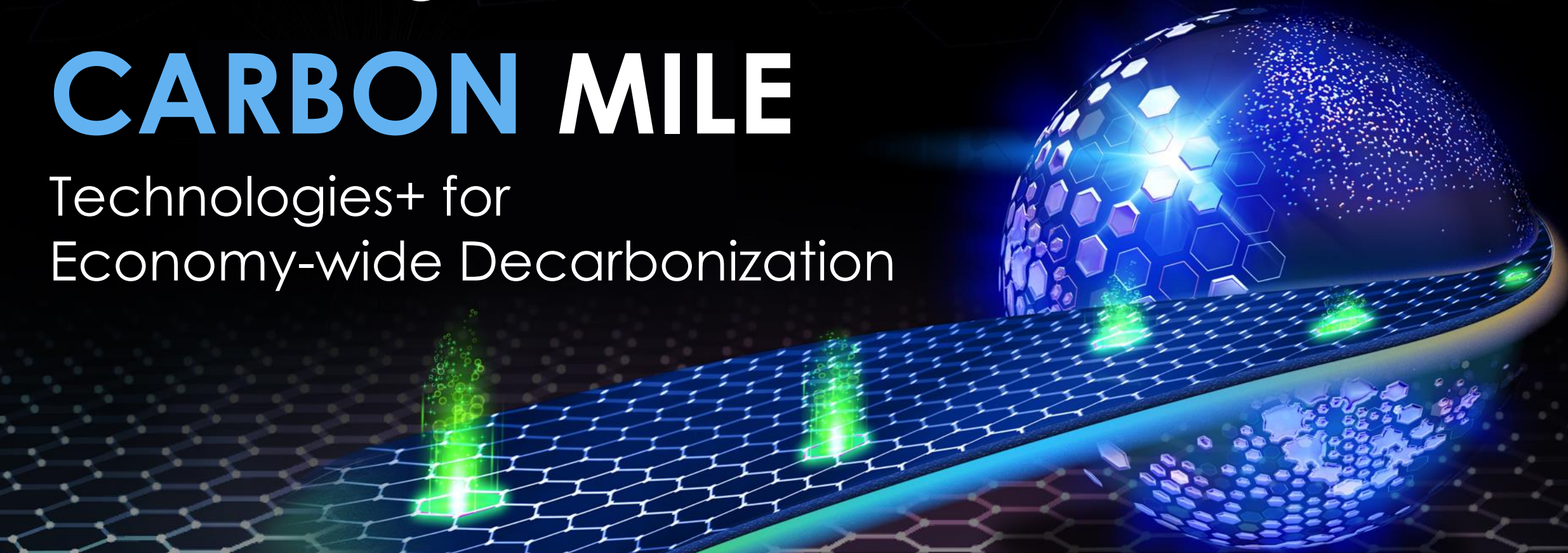
# THE LAST CARBON MILE

## Technologies+ for Economy-wide Decarbonization



**Neva Espinoza**
Vice President, EPRI

# Energy Transition Will Be Extensive

## Decarbonization

~10-15 years

Accelerate economy-wide, low-carbon solutions

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

~15-30 years

Achieve a net-zero clean energy system

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

## Transformation

Drive affordability of a clean and resilient energy system through digital transformation

- Power system modernization: pervasive sensors, monitoring, advanced analytics using AI
- Upgraded and expanded communications infrastructure and control systems

## Resiliency

~10-15 years

Mitigate climate impacts and cyber/physical risks

- System and asset hardening
- Improved response
- Faster recovery
- Cybersecurity

~15-30 years

Future proof energy system design basis

- Resilient power system design
- Advanced asset design and strategic undergrounding
- Smart integration of energy carriers

**Making Energy More**

**Clean** | **Affordable** | **Reliable**

# Decarbonization Pathways Enabled by Innovation

## Decarbonization

**Accelerate economy-wide, low-carbon solutions**

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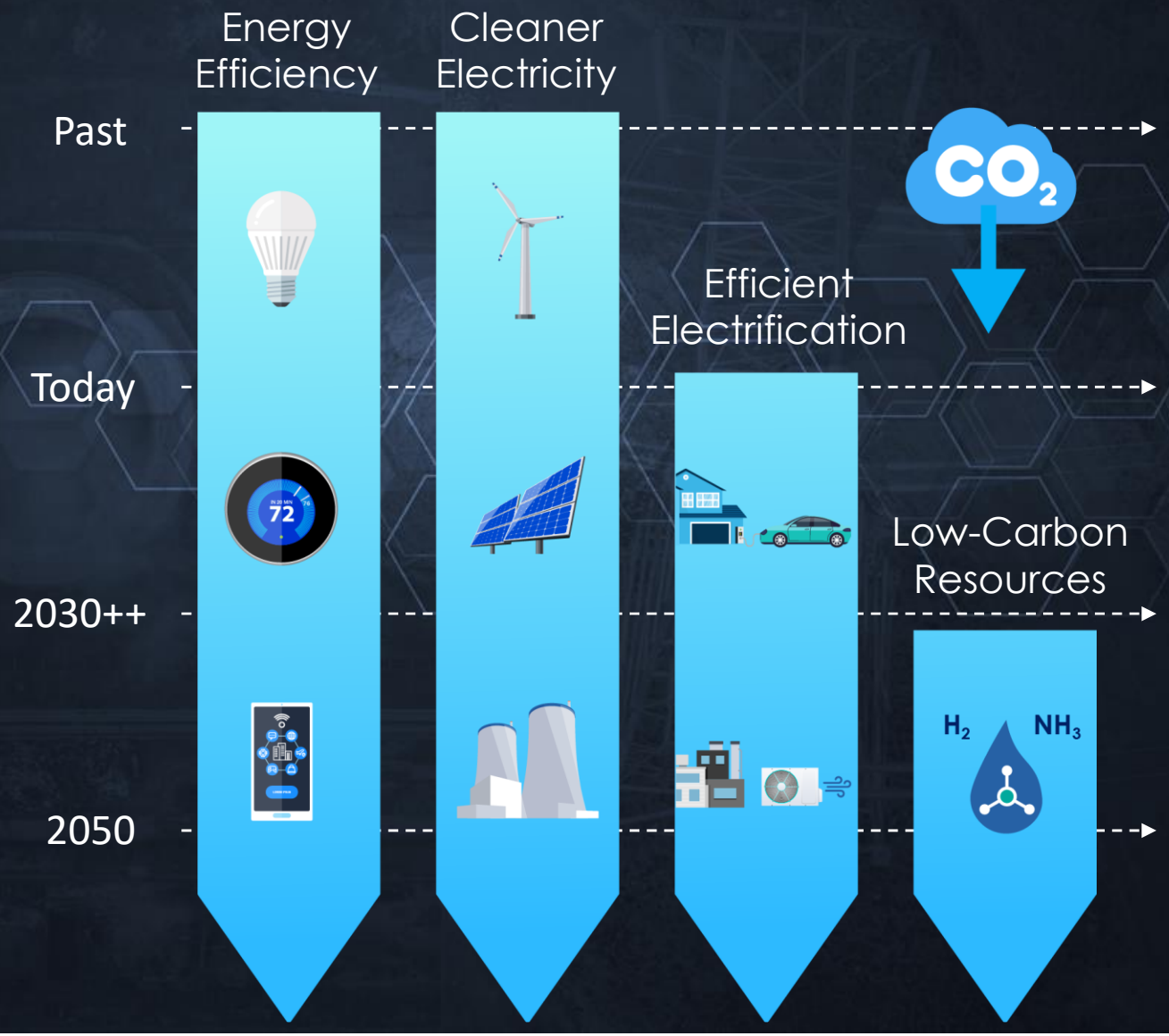


## DECADE OF CHANGE

# WHAT 2030 LOOKS LIKE

2020 — 2030

### Extreme Weather

1-in-100-year events are now 1-in-10

### Renewables

3X to 4X growth by 2030

### Electric Transportation

~1/2 of new car and fleet sales electric

### Critical Minerals

transitioning from fuel to material dependent system

**Grid Hardening**
**Community Resilience**

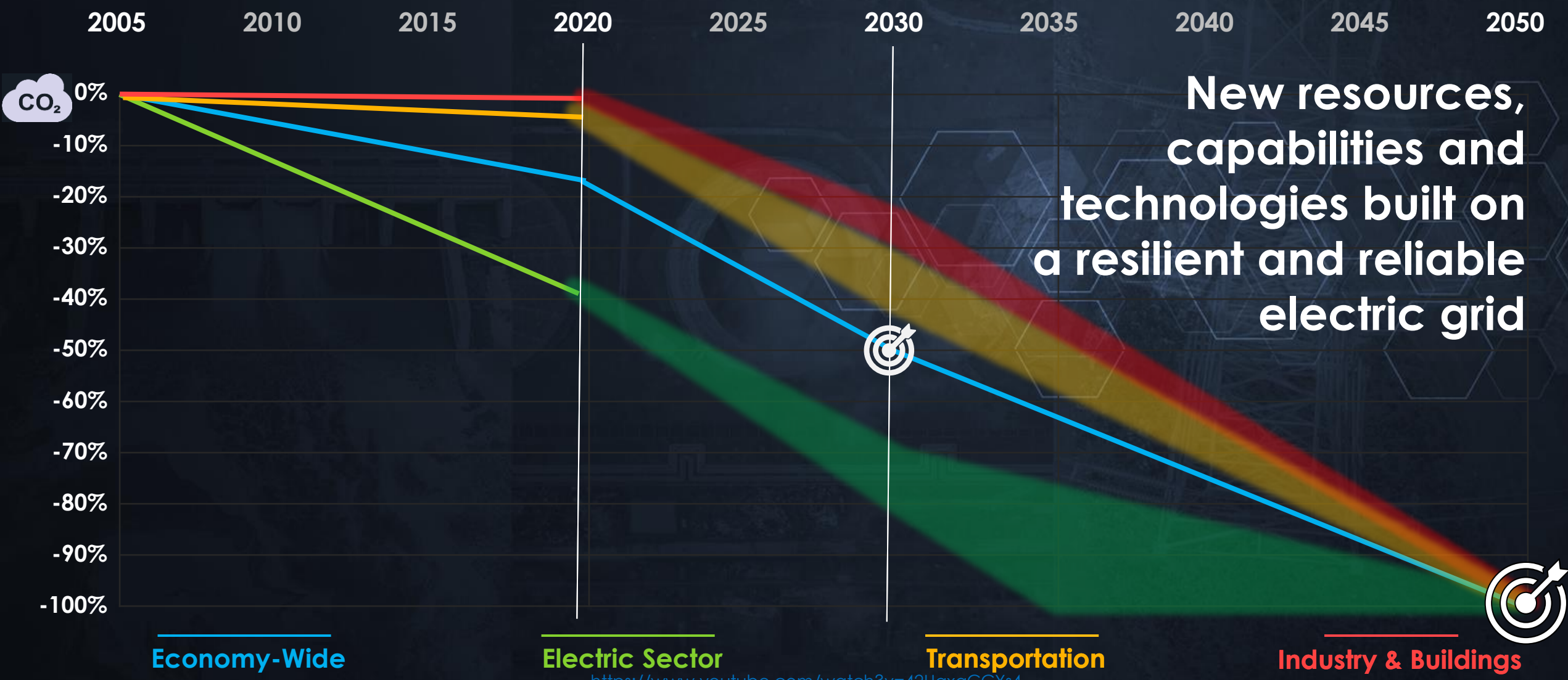
**Resource Adequacy**
**Transmission**

**Societal Dependance**
**Reliable Electricity**

**Critical Mineral Supply Chain**

# U.S. GOALS

## Pathway to Net-Zero
grid underpins the transition

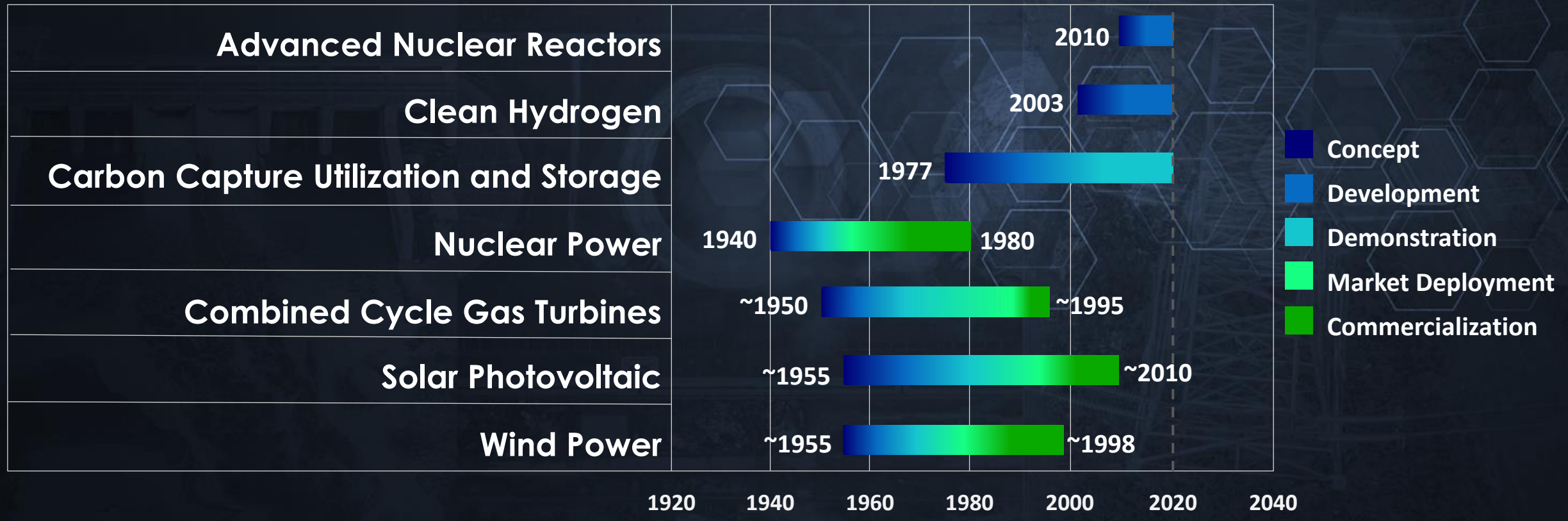



**New resources, capabilities and technologies built on a resilient and reliable electric grid**

https://www.youtube.com/watch?v=42UqxqCCYs4

# TECHNOLOGY

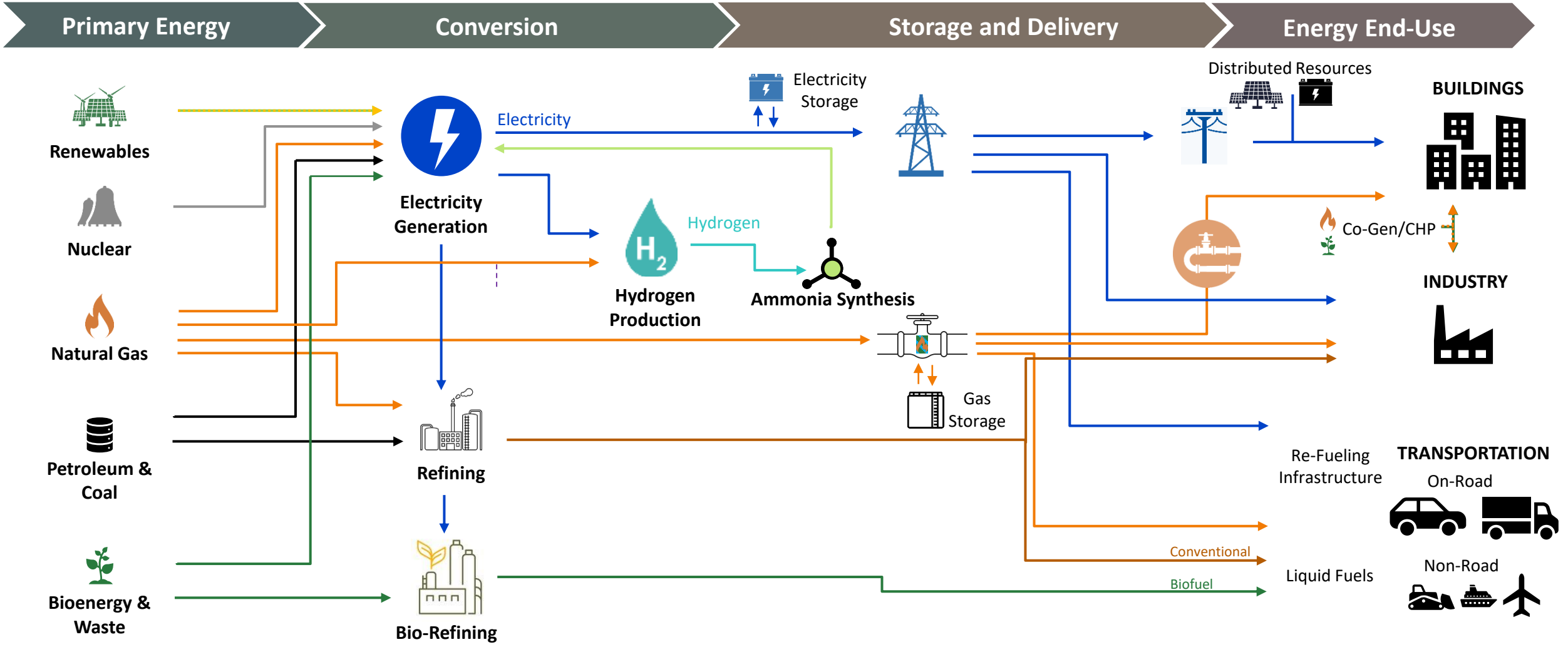
## Decades of Effort
from concept to commercialization




*Notional timelines*

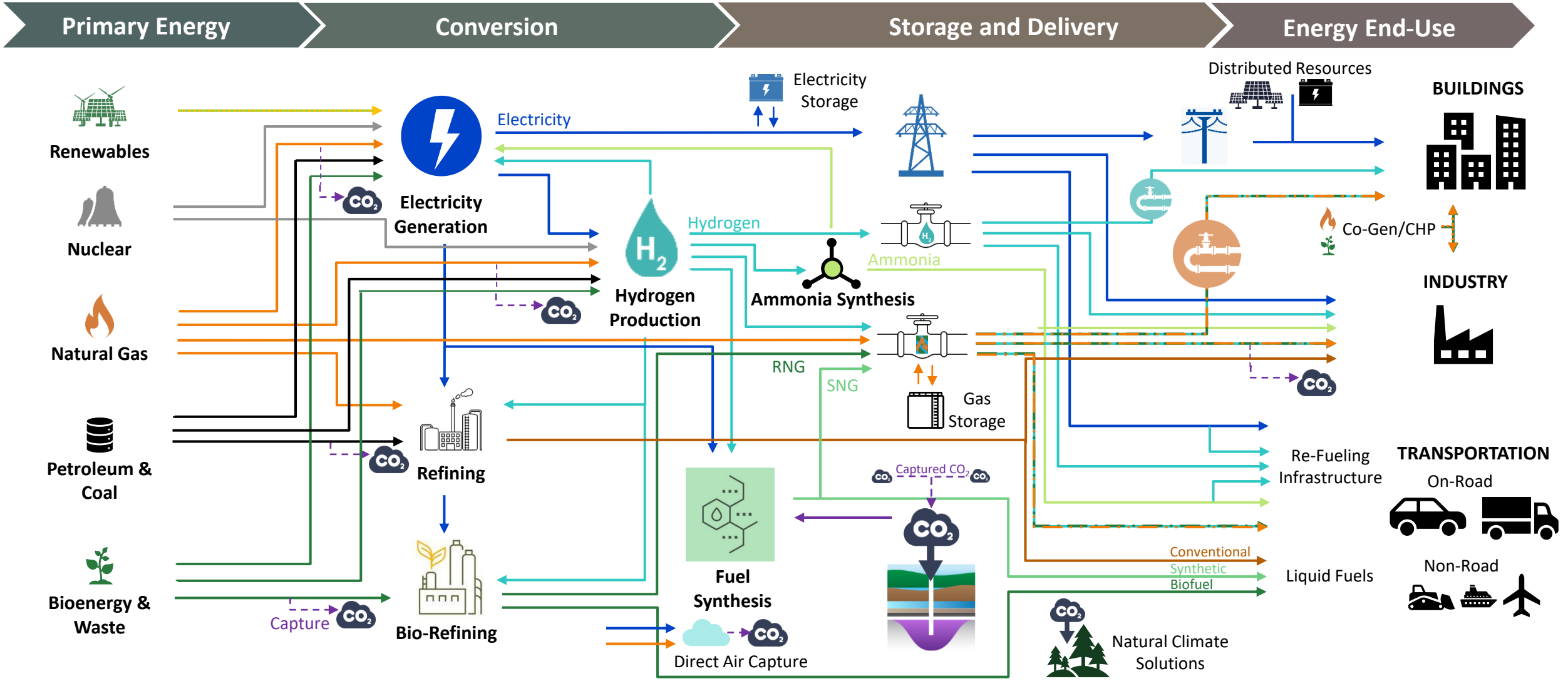
# TECHNOLOGY+++

## Energy System won't be as 'simple' as today



# COMPLEXITY

## New Resources and Players
how will they fit and transition?



# CCUS

# Demonstration to Deployment
## acceleration and collaboration needed today

## Capture

**"Capture dominates the cost of CCUS."**

*Abhoyjit Bhown, EPRI*

## Utilization

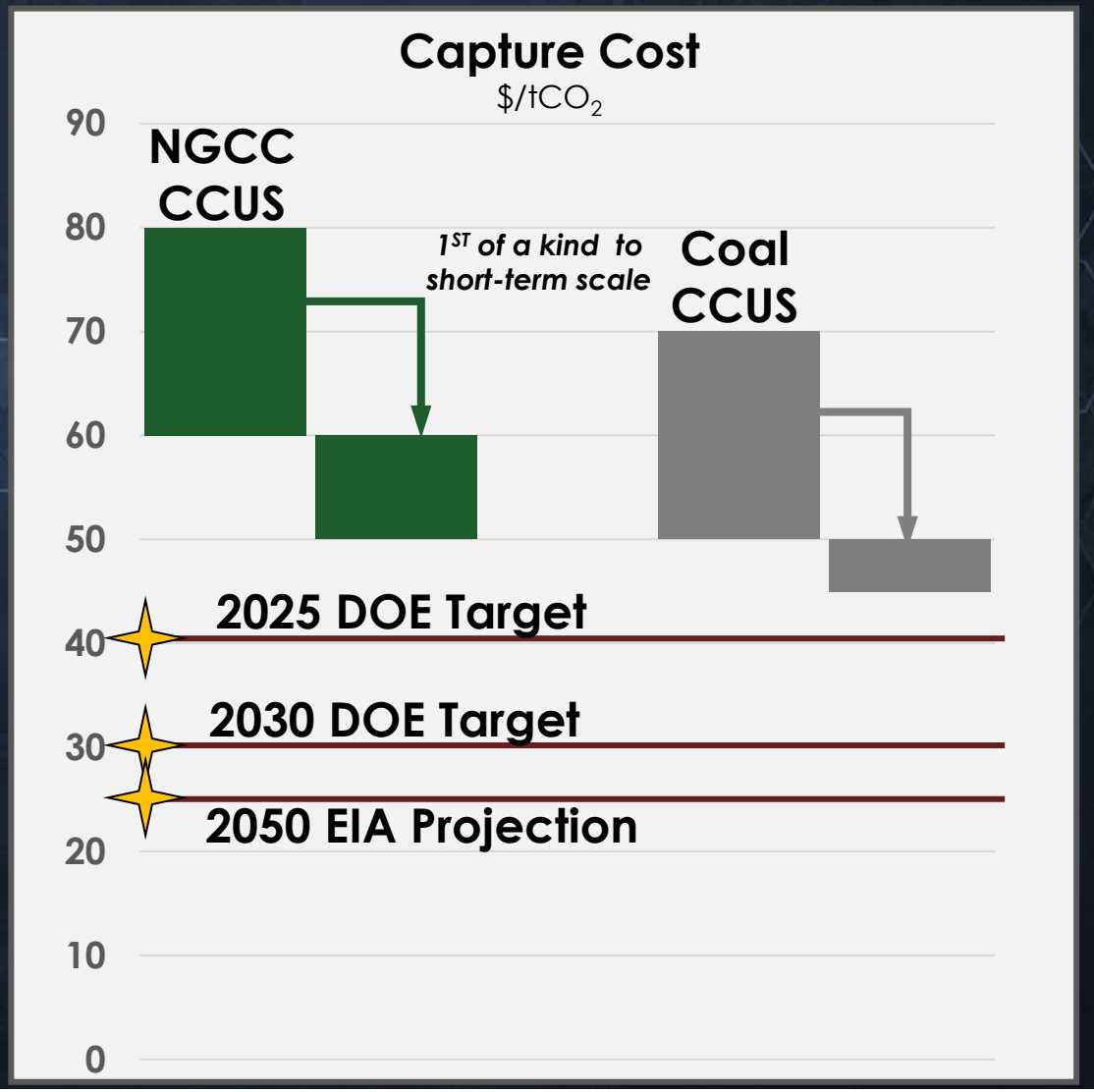
**"$CO_2$ use can complement $CO_2$ storage but is not an alternative."**

*International Energy Agency*

## Storage

**"Risk comparable to risks of current activities such as natural gas storage, EOR, and deep underground disposal of acid gas"**

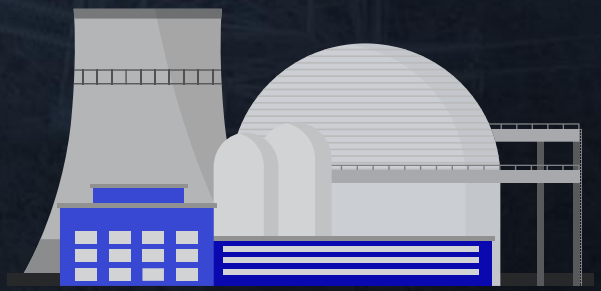
*The Intergovernmental Panel on Climate Change*



# ADVANCED NUCLEAR

## Global Experience
US deployment this decade

- Increased flexibility
- Higher availability and longer operating life – typically 60 years
- Most current US plants have about $5x10^{-5}$ core damage frequency; modern plants are about ten times better than this
- Ability to reach unique communities
- New reactor designs can load-follow closer, faster, and more flexibly than current designs
- With the needed infrastructure, some ARs can convert up to 95% of fuel energy to usable electricity vs. traditional conversion of ~5%)
- More conducive to decarbonization goals
- Many new designs are small – at or below 300 MWe

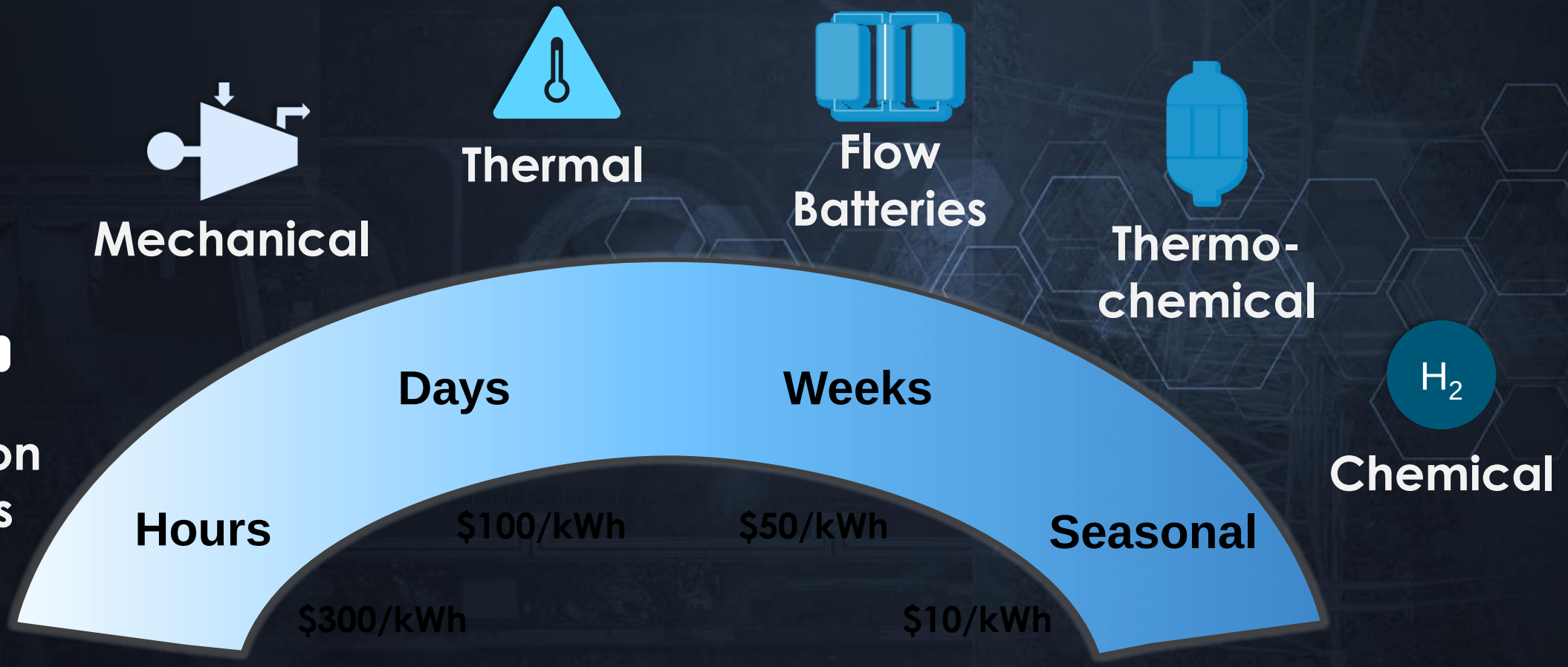


*Source: Resources for the Future, Advanced Nuclear Reactors 101, March 2021*

# ENERGY STORAGE

## Batteries and Beyond

>100 different technologies




A range of energy storage technologies will be needed

# HYDROGEN

# Expanding the Energy Economy
## the role of alternate energy carriers

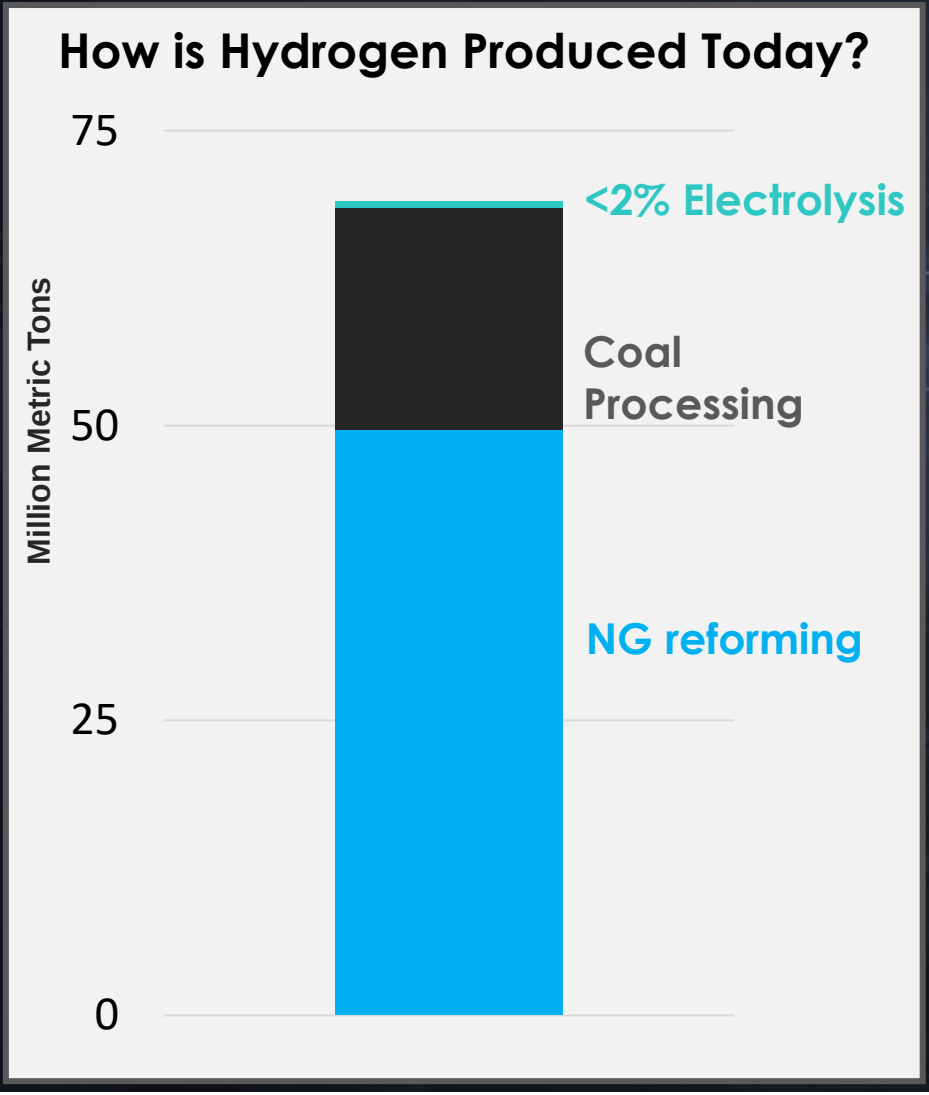
## WHAT IF...

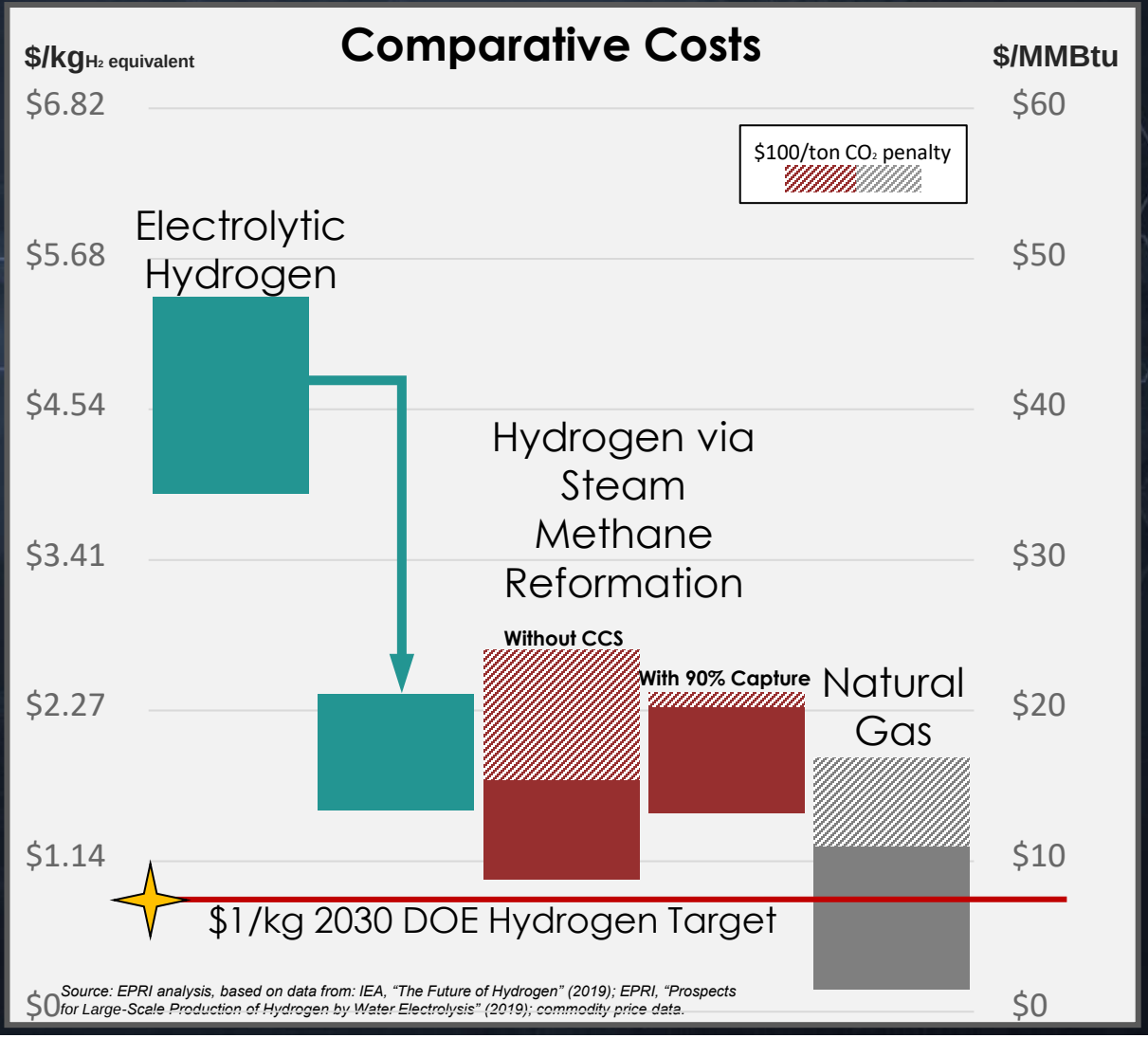
***All of the hydrogen used globally today was produced from electricity?***

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

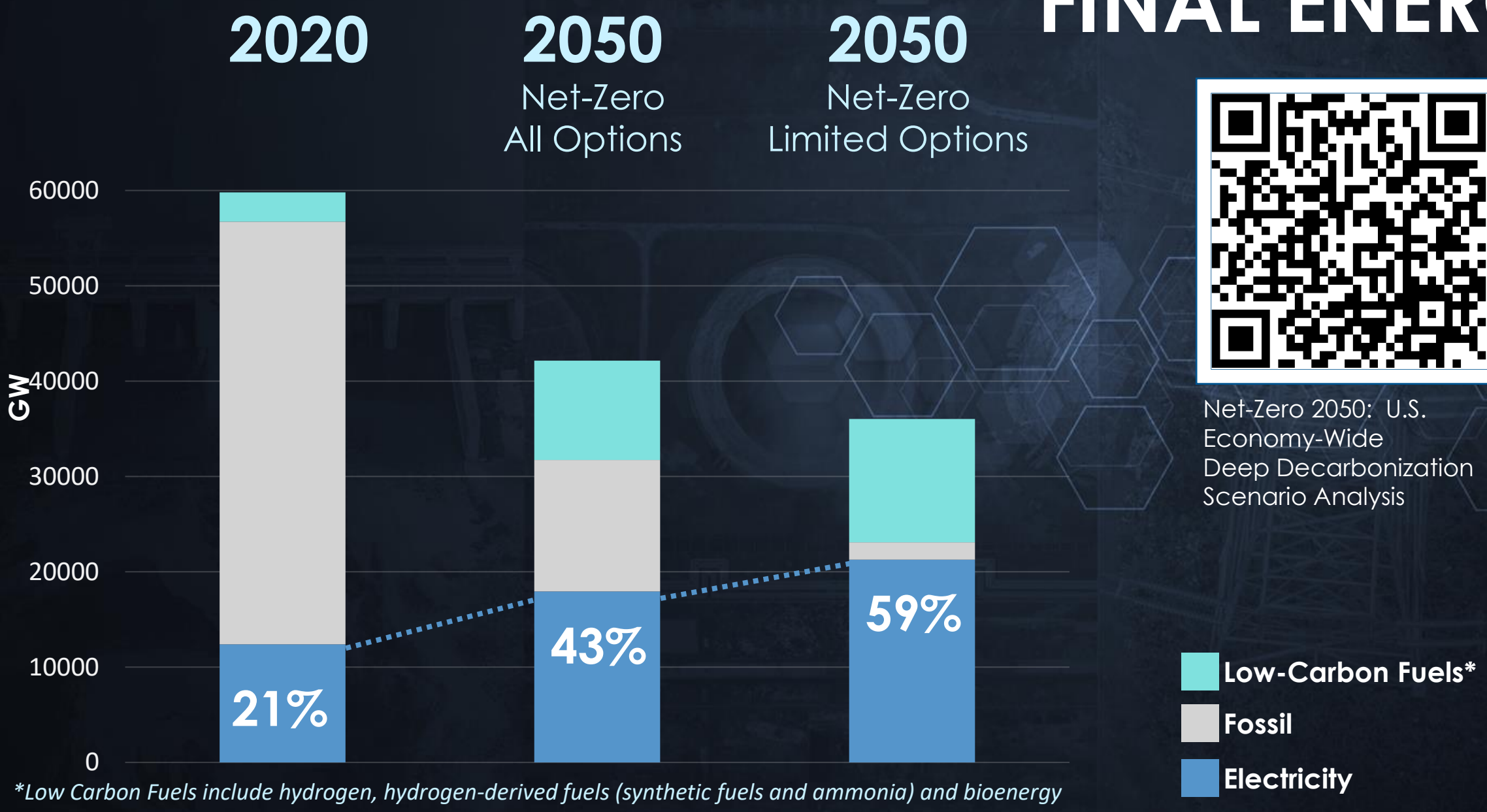
**88%** of the electricity generation in the **United States** today

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



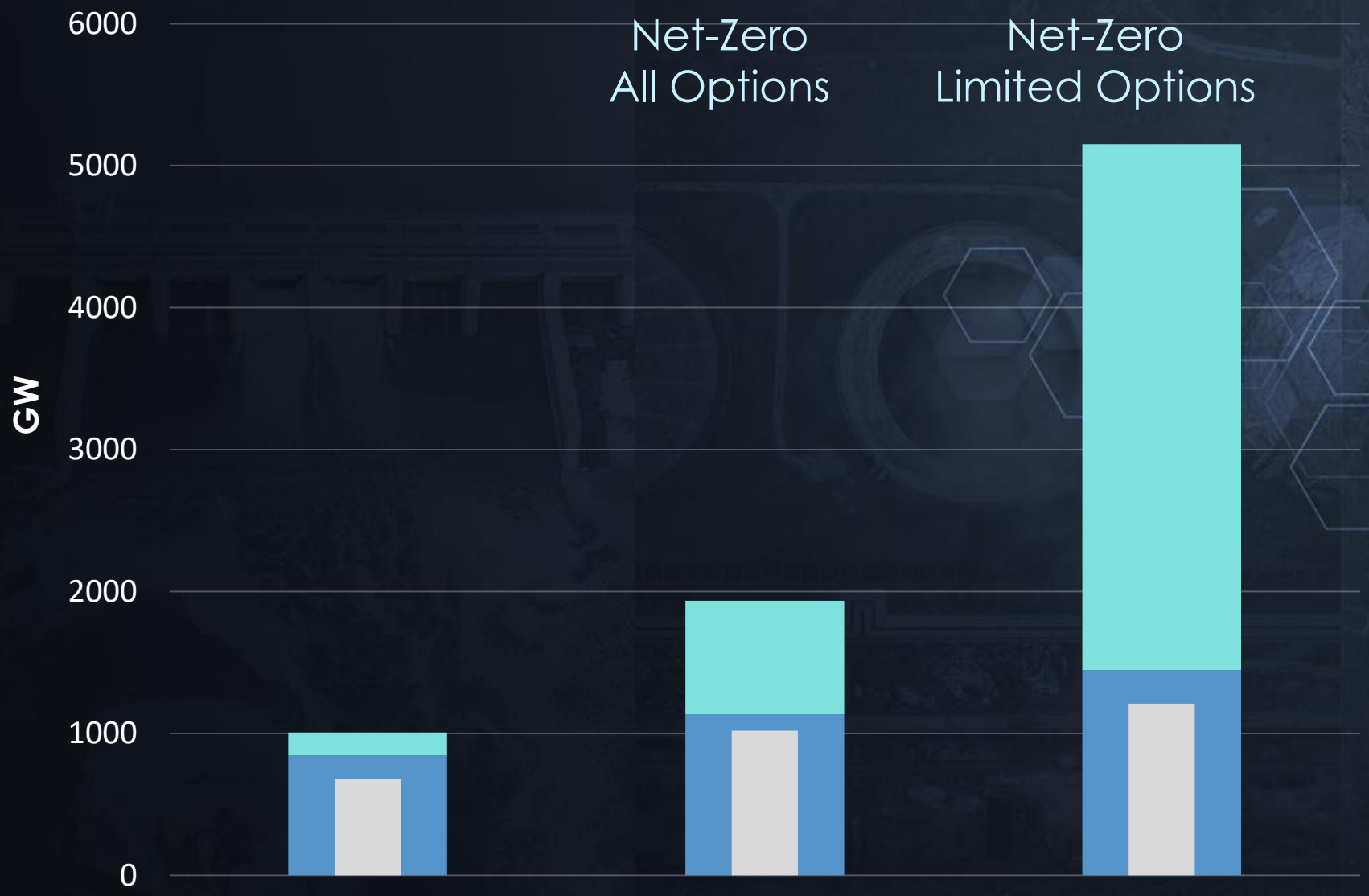
# FINAL ENERGY




Net-Zero 2050: U.S. Economy-Wide Deep Decarbonization Scenario Analysis

**Low Carbon Fuels include hydrogen, hydrogen-derived fuels (synthetic fuels and ammonia) and bioenergy*

# CAPACITY

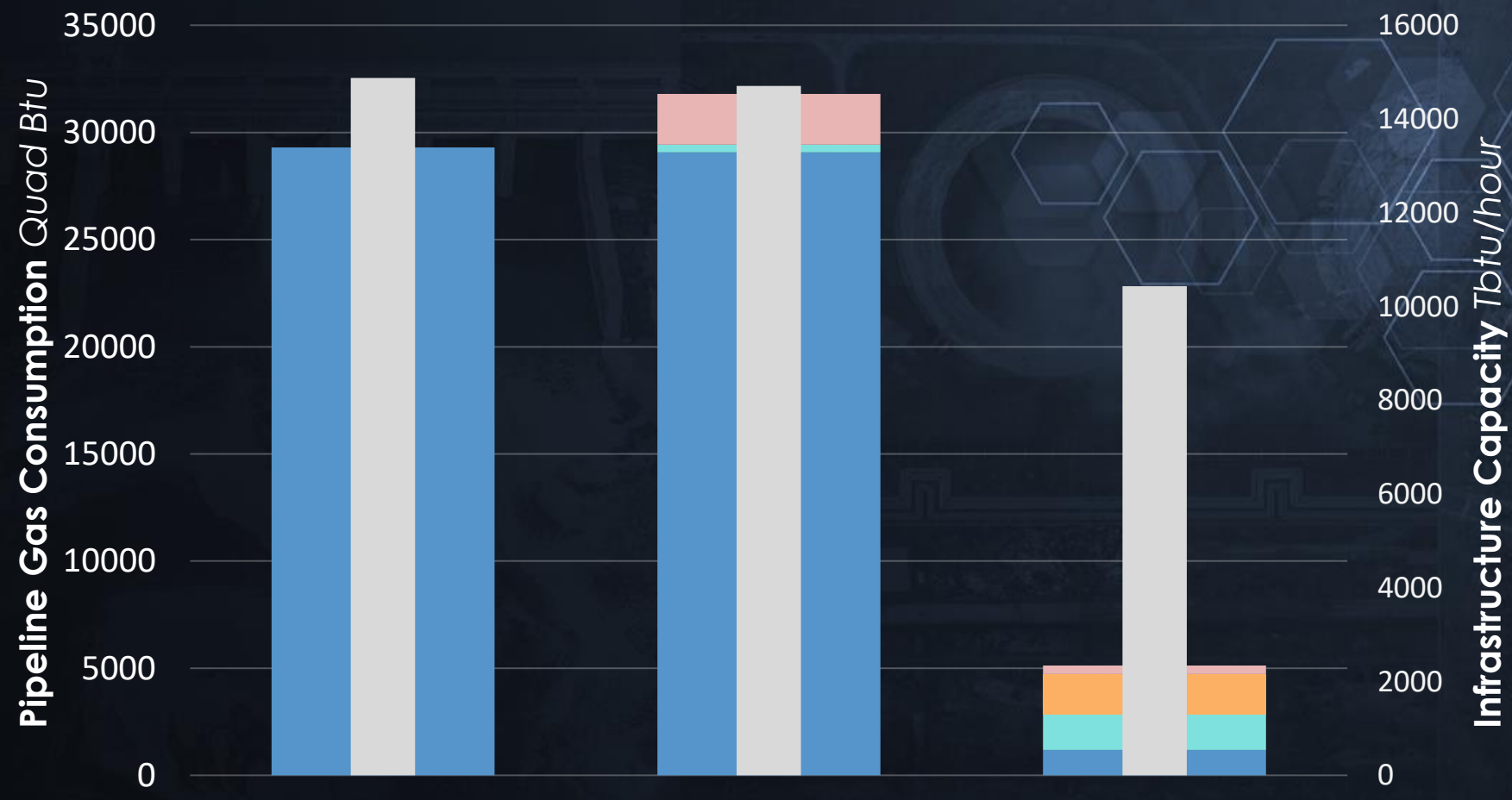



**Growing peak** across all scenarios

Highly renewable, **inverter-based** system

**Firm capacity** crucial to manage peak

# PIPELINE GAS




Shift in the way we think about gaseous **fuels**, **infrastructure**, and **assets** with infrastructure critical to the transition

# THE LAST CARBON MILE

## ENABLED BY OPTIONALITY, INNOVATION & COLLABORATION

### OPTIONALITY

Leveraging the full portfolio of existing and emerging energy resources while accounting for regional differences

### INNOVATION

Developing and deploying innovative solutions across the clean energy economy

### COLLABORATION

Reaching across industry and government to align technology development and deployment with customer needs