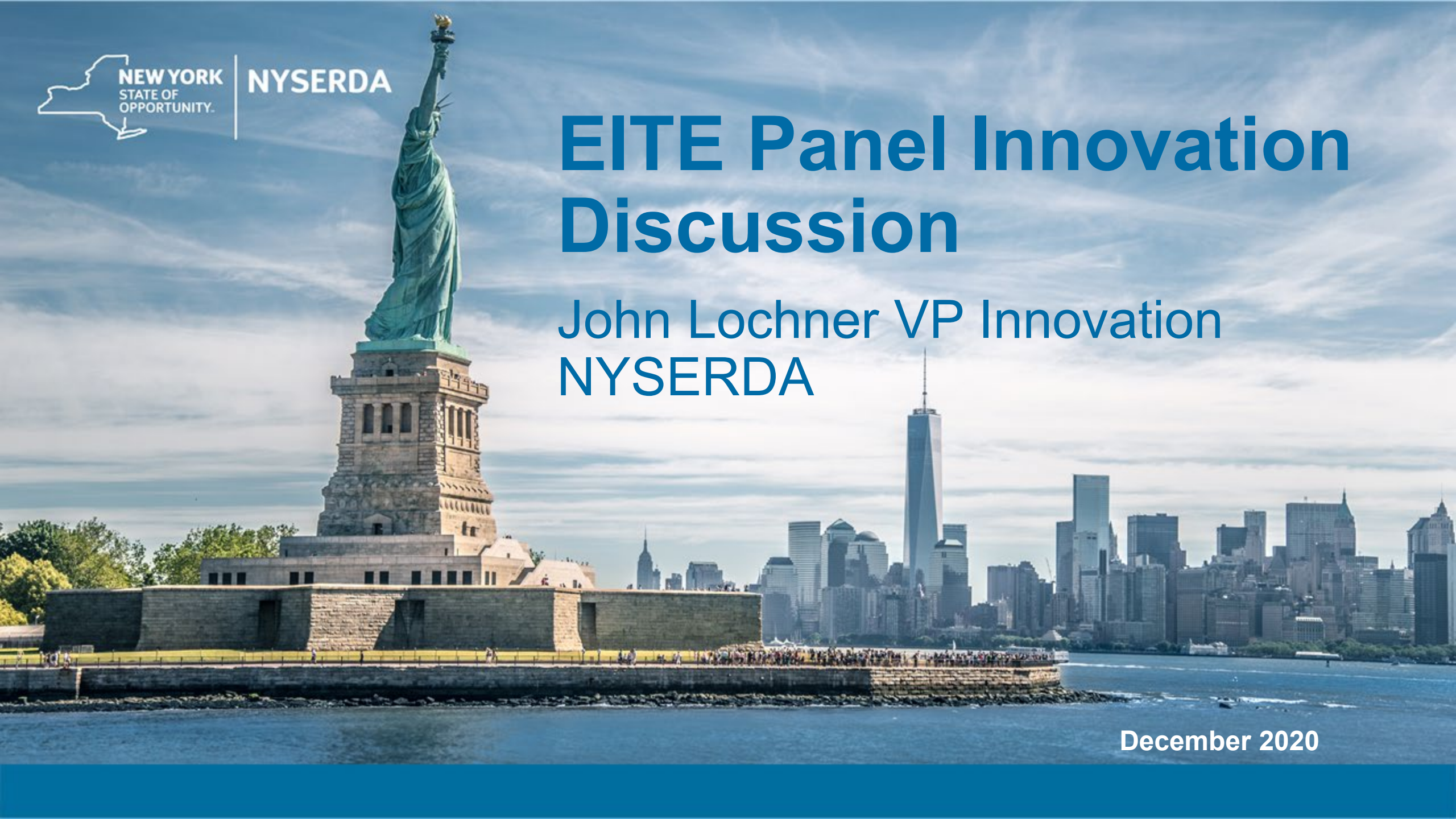

EITE Panel Innovation Discussion

John Lochner VP Innovation
NYSERDA

December 2020

Agenda

1. Brief overview of Innovation
2. Review of Deep Decarbonization Workshop Materials
   a) Hydrogen
   b) Carbon Capture
3. New York Opportunities

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The foundational source of long term global economic growth and improvements of quality of life is technological innovation. Technological Innovation can be linked to three quarters of the US growth rate since WW I

-U.S. Chamber of Commerce

The innovation sector has the largest [jobs] multiplier of all: about three times larger than that of manufacturing.

- MIT Sloan Management Review

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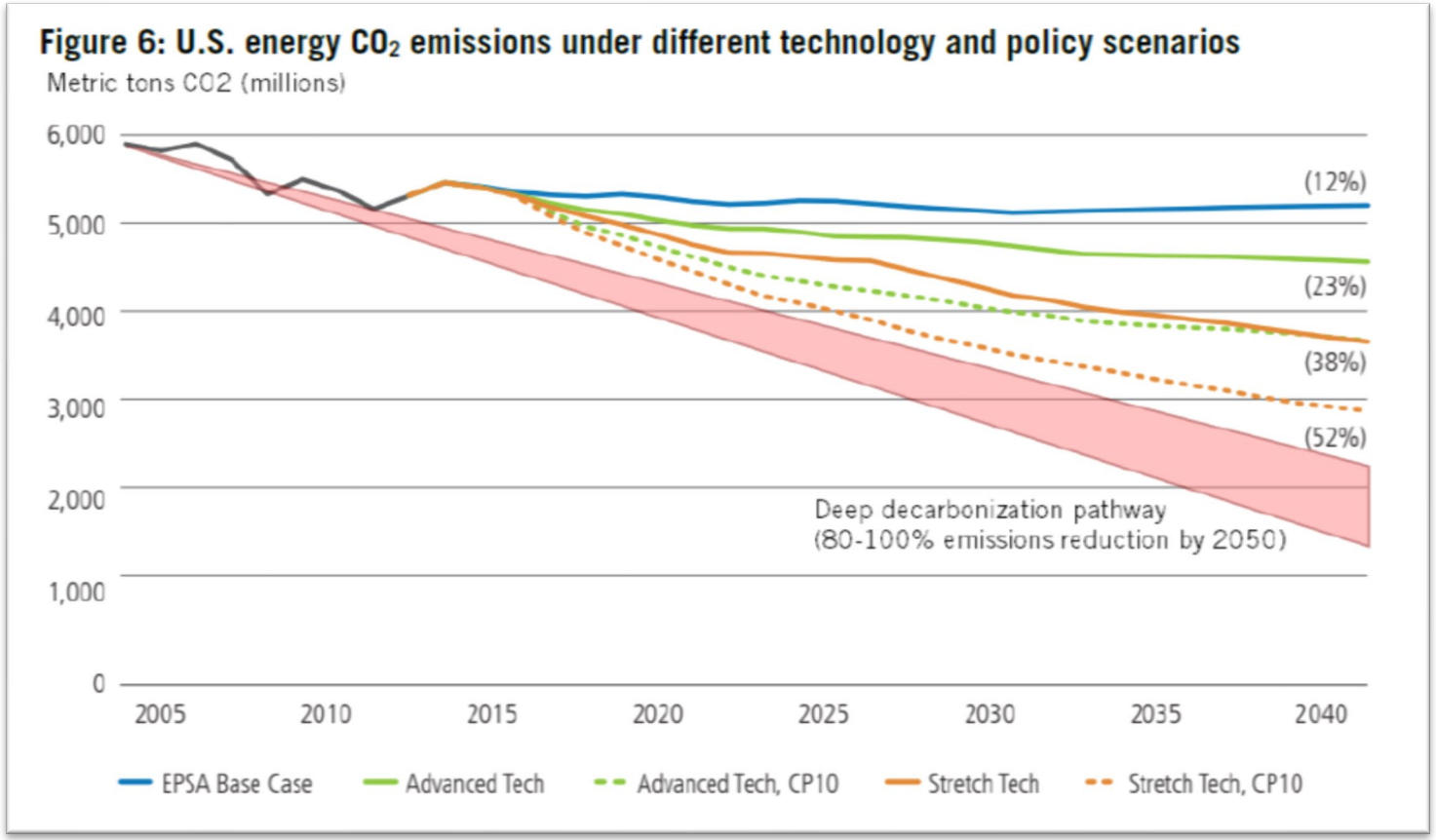
National Innovation Funding Needs for Decarbonization by Mid Century

- DOE Findings that 80% decarbonization only achievable if
  - R&D in the Federal government is DOUBLED for energy applications
  - All DOE energy aspirational goals are completely met
  - $10 / ton of CO2e exists and increases by 5% annually



Innovation funding gaps exist at all stages

Deep Decarbonization Workshop Overview

1. Hydrogen
2. Carbon Capture

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Hydrogen

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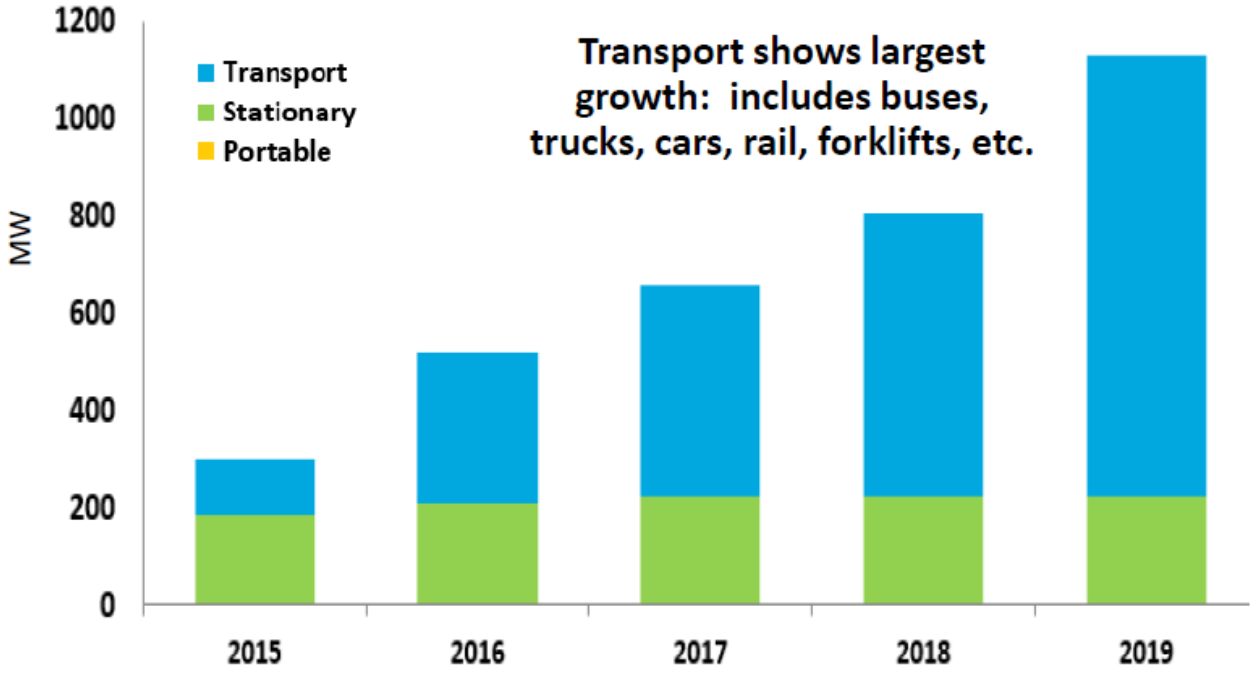
Hydrogen & Fuel Cell Global Growth

Global fuel fell shipments surpass 1 GW



Source: DOE

Source: E4tech for DOE analysis project

25-fold increase in electrolyzers deployed in the last decade

<1MW in 2010 to >25 MW by the end of 2019

Global FCEVs doubled to >25,200

>12.3K sold in 2019 vs. 5.8K in 2018

470 H_2 fueling stations worldwide

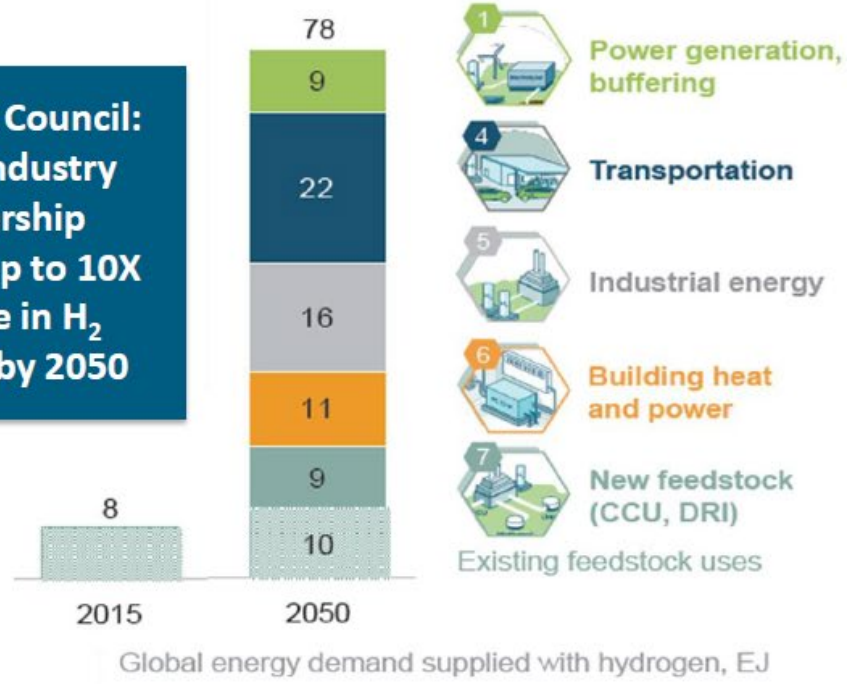
> 20% increase from 2018

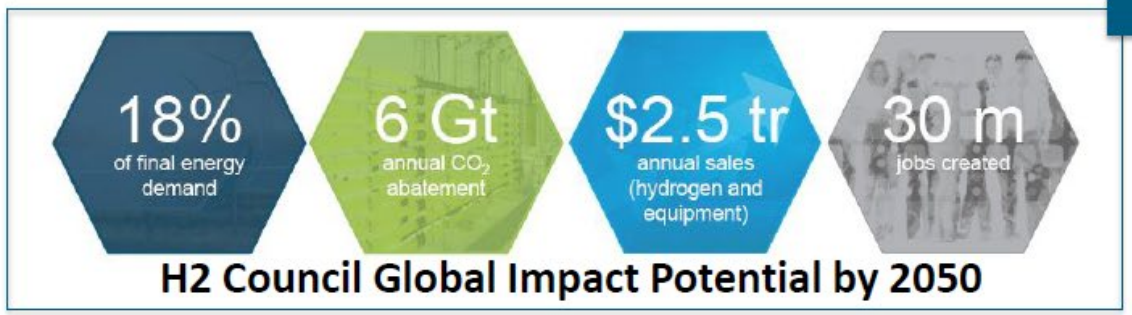
Source: IEA (2020), *Hydrogen*, IEA, Paris, https://www.iea.org/reports/hydrogen

Global Hydrogen Roadmaps & Plans

H2 Ministerial Global Action Agenda Goals:
"10, 10, 10"
10M systems, 10K stations, 10 years

Hydrogen Council: Global industry partnership projects up to 10X increase in H_2 demand by 2050





Source: DOE

Global Hydrogen Goals & Commitments

€65bn

Investment required by 2030

€20bn

EU investment in funding initiatives

Green Deal, Horizon 2020, EU Innovation Fund, IPCEI, Green Ports & Airports

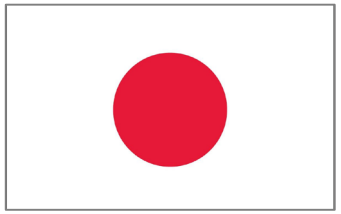
Clean Hydrogen Alliance at CEO Level

European Clean Hydrogen Alliance

REUTERS

Australia fast tracks mega renewable energy, hydrogen project

At full capacity, **the project could generate up to 100 terawatt hours a year. By comparison, Australia generated 265 terawatt hours last year.** The **site is 6,500 square kilometres, more than double the size of Luxembourg**.



Aims to achieve **cost parity with competing fuels such as gasoline** in the transportation sector or **liquefied natural gas (LNG) in power generation** and covers the entire supply chain from production to downstream market applications.

Existing Hydrogen Infrastructure in the U.S.

Examples of Applications

- **>500MW** — Backup Power
- **>35,000** — Forklifts
- **>14 MW** — PEM* Electrolyzers
- **>60** — Fuel Cell Buses
- **>45** — H_2 Retail Stations
- **~9,000** — Fuel Cell Cars

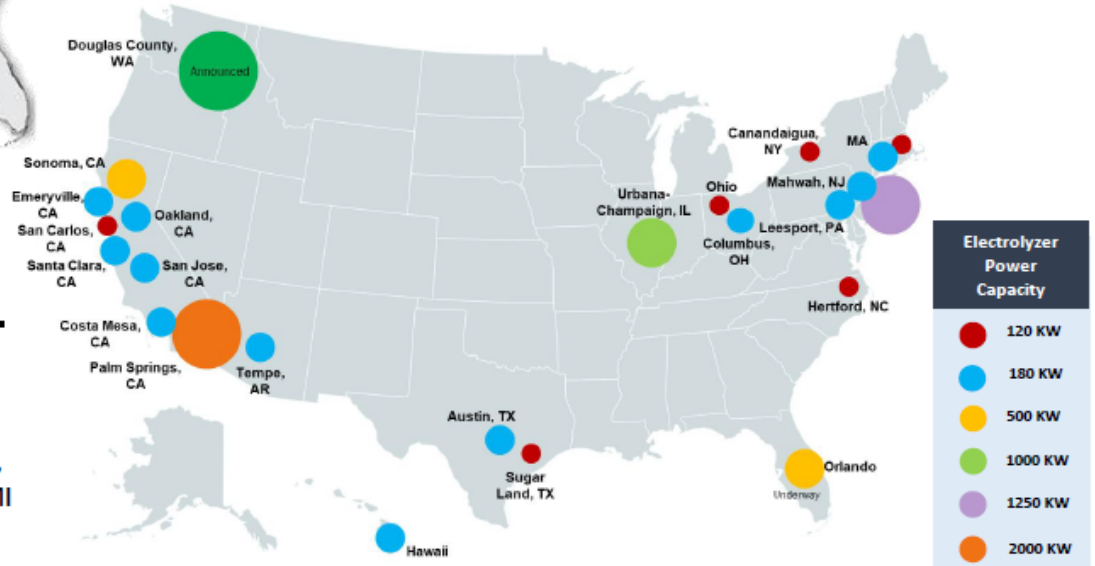
Hydrogen Production Across the U.S.

0 – 50
50 – 100
100 – 200
200 – 400
400 – 800

Hydrogen Production Units
Gaseous Metric Tons/Day

- 10 million metric tons produced annually
- More than 1,600 miles of H_2 pipeline
- World's largest H_2 storage cavern

PEM Electrolyzer Deployment Across the U.S.



* Polymer electrolyte membrane

Hydrogen Stations Plans Across States

California	Northeast	HI, OH, SC, NY, CT, MA, CO, UT, TX, MI
200 Stations Planned CAFCP Goal	12 – 20 Stations Planned	And Others

Source: DOE

Carbon Capture

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Circular Carbon Economy

> **Only one way to stabilize climate: net-zero everywhere**
  - Any emissions anywhere add to atmospheric CO_2 concentration
  - Every year of delay makes problem worse
  - We haven't yet fielded solutions for about 50% of the portfolio

> **For net zero: CO_2emissions - CO_2removals = 0**
  - Any residual emissions must be balanced by removal
  - Likely need 10 Gt/y CO_2 removal by 2050
  - Any delay or failure requires more CO_2 removal

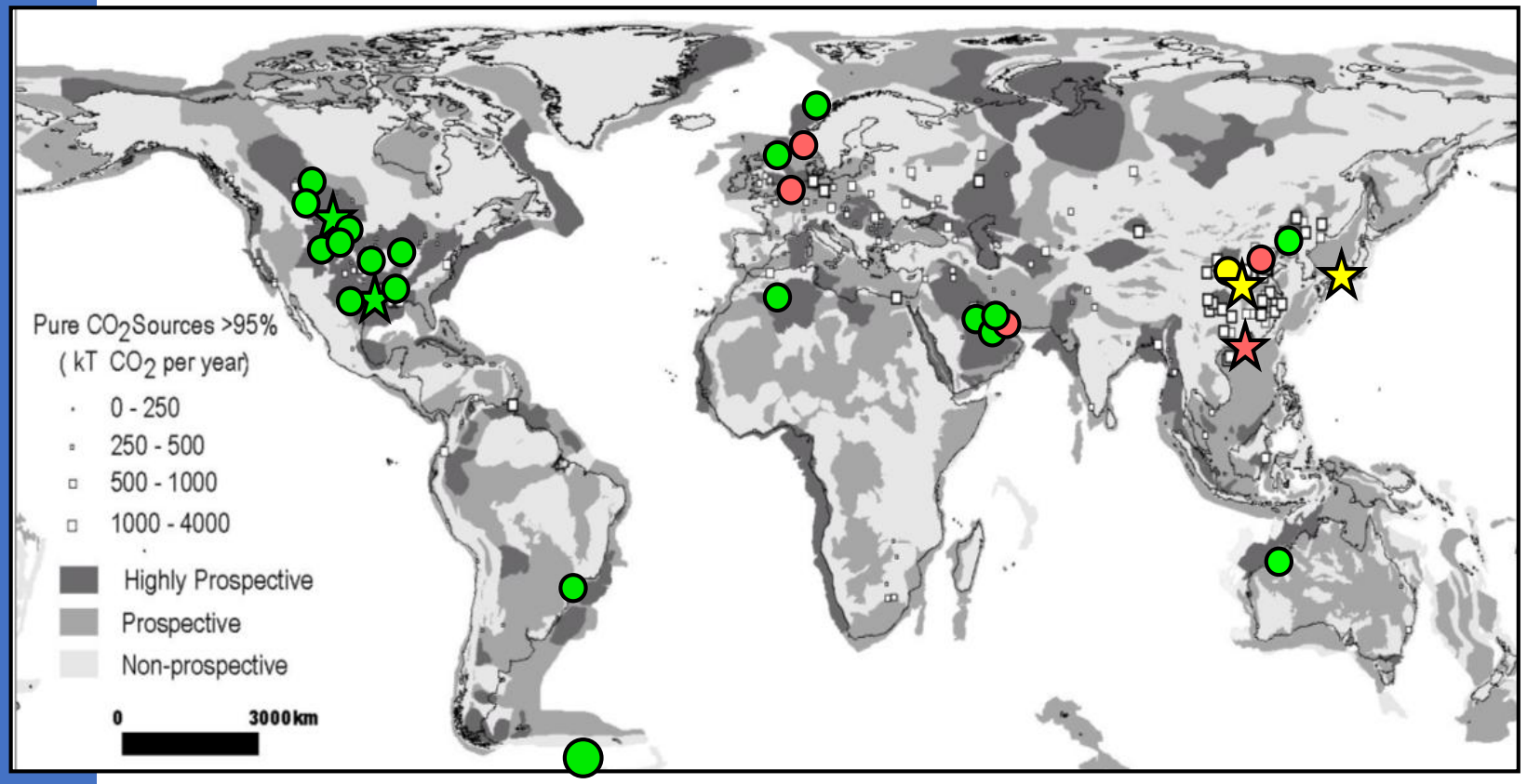
> **Carbon from the earth must be returned to the earth**
  - Natural systems must return to balance
  - Biosphere has limited capacity (especially in State)
  - Risk of return is getting worse

Source: Julio Friedman and Columbia SIFA

Current Deployments

21 operating plants, storing ~35m tons CO_2 each year

Estimated storage worldwide: 10-20 trillion tons



Operating

Under construction

Advanced planning

Industrial project

Power project

Source: Julio Friedman and Columbia SIFA

By the Numbers

10 nations have commercial CCS facilities

- U.S., Canada, Norway, Algeria, Australia, China, UAE, Saudi Arabia, Qatar, Brazil
- Countries in advanced development: Netherlands, Japan, U.K.
- 10 nations mention CCS in their NDCs

21 operating facilities world-wide

- ~40M tons/year anthropogenic CO_2
- ~260M tons cumulative
- Facilities: Power (2) hydrogen (5), steel (1), chemicals (2) ethanol (1), natural gas processing (many)
- Over 100 pilot and demo projects with >20 years of science
- Monitoring tools and regulatory framework well established

Science & technology well established

- First commercial carbon capture facility: 1938
- First large-scale CO_2 injection: 1972
- First climate-based CO_2 return project: 1996 (Sleipner, Norway)

Source: Julio Friedman and Columbia SIFA

Many Approaches to Carbon Removal

Source: Julio Friedman and Columbia SIFA, Carbon 180

Carbon management benefits to a just transition

Local Air Quality Improvements

- Some industrial facilities with high CO_2 emissions also emit high levels of criteria air pollutants such as sulfur dioxide (SO_2), nitrous dioxide (NO_2), and particulates
- **Post-combustion carbon capture requires reduction of these other pollutants creating local air quality benefits**

Local Economic Activity

- CCS projects can **stimulate local economic activity**, including new construction, operations, and maintenance jobs
- **Multiplier effects across the supply chain can drive additional economic benefits**

Job Creation and Preservation

- The economic benefits associated with **job training** could provide new employment opportunities in the low carbon economy
- CCS activities support **employment** for skill sets which may otherwise become obsolete in a clean energy transition

Source: Julio Friedman and Columbia SIFA

Source: EFI & Stanford Univ, 2020

Opportunities for New York

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Economic Development Through Climate Innovation

BROOKINGS

Source: Brookings & ITIF

How Can New York Help Enable Needed Technologies

- **Increase State funding of Research, Development & Deployment for climate innovations**
- **Promote engagement with Federal initiatives & funding**
  - Support allocation of federal dollars to climate RD&D
  - Coordinate with DOE and other agencies to support programs of interest and co-fund investments
- **Coordinate technology needs with New York State competitive advantages and economic development strategies**
  - Roadmaps for developing & increasing in-State supply chains, ecosystems, and R&D expertise

How Can New York Help Enable Needed Technologies

- **Technology agnostic policies to reach climate goals**
  - RECs, procurements, & others
- **Assess tax policies to support capital investment in localities and R&D activities in the State**
- **Engage catalytic capital sources to fund demonstrations & pilots as an industry**
- **Fellowships & support for PHDs & labs / Support to universities**
- **Develop and maintain technology roadmaps to assess and revise priority solutions**