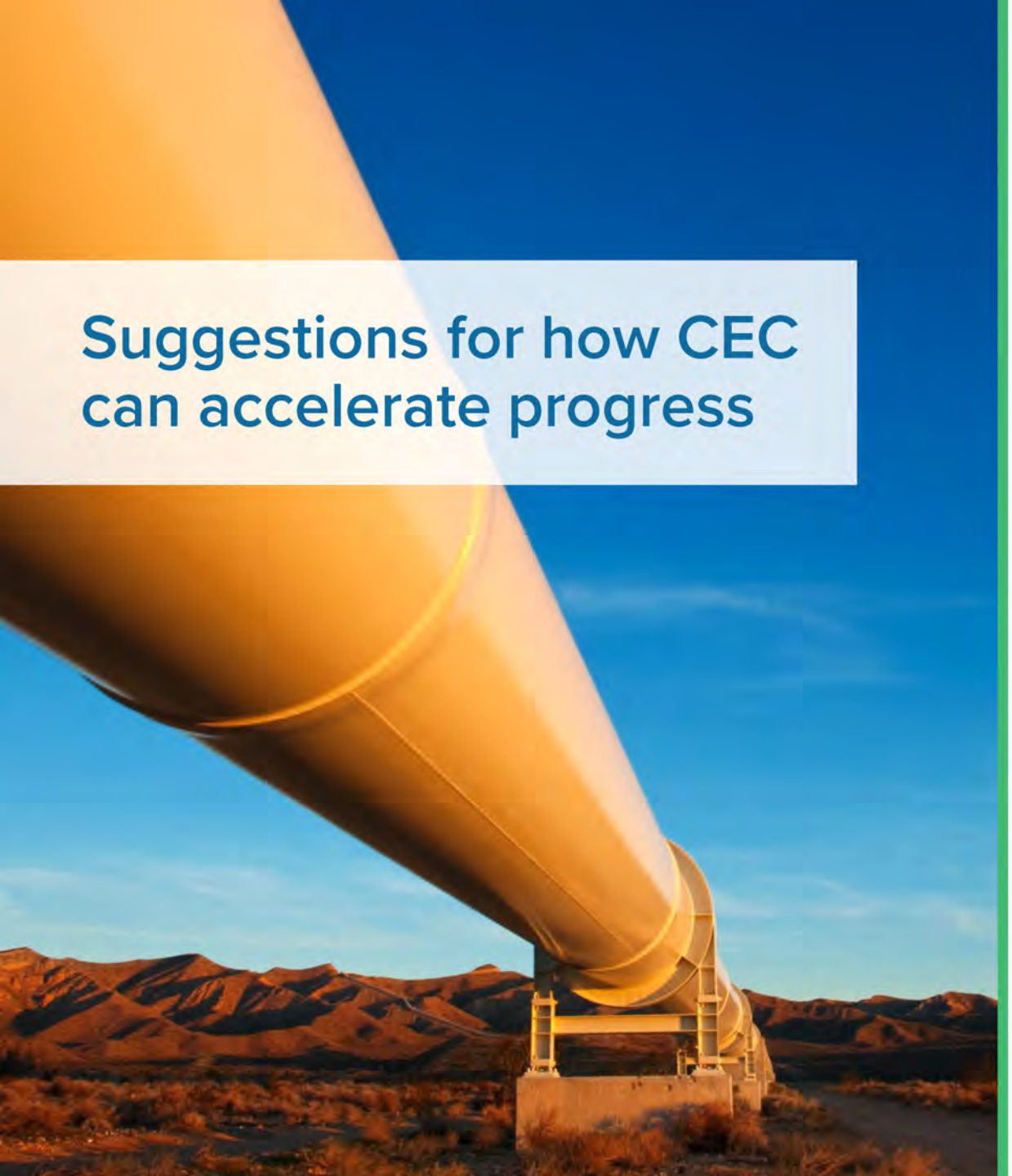
- **In-basin electrolytic production**
- **Issues:**
  - Definition of green hydrogen; RPS & SB 100 compliance
  - Siting and permitting
  - Ancillary services value streams
  - Electrolysis tariff (if third party owned)
  - Thermal power plant permitting
  - Cost allocation and cost effectiveness

2025-2030
Natural Gas Pipeline Pathway

- **Injection into existing gas pipelines (blend)**
- **Issues:**
  - Pipeline integrity/safety
  - Regulations: Blending/injection tariff
  - Guarantees of origin/program eligibility
  - Feasibility of synthetic green methane
  - Cost allocation and cost effectiveness

2030-2035
100% H2 Pipeline Pathway

- **100% H2 pipeline is needed to achieve $1.50/kg and to manage seasonal demand via connection with geologic storage**
- **Issues:**
  - Economic regulatory ambiguity
  - Long lead time
  - Eminent domain and permitting
  - Cost allocation and cost effectiveness



Suggestions for how CEC can accelerate progress

1. Improve regional modeling of optimal portfolios – electric and gas sector optimization connecting green hydrogen industrial hubs. Electrolysis could be added to the electric load forecast
2. Help study and provide vision for accelerating transformation of existing assets and skilled jobs: repurposing gas and oil assets, natural gas pipeline conversion, sectoral convergence
3. Accelerate green hydrogen industrial hub development: nexus of green ammonia for shipping and agriculture; electrolytic tariff design; expand industrial applications
4. Clarify that green hydrogen used as a fuel in fuel cells and turbines can qualify for the RPS in the guidebook
5. Help create alignment with key stakeholders including labor and environmental justice groups
6. Needed RD&D: blending and injection demonstrations, underground geologic storage (aquifers, retired oil wells, retired natural gas caverns)

Stay in touch and access free educational resources

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GREEN HYDROGEN COALITION

Q&A Session

Contact information:

Dr. Laura Nelson, Vice President
lnelson@strategen.com
Janice Lin, Founder & President jlin@strategen.com

Appendix

GREEN HYDROGEN COALITION

Purpose

Accelerate decarbonization to combat climate change

Core Values

- Technology & business model neutral
- Respect & collaboration
- Integrity
- Safety
- Environmental Justice
- Impact

*The GHC is a 501c3 Tax Exempt Non Profit Corporation

GREEN HYDROGEN COALITION

Plants make fuel from water and sun,
and so can we

Green hydrogen is the strategic fuel
for our generation

The GHC's initiatives and efforts are designed to overcome five major barriers to achieve a scaled green hydrogen future:

General lack of understanding & education	Need for leadership, focus & alignment	High cost of green hydrogen & related infrastructure	Decoupled gas & electricity sector planning	Comprehensively valuing all green hydrogen's benefits, not just costs
				

GREEN HYDROGEN COALITION

GHC's core organizational efforts

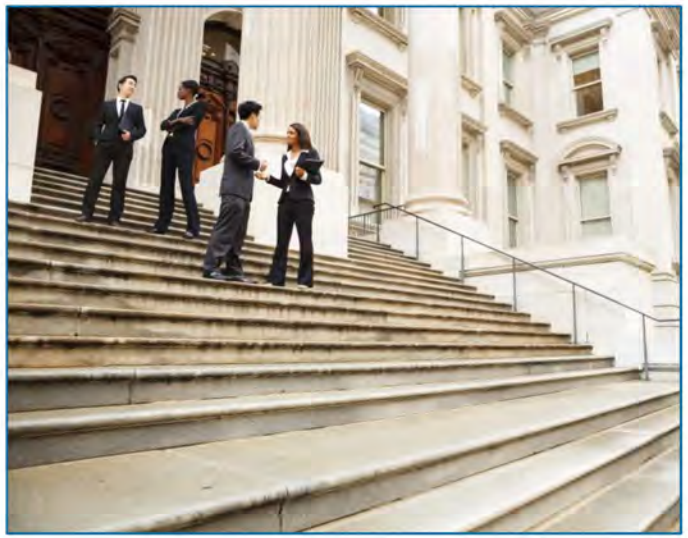
Education

Build green hydrogen knowledge and consensus
Link

Coalition Building

Align stakeholders around landmark capital and infrastructure projects (Ex: Intermountain Power Project)
Link

Market Development



Develop the policies, rules and practices to advance the production and use of green hydrogen
Link

Green hydrogen can decarbonize multiple sectors

Agriculture

High-heat industrial applications

Transportation

Power

Mining

Energy Storage

GREEN HYDROGEN COALITION

How will HyDeal LA accomplish these goals?
Project Overview

GREEN HYDROGEN COALITION

The path to a green hydrogen economy and clean energy future in Los Angeles

Phase 1:
Keep leading where LA is already ahead

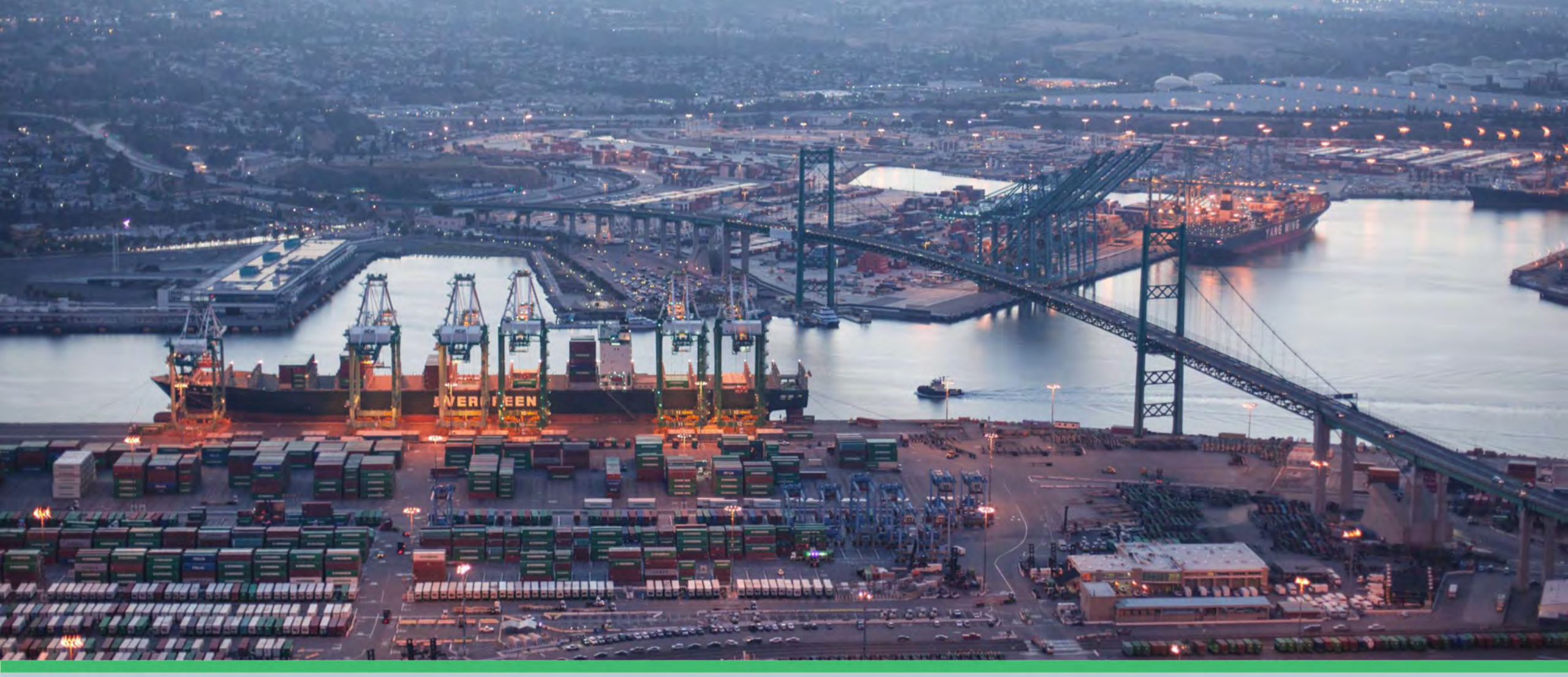
Phase 2:
Tackle some of our biggest decarbonization challenges

Phase 3:
Become a global leader in clean fuel exports & create economic opportunities

GREEN HYDROGEN COALITION

HyDeal Los Angeles
Phase 1 Deliverables

- **Downstream (Offtakers)** - identify qualified, aggregated annual demand (Mt) needed by 2035 on a site-by-site basis
- **Midstream (Transport & Storage)** - create a system map to meet that demand, combining greenfield and brownfield development
- **Upstream (Project Developers)** - vet production cost models to hit the headline price target on or before 2035 in targeted markets
- **Finance and legal participants** - achieve in-principle agreement on term sheets for contracts that could underpin large scale investment.



The Port of LA and Long Beach are ideal starting points for multi-sectoral green hydrogen development and export

LA has established momentum and leadership with green hydrogen

LA100 calls on green hydrogen as a “leading option” for decarbonization

Intermountain Power Project is a model for green hydrogen as a dispatchable, zero-carbon power source

LA is home to more hydrogen fueling stations than any other county in the United States.

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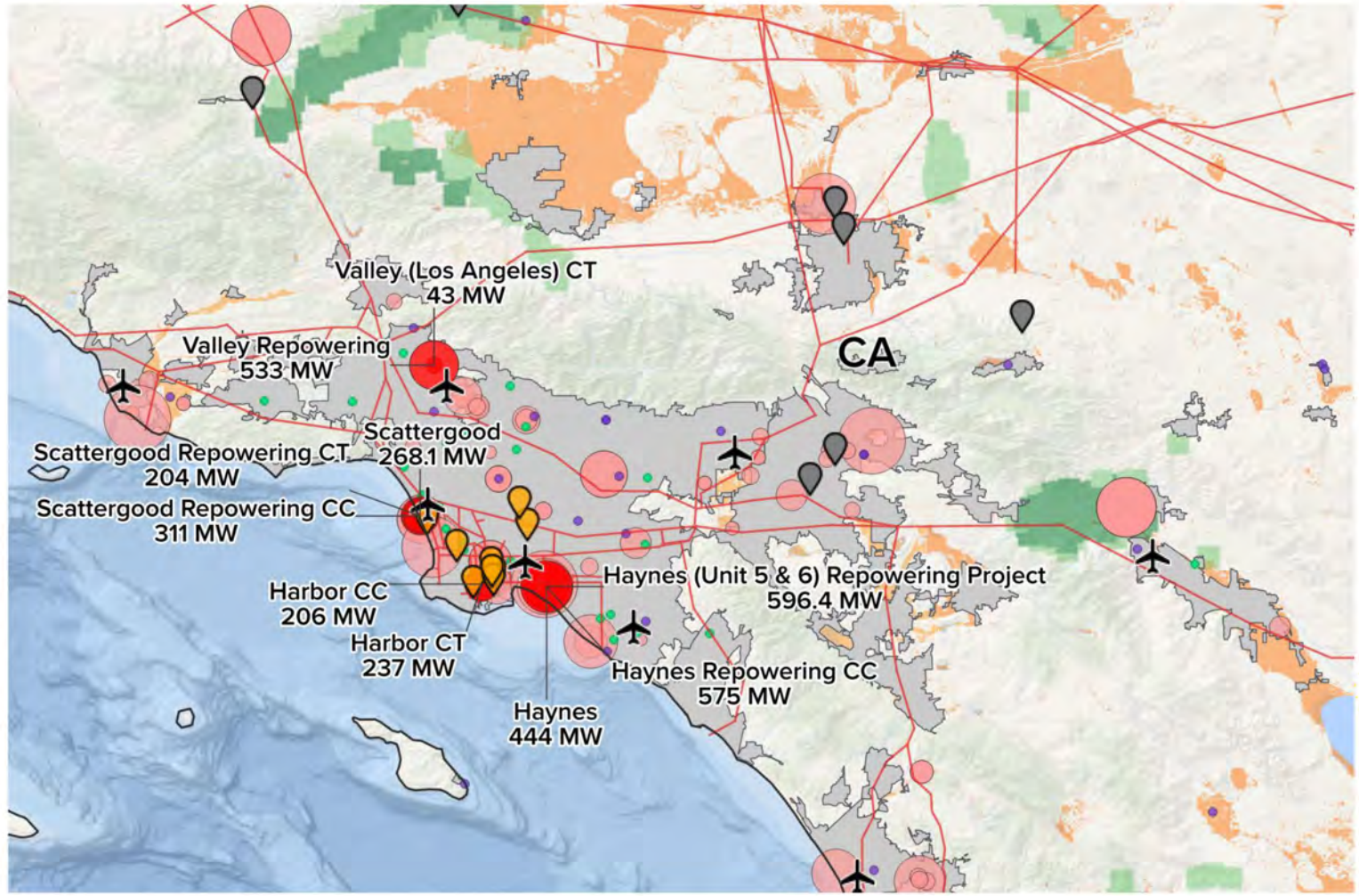
Los Angeles has abundant at scale green hydrogen offtakers

HyDeal Los Angeles will support Green LA and the 2028 Los Angeles Olympic Games

- Natural Gas Pipelines
- Gas Power Plants
- LAWP Power Plants
- Wind Resource
- Solar Resource
- Urban Areas of LA and LA County
- Oil Refineries
- Cement Plants
- Airport
- Backup Generators
- Hydrogen Fuel Stations



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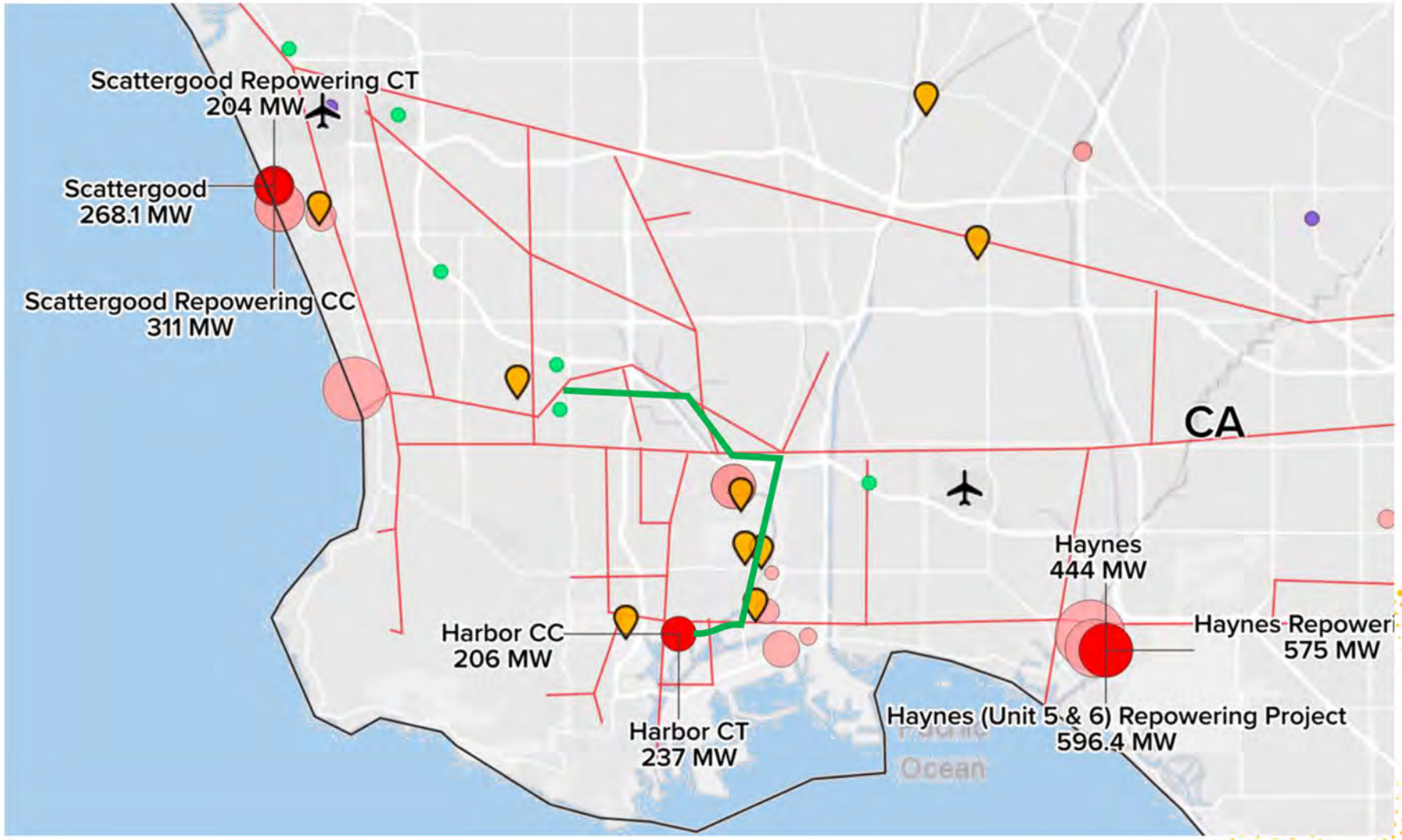
The Port of LA and Long Beach are ideal starting points for multi-sectoral green hydrogen development

High concentration of offtaker opportunities and existing H2 infrastructure

- Hydrogen Pipeline
- Natural Gas Pipelines
- Gas Power Plants
- LAWP Power Plants
- City of Los Angeles
- Oil Refineries
- Airport
- Backup Generators
- Hydrogen Fuel Stations



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Green hydrogen for power generation and reliability

Continuing the vision created by the IPP in the LA Basin: Converting Scattergood, Harbor, Haynes and Valley Generation Stations

Based on real world thermal conversion projects, we have identified the average job potential of Converting 4 large thermal power plants - such as LADWP's Generating Stations - to hydrogen turbines that use electrolytic hydrogen from wind and solar.

Jobs Created

- During Peak Construction: **8,232**
- For Ongoing Operations: **504**

Photo Source: Los Angeles Clean Energy Coalition

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Pipeline conversion to green hydrogen happening now in Europe

European Banks provide €80MM for 120km Green Hydrogen Pipeline Expansion and Enhancement

KfW IPEX-Bank concludes first-ever financing for hydrogen infrastructure

KfW IPEX-Bank is financing the expansion and operation of the gas transport pipeline network of the German operator Nowega GmbH. It will provide debt capital of around EUR 40 million, with a further EUR 40 million contributed by DekaBank.

"For the energy transition to be successful in the long term, we need alternatives to fossil fuels – hydrogen will play a key role in this process," explains Markus Scheer, member of the Management Board of KfW IPEX-Bank. "An important building block in this context is the necessary infrastructure, the establishment of which we are very happy to support with our first-ever financing in this segment."

Source: KFW IPEX Bank Press Release January 2021: https://www.kfw-ipex-bank.de/Presse/News/Pressemitteilungsdetails_628864-2.html

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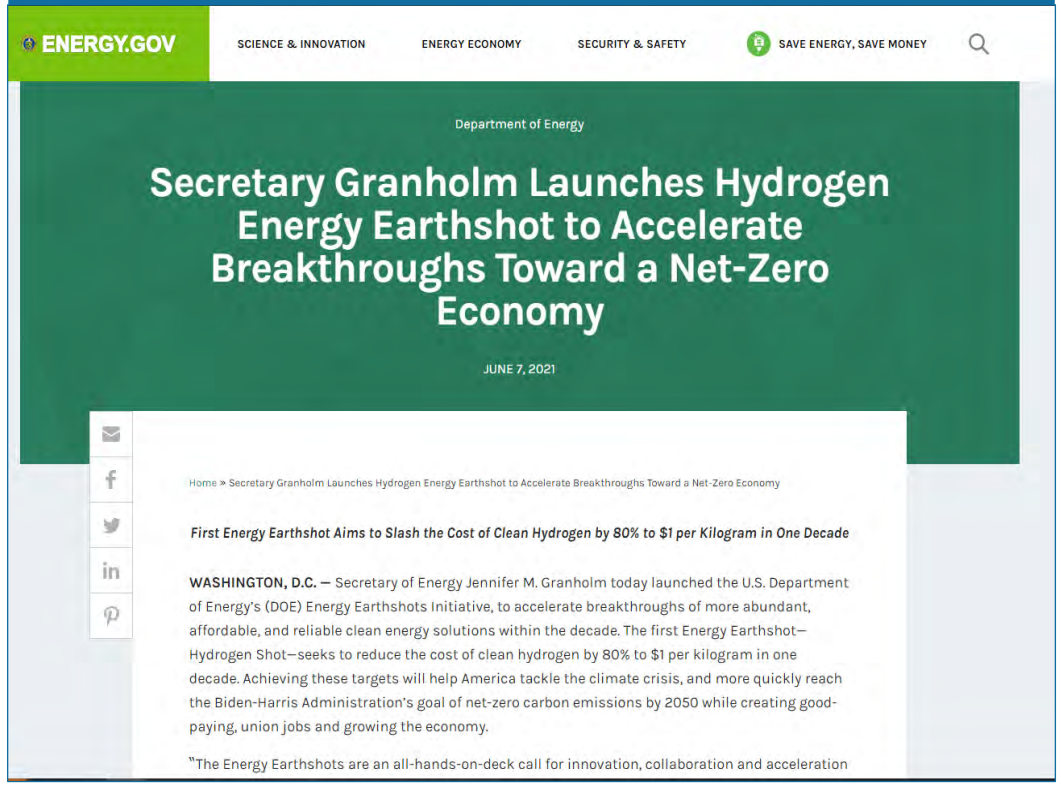
Federal funding is available to jumpstart infrastructure development

DOE Earthshots Initiative Starts with Hydrogen



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Department of Energy

Secretary Granholm Launches Hydrogen Energy Earthshot to Accelerate Breakthroughs Toward a Net-Zero Economy

JUNE 7, 2021

Home » Secretary Granholm Launches Hydrogen Energy Earthshot to Accelerate Breakthroughs Toward a Net-Zero Economy

First Energy Earthshot Aims to Slash the Cost of Clean Hydrogen by 80% to $1 per Kilogram in One Decade

WASHINGTON, D.C. – Secretary of Energy Jennifer M. Granholm today launched the U.S. Department of Energy's (DOE) Energy Earthshots Initiative, to accelerate breakthroughs of more abundant, affordable, and reliable clean energy solutions within the decade. The first Energy Earthshot—Hydrogen Shot—seeks to reduce the cost of clean hydrogen by 80% to $1 per kilogram in one decade. Achieving these targets will help America tackle the climate crisis, and more quickly reach the Biden-Harris Administration's goal of net-zero carbon emissions by 2050 while creating good-paying, union jobs and growing the economy.

"The Energy Earthshots are an all-hands-on-deck call for innovation, collaboration and acceleration

Biden's Jobs Plan Has Opportunities for Hydrogen

- **$35 billion in R&D funds** for various climate change solutions, including hydrogen, under new ARPA-C initiative
- **$100 billion in investments to the grid** to drive low-cost renewable energy resources and long-duration/seasonal energy storage.
- **$46 billion for expanded domestic manufacturing capacity** of clean energy technologies
- **New production tax credit** to spur capital-project retrofits and installations, including hydrogen demonstrations in distressed communities

Keep Leading Where LA is Already Ahead

Ground transportation

Continue developing new hydrogen fueling stations, and support green hydrogen at all hydrogen fueling stations

Meet the growing green hydrogen demand

Leverage existing pipeline infrastructure to bring low-cost green hydrogen to the basin

- Utilize existing natural gas pipeline through injection
- Utilize pipeline right of ways for new, exclusively hydrogen pipelines
- Repurpose existing natural gas pipelines

Leverage existing transmission infrastructure and capacity to produce green hydrogen locally through electrolysis

- Utilize excess transmission capacity to import low-cost renewable electricity for electrolysis
- Maximize local rooftop solar

Create green hydrogen locally through gasification

- Divert organic municipal solid waste and non-recyclable paper and ocean plastic from landfills to thermochemically produce green and low carbon hydrogen in the LA basin (see next slide)

Solutions to our biggest decarbonization challenges

Repurposing waste to meet green hydrogen demand

Every day, LA produces **89,000 tons of waste per day.**

Much of this waste – organic materials and non-recyclable paper and plastic – **can be gasified** to provide low-carbon hydrogen.

SB 1383 requires that **75% of this waste be diverted** from landfills by 2025.

Green hydrogen production is the solution to reducing waste in landfills, emissions from landfills, and creating a more circular economy

HyDeal NA and HyDeal LA Core Principles

We are creating a *community* designed to achieve **disruptive transformation** with green hydrogen:

1. **Think Big** – we need out of the box, multi-sectoral thinking that challenges the status quo
2. **Respect + Empathy = Trust.** Our strength is in our diversity of thinking and approaches. Consider and try on different viewpoints. Look for solutions where all parties win.
3. **Participate** – sharing your ideas will spark other ideas – don't withhold your constructive feedback and suggestions. Raise issues right away
4. **Foster Competition** – support technology and business model approaches that are technology agnostic and competitive
5. **Collaborate to Fight Climate Change**
   - HyDeal NA and HyDeal LA will not discourage progress for other pathways to accelerate decarbonization
   - Inclusivity - find ways to build bridges with relevant stakeholders and the broader clean energy community.
   - Equity –ensure that historically disadvantaged communities benefit from HyDeal NA and HyDeal LA efforts

With green hydrogen, 100% renewable energy is possible at competitive costs with today's wholesale electricity prices

	Explanation	Variable	Units	2028	2035	2045
Hydrogen Blended Costs	Hydrogen Cost Assumptions	Delivered GH2 Commodity Cost[5]	$/kg	**$2.00**	**$1.50**	**$1.00**
		Green Hydrogen Levelized Cost, *a*	$/MWh	**$116**	**$87**	**$58**
	IPP Plant at 100% Green Hydrogen	% Hydrogen Plant Consumption	%	**100%**		
		Power Plant Capacity Factor[1]	%	**65%**		
		Heat Rate[2]	BTU/kWh	**6400**		
		CCGT Units, *b*	$/MWh	**$26**		
	Carbon Abatement Cost Assumptions	GHG Cost[4]	$/metric ton CO_2	**$50**		
		GHG Savings, *c*	$/MWh	**($17)**		
	PPA Cost Assumptions	Blended Renewable Energy PPA Cost, *d*	$/MWh	**$15**		
	Blended GreenH_2 + PPA cost to achieve 24x7 100% renewable electricity	25%(a+*b*+c) +75%(*d*)	$/MWh	**$42**	**$35**	**$28**

1. Capacity Factor based on generic CC plant from modeling performed for CEC 1368 Requirements;
2. Heat rate based on levelized heat rate of advanced class units;
3. CC Unit costs based on minimum costs for O&M of equipment, based on utility grade requirements (O&M, financing, excludes fuel);
4. GHG Costs are provided as a floating variable. Reference IEPR Reports for cost projections;
5. Hydrogen commodity cost is based on projections from DOE based on technology development;
6. Hydrogen levelized costs of hydrogen generation based on green hydrogen including storage and transporation, and CCGT equipment modifications required;
7. Solar and wind $/MWh costs may fluctuate with market price. Sourced from Pacificorp's tariffs. Seeing rates currently at $5/MWh

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