8th Annual EPRI-IEA Workshop

Challenges in Decarbonisation: Building a Resilient Net-Zero Future

Panel 1: Flexibility and Resiliency in Decarbonised Energy Systems

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Decarbonization Pathways Enabled by Innovation

~10-15 years

~15-30 years

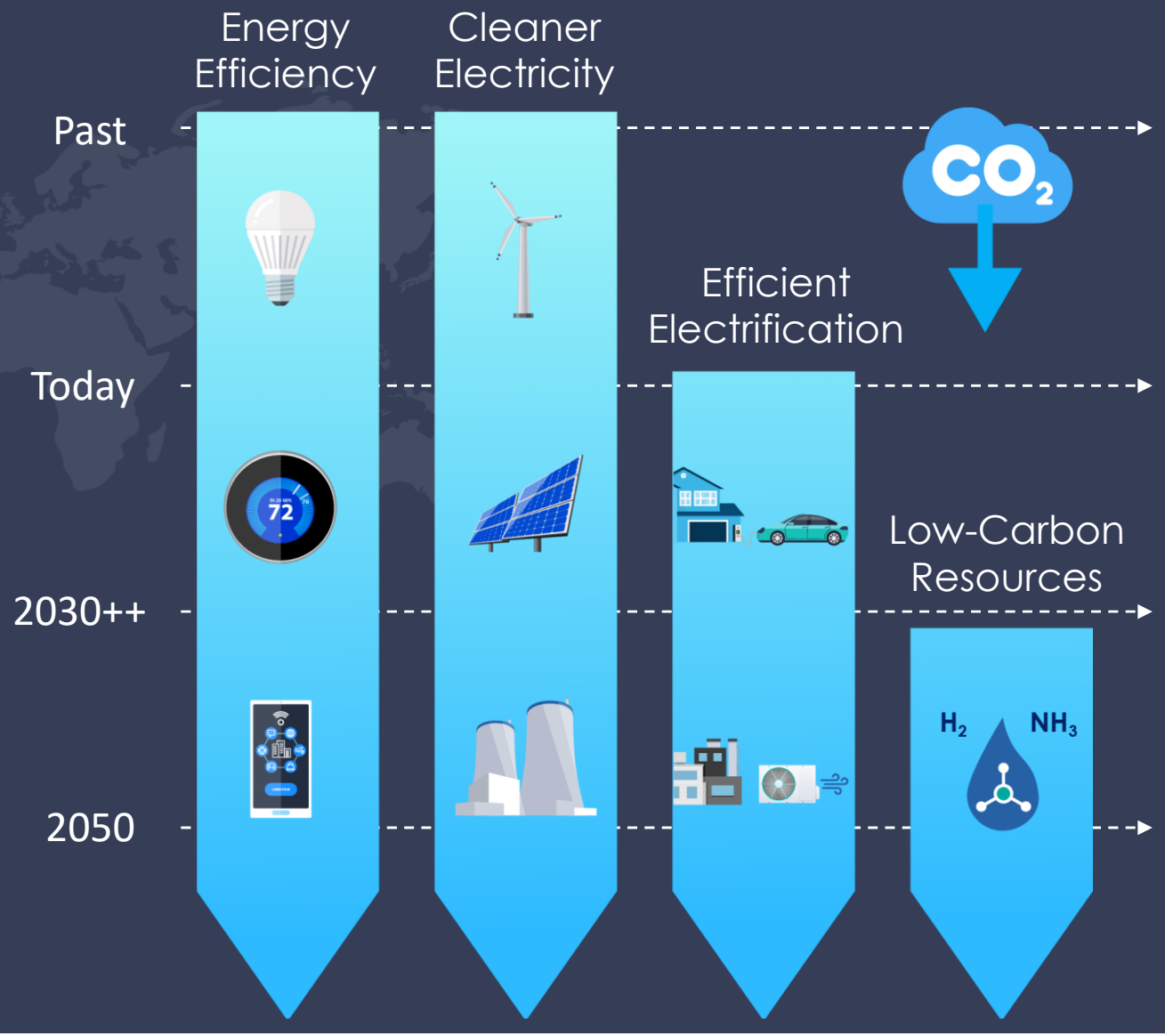
Decarbonization

Accelerate economy-wide, low-carbon solutions

- Electric sector decarbonization
- Transmission and grid flexibility: storage, demand, EVs
- Efficient electrification

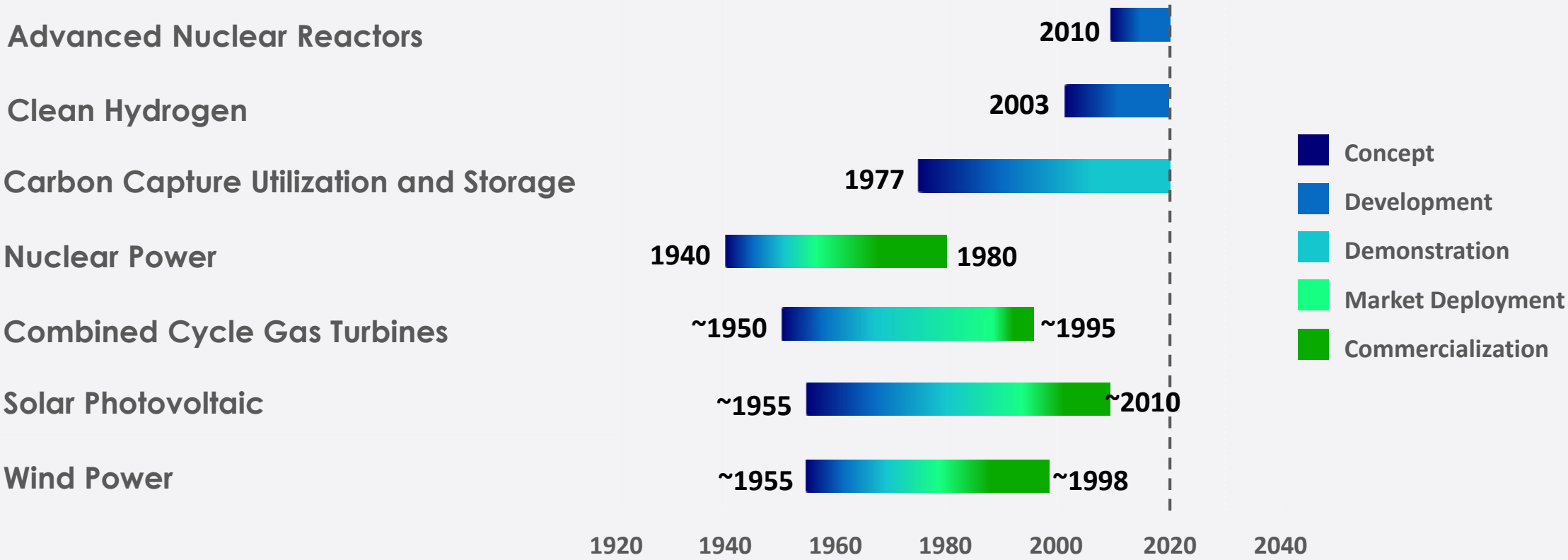
Achieve a net-zero clean energy system

- Ubiquitous clean electricity: renewables, advanced nuclear, CCS
- Negative-emission technologies
- Low-carbon resources: hydrogen and related, low-carbon fuels, biofuels, and biogas



TECHNOLOGY

Decades of Effort
from concept to commercialization

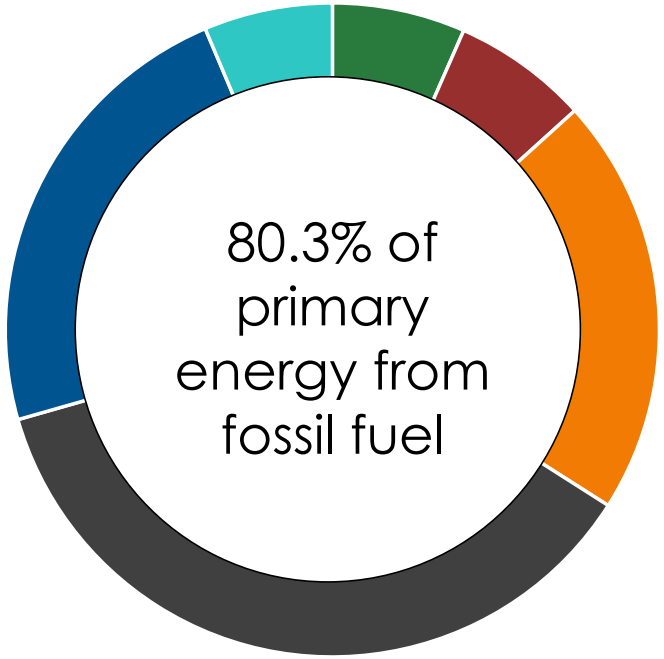


Notional timelines

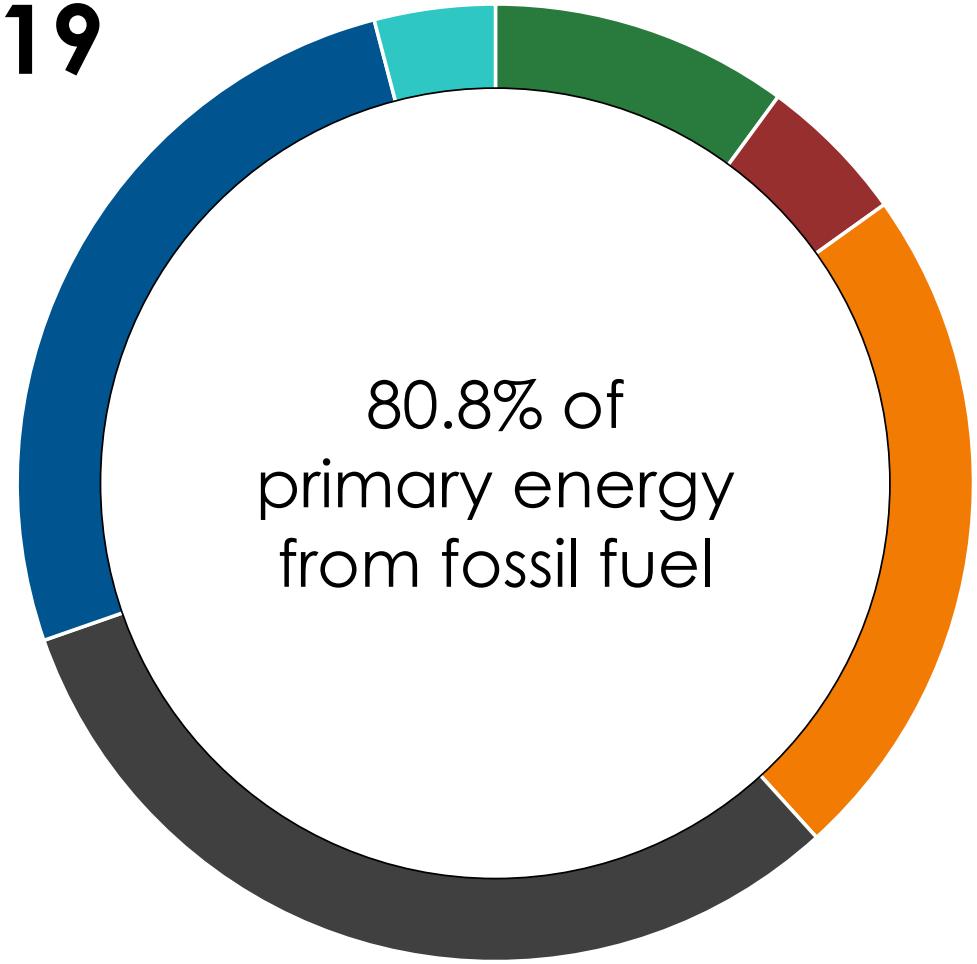
Energy Transformation

Global Energy reliant on fossil fuels

2000



2019



Biomass
Renewables
Nuclear
Natural Gas
Oil
Coal

Reference: https://www.iea.org/data-and-statistics/charts/global-primary-energy-demand-by-fuel-1925-2019

Global Role of CCUS

Energy Sector
contributions to net zero

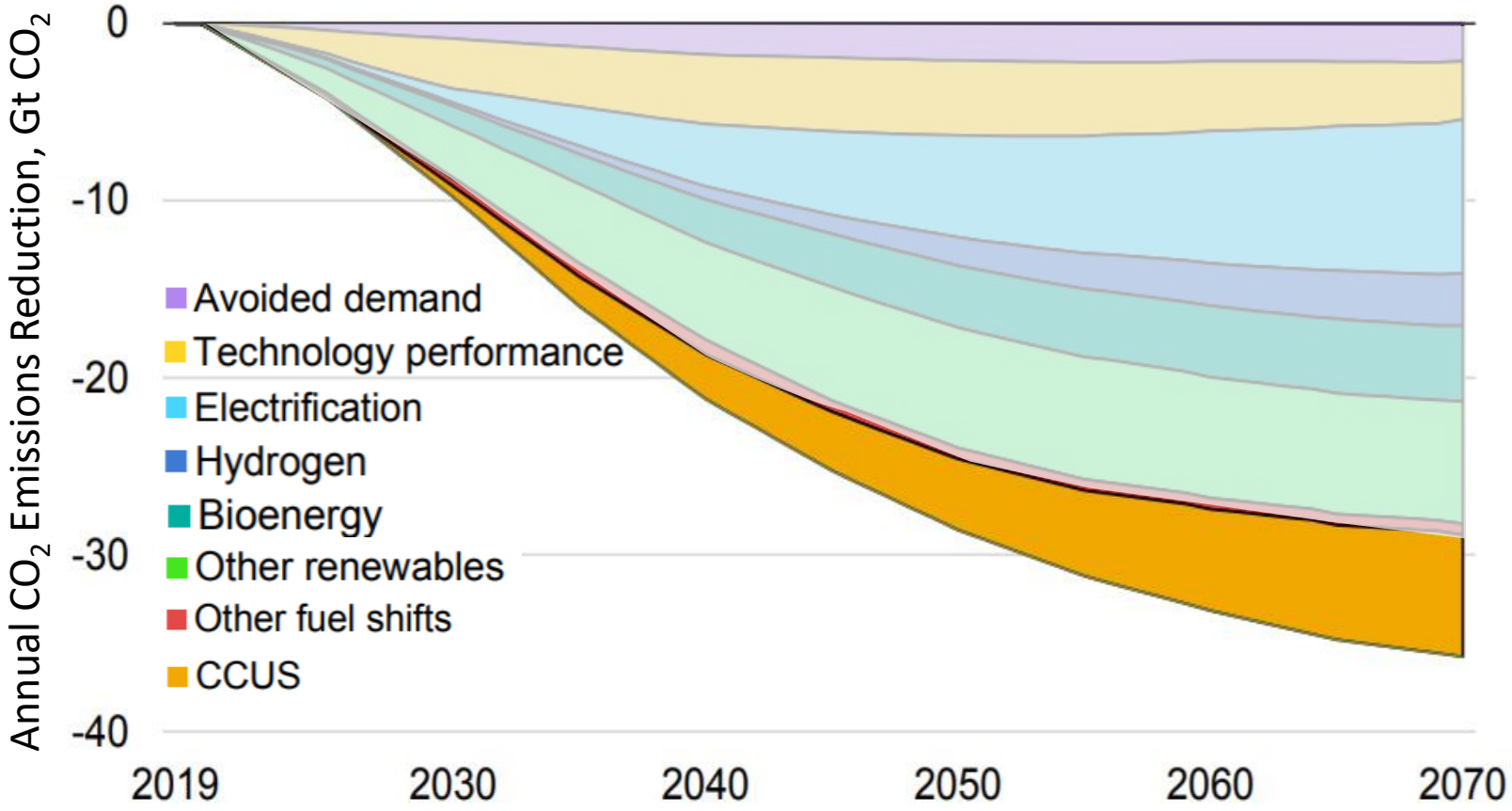


Figure from IEA, 2020

IEA Net Zero from Energy Sector

CCS 15% of cumulative global emissions by 2070

IPCC Global Warming of 1.5°C

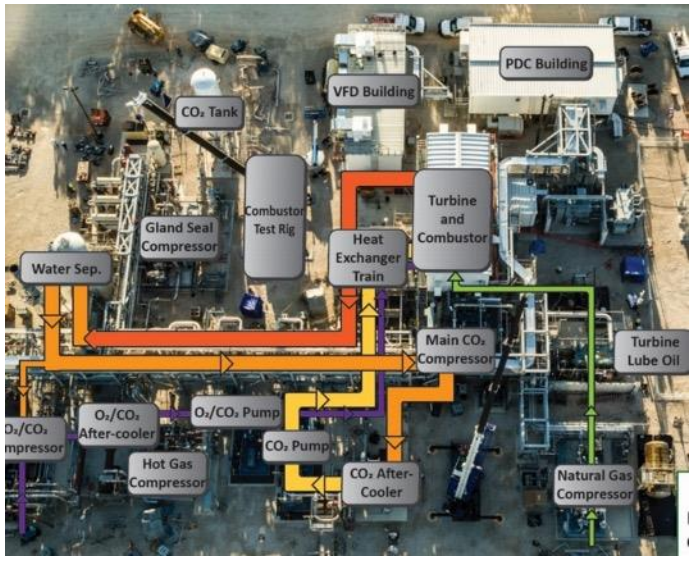
Up to 300 Gt CO_2 stored cumulatively through 2050

References: International Energy Agency, Special Report on CCUS, Energy Technology Perspectives, 2020
IPCC Special Report on Global Warming of 1.5 °C, WG 1, 2019

CO_2 Capture on Coal and Natural Gas Power Generation

Coal Flue Gas
~12-15% CO_2

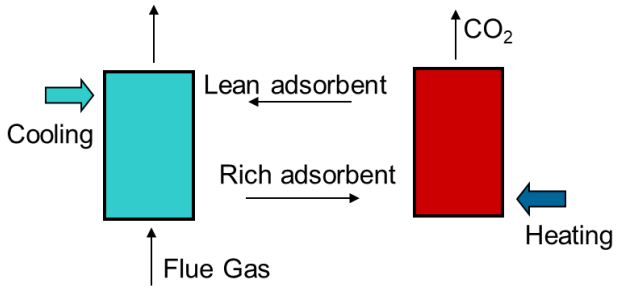
Nat. Gas Combined Cycle Flue Gas
~3-4% CO_2



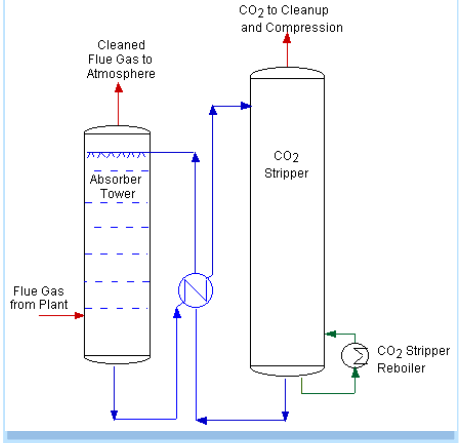
Nat. Gas
Allam Cycle
>98% CO_2 (anticipated)

CO_2 Capture Technologies for Coal and Natural Gas

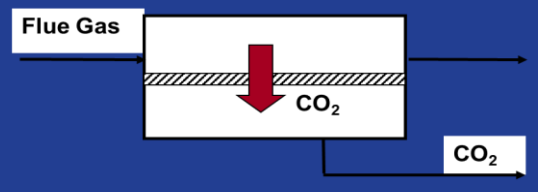
Adsorbent

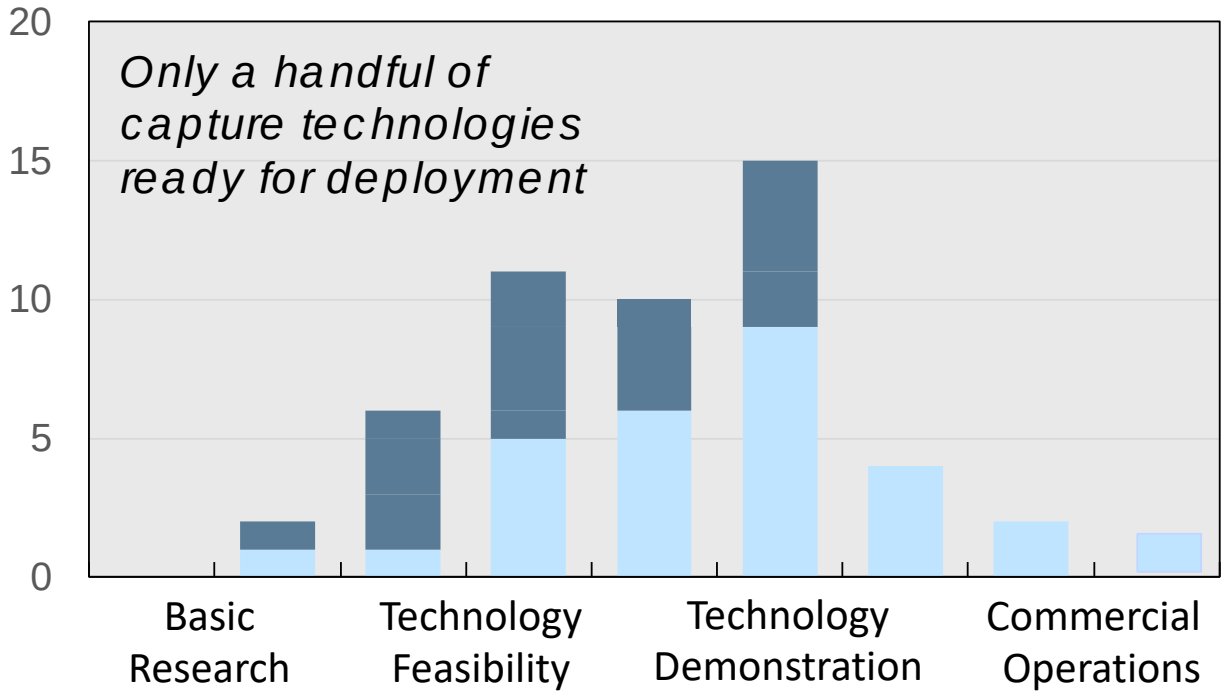


Solvent



Membrane

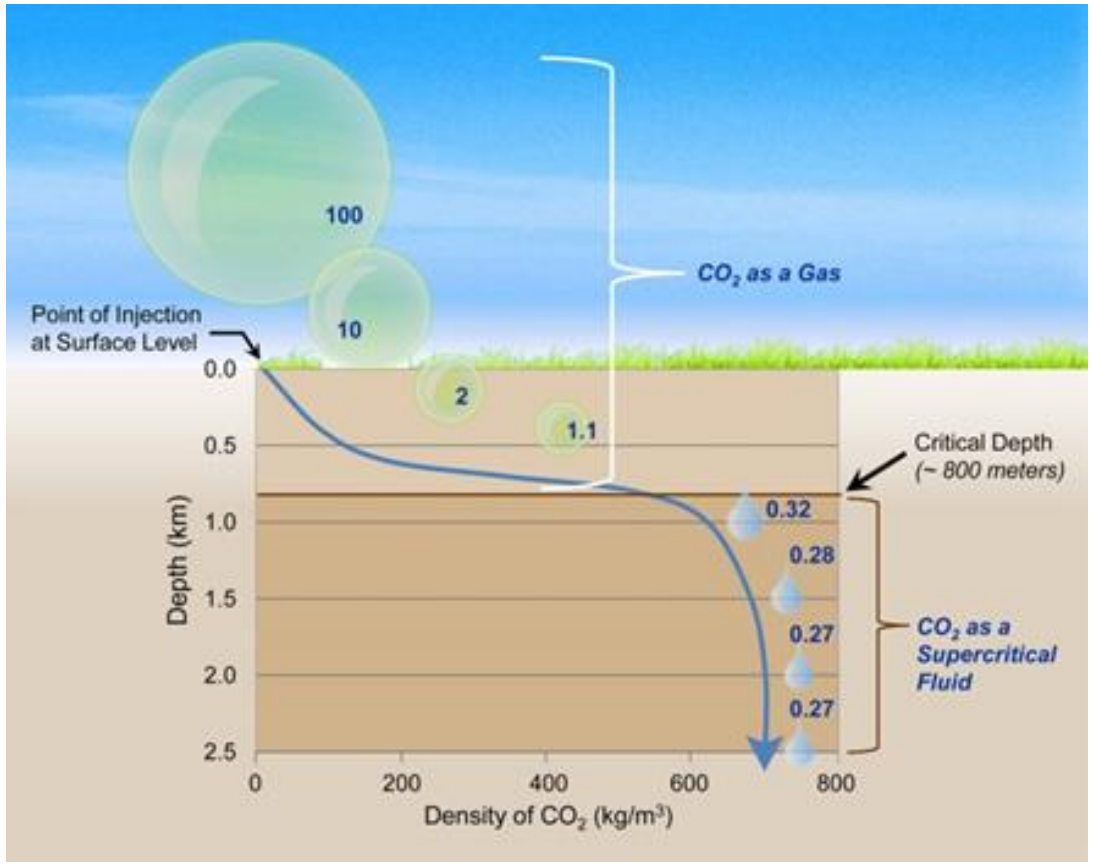




CO_2 Geologic Storage Options

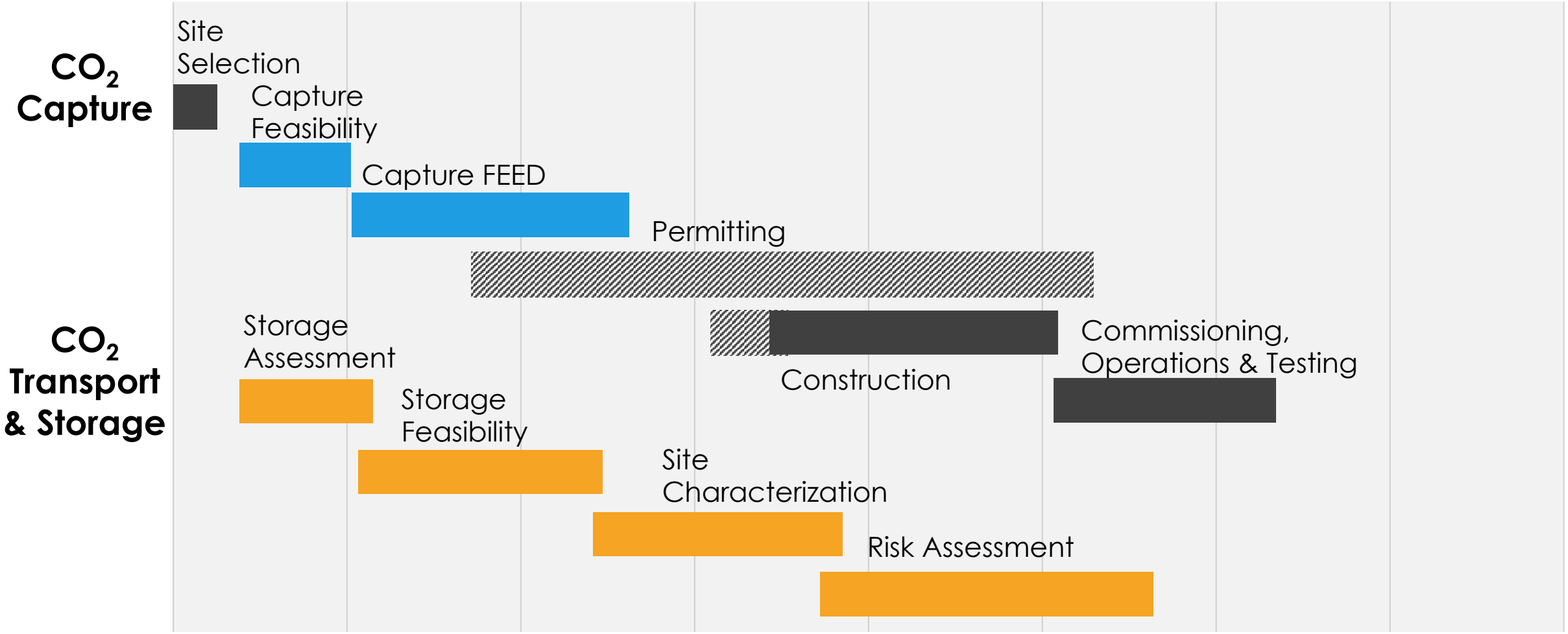
- Saline formations
  - Largest capacities, most common
- Oil and gas fields
  - Depleted fields
  - Enhanced oil recovery (EOR)
  - Enhanced natural gas recovery
- Coal seams
- Enhanced coal bed methane
- Other
  - Basalts, shales, cavities

Geologic storage potential may be geographically constrained



Source: NETL https://netl.doe.gov/coal/carbon-storage/faqs/carbon-storage-faqs. (Accessed 10/3/21). Illustration of Pressure Effects on CO_2 (based upon image from CO2CRC). The blue numbers show the volume of CO_2 at each depth compared to a volume of 100 at the surface.

CCS Demonstration Project Commitment is 7-10 Years



Energy Storage Today

Can these technologies meet all energy storage needs?

Pumped Hydro

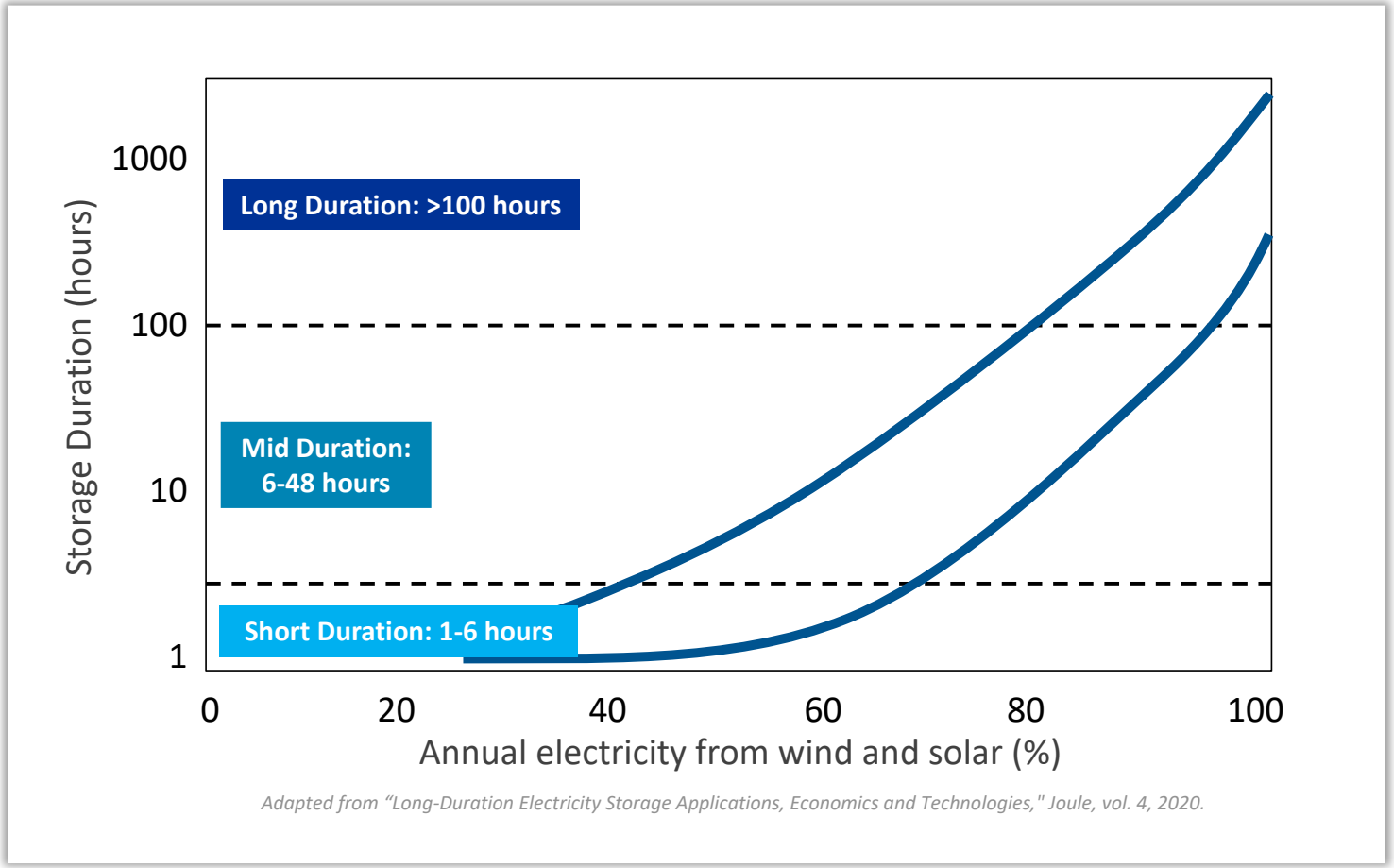
9 TWh (93%)
Size: GWhs, 8–12 hours

Lithium-Ion Batteries

0.7 TWh (7%)
Size: MWhs, 1–6 hours

Energy Storage Evolution

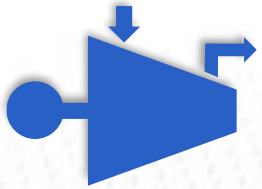
- **As intermittent renewables increase, the duration of energy storage needed also increases**
- **As storage duration increases, different types of energy storage are needed**



Adapted from "Long-Duration Electricity Storage Applications, Economics and Technologies," Joule, vol. 4, 2020.

Different durations of energy storage will be required

Energy Storage Types



Electrochemical	Thermal	Mechanical	Chemical
Reversible chemical reaction generates an electrical potential difference	Energy storage achieved by heating bulk media	Kinetic or potential (compression or gravitational)	Reaction produces product that can generate heat or power

Different technologies for different purposes

Energy Storage

Industry Needs
Questions from decision makers

What does it cost?

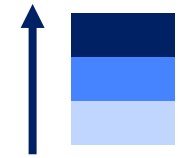
How will it perform?

What value does it provide?

How does it operate in the field?

Once installed, how do we best operate and maintain it?

Energy Storage Comparison



	Li-Ion Batteries	Pumped Hydro	Thermal	Mechanical	Chemical
Cost of Storage					
Duration					
Efficiency (AC-AC)					
Environmental					
Footprint					
Inertia					
Maturity					
O&M					
Response Time					
Safety					
Scalability					
Startup Time					

No energy storage technology is one-size-fits-all

Beyond 2030

Integration of Low-Carbon Energy Carriers

Hydrogen Ammonia Synthetic/ Derivative Fuels Biofuels

Production Sources

Next Gen Technologies

Integrated Clean Electricity

Integrated Nuclear (Current & Advanced)

Natural Gas with CCS

Delivery & Storage

Existing Natural Gas Pipeline through Blending and/or New Infrastructure

Shipping, Trucking, and Conversion/Intermediates

Aboveground and Underground Storage

End Use Applications

Combustion

Heavy Duty Transportation

Electricity Generation

Advanced Fuel Cell

Large Industry

Chemical Processes

Hydrogen

Expanding the Energy Economy
Hydrogen production costs

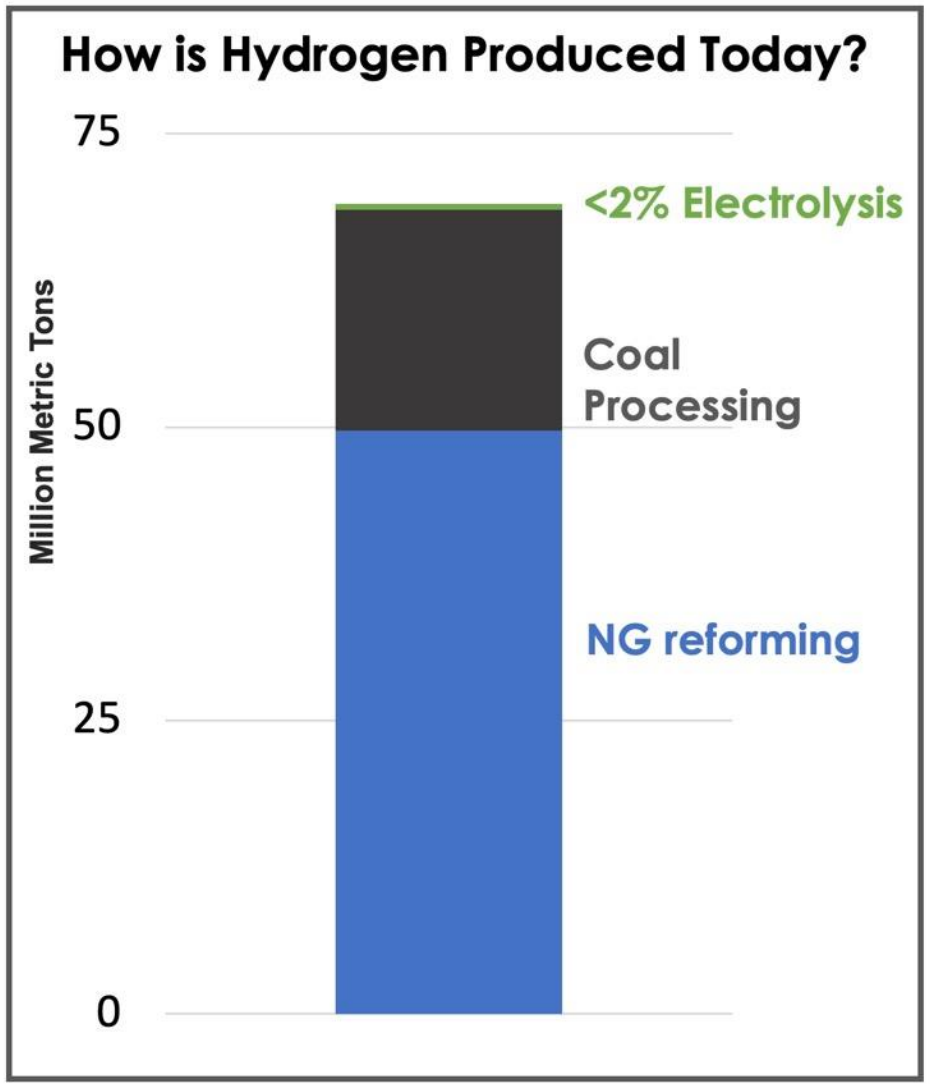
WHAT IF...

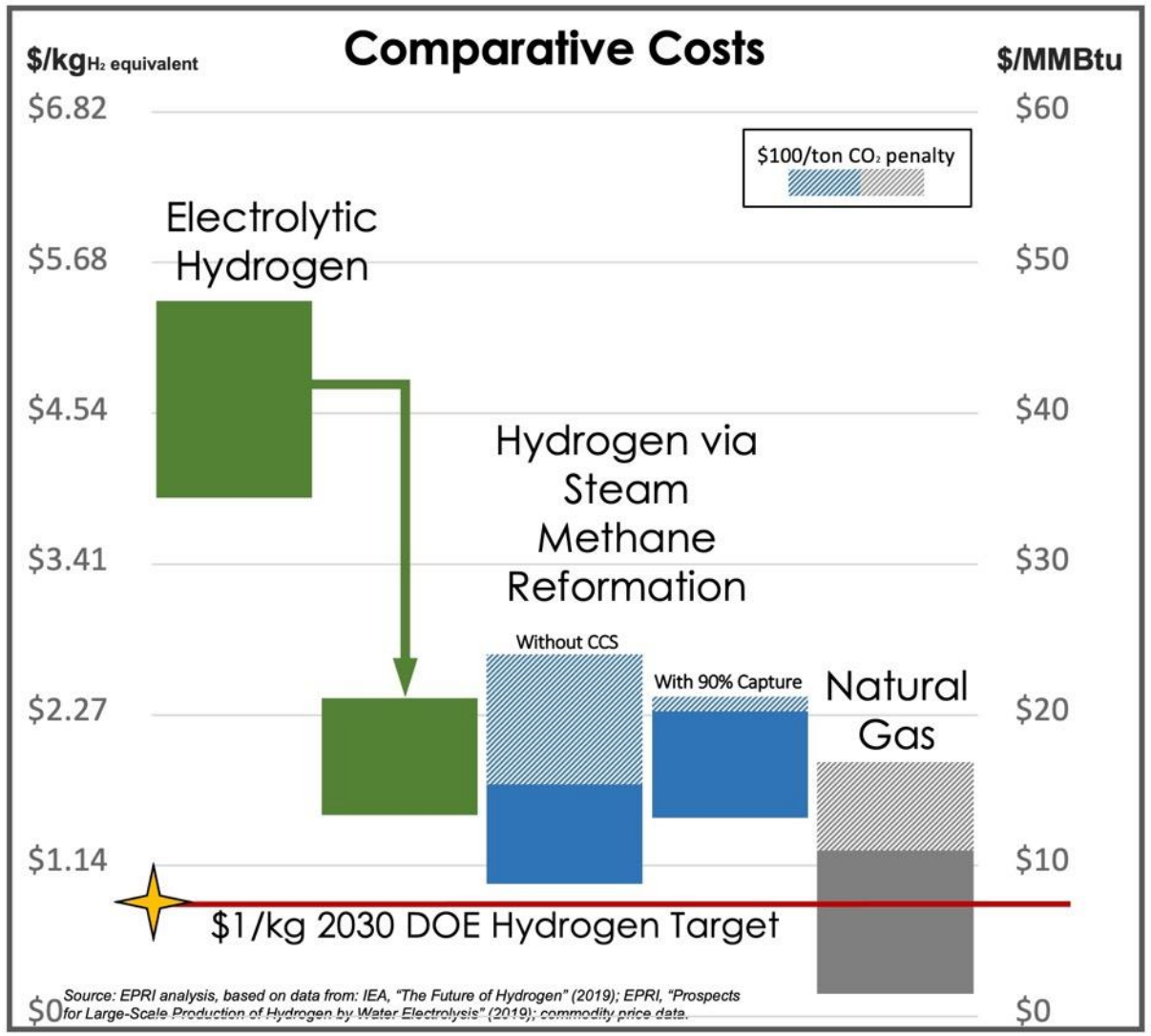
All of the hydrogen used globally today was produced from electricity?

The amount of **electricity consumed** would be equal to

88% of the electricity generation in the **United States** today

nearly **14%** of electricity consumption **worldwide**





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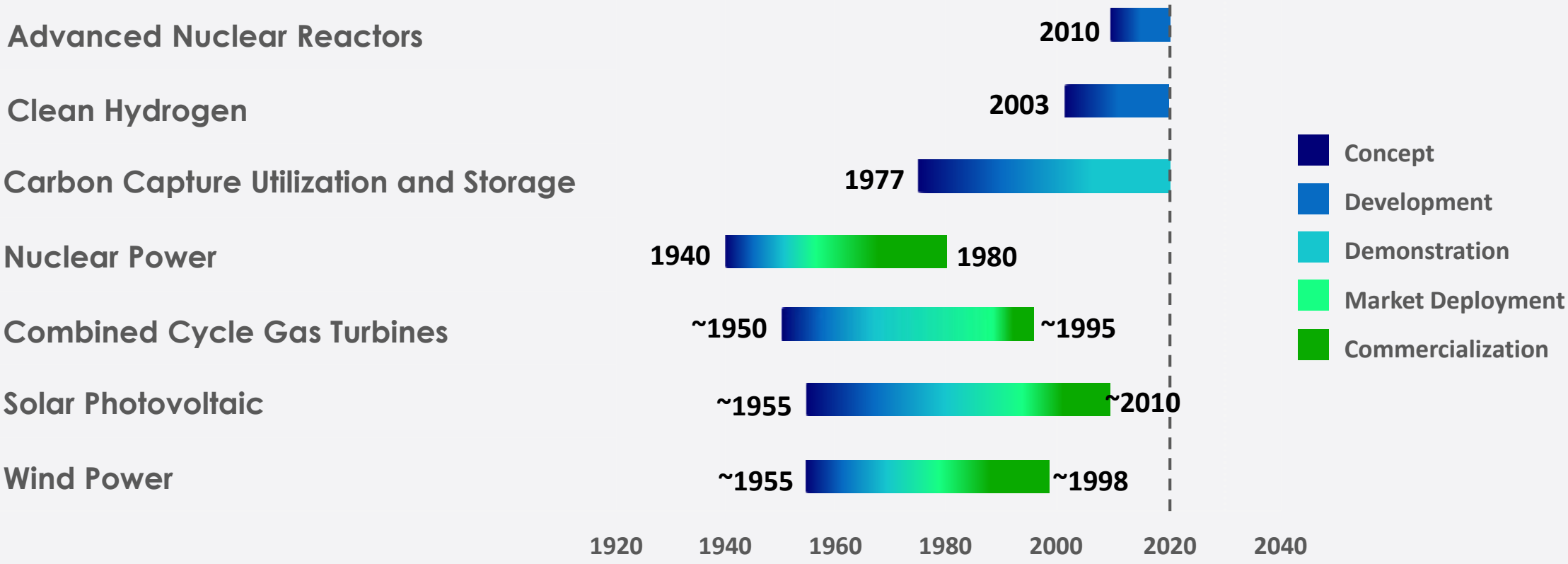

Notional timelines