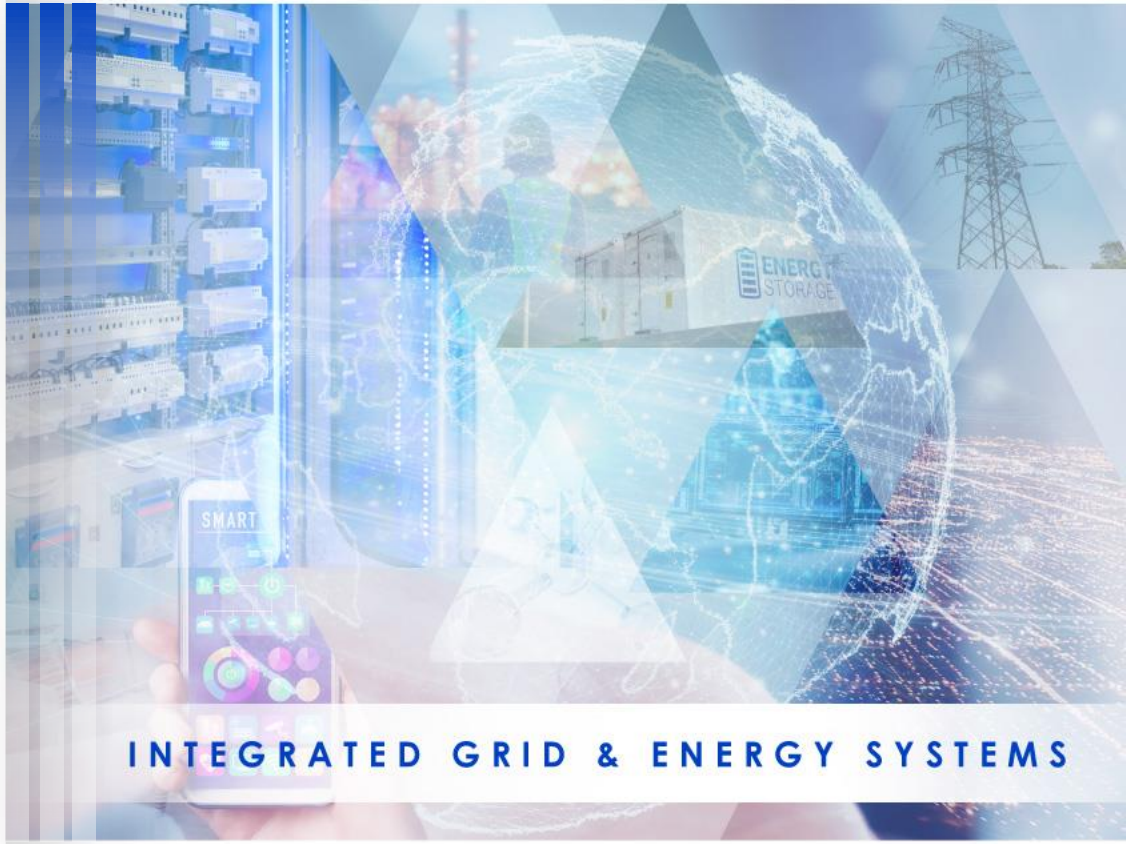
EPRI ELECTRIC POWER RESEARCH INSTITUTE

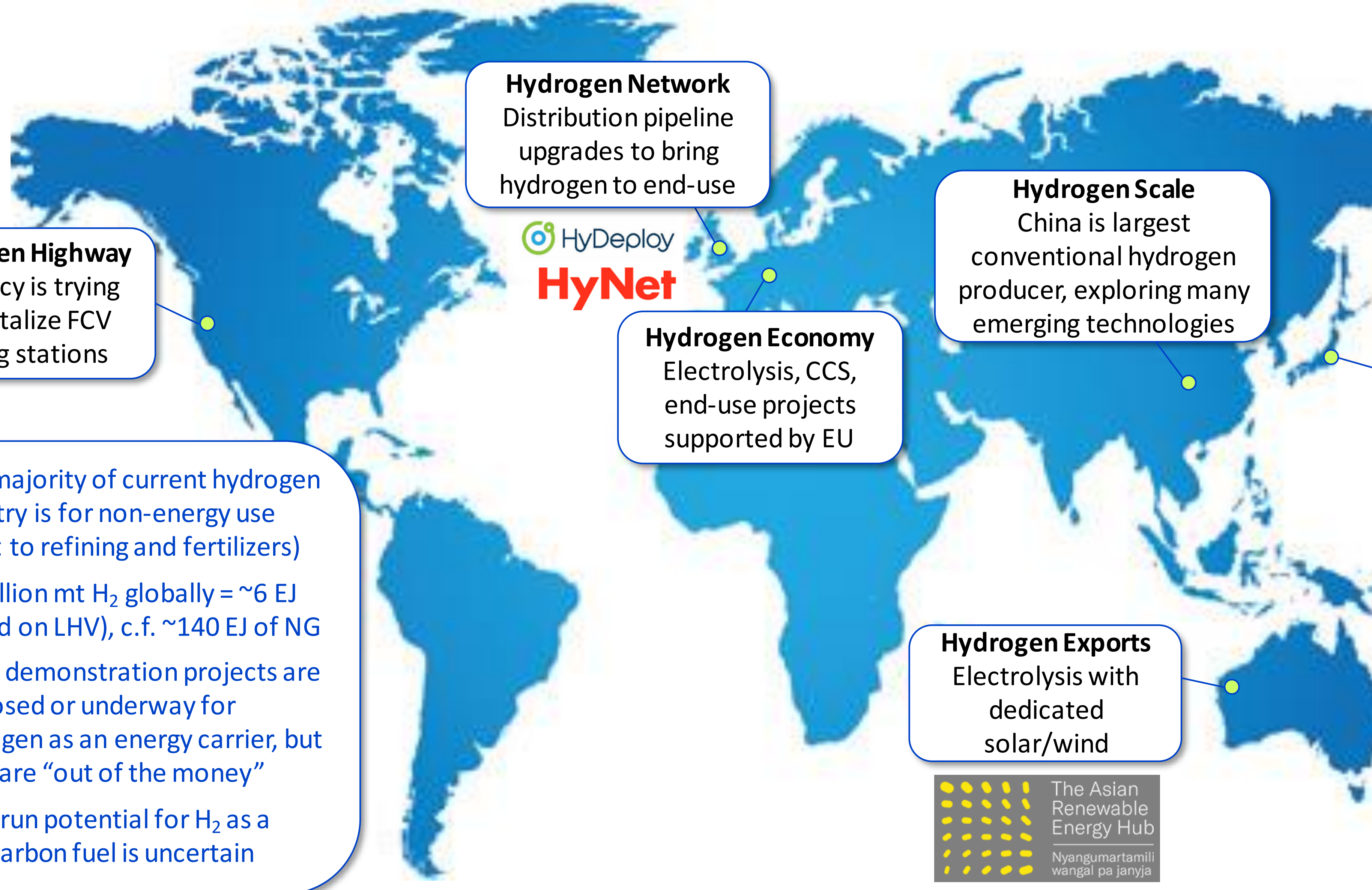
Hydrogen's Potential Role as a Low-Carbon Fuel

Geoffrey J. Blanford, Ph.D.
Senior Technical Executive, Energy Systems and Climate Analysis

May 15, 2020
EPRI Energy & Climate Research Seminar
Decarbonization Opportunities and Challenges



Hydrogen Activities Today (a few examples)



CALIFORNIA HYDROGEN HIGHWAY NETWORK

Hydrogen Highway
CA policy is trying to revitalize FCV fueling stations

Hydrogen Network
Distribution pipeline upgrades to bring hydrogen to end-use

HyDeploy

HyNet

Hydrogen Economy
Electrolysis, CCS, end-use projects supported by EU

Hydrogen Scale
China is largest conventional hydrogen producer, exploring many emerging technologies

Hydrogen Strategy
Regional imports to replace gas/oil, FCV manufacturing

Hydrogen Exports
Electrolysis with dedicated solar/wind

The Asian Renewable Energy Hub
Nyangumartamili wangal pa janyja

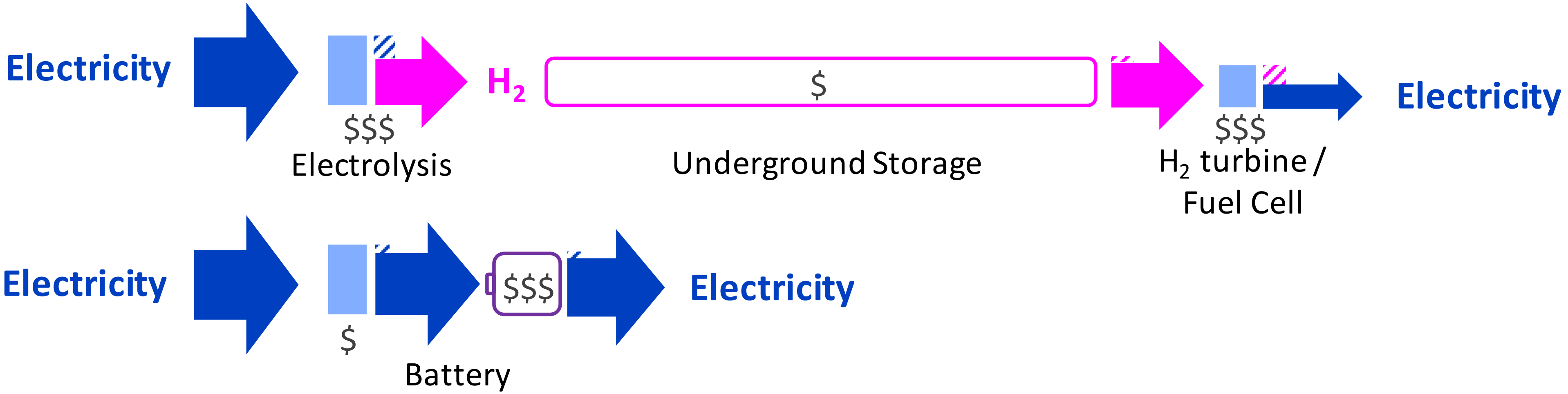
- Vast majority of current hydrogen industry is for non-energy use (input to refining and fertilizers)
- 70 million mt H_2 globally = ~6 EJ (based on LHV), c.f. ~140 EJ of NG
- Many demonstration projects are proposed or underway for hydrogen as an energy carrier, but most are "out of the money"
- Long-run potential for H_2 as a low-carbon fuel is uncertain

Links:

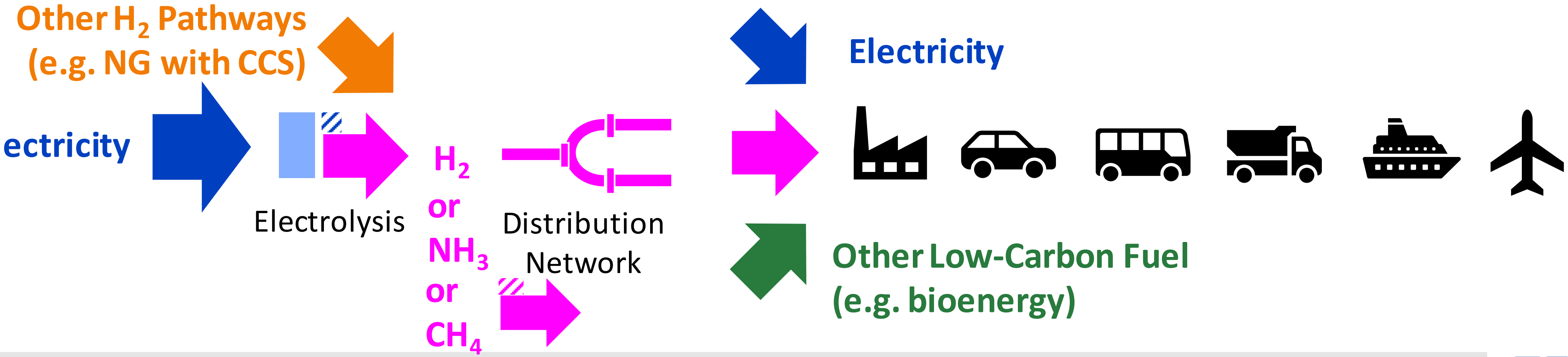
https://ww2.arb.ca.gov/our-work/programs/hydrogen-fueling-infrastructure
https://hydeploy.co.uk/, https://hynet.co.uk/,
https://asianrehub.com/
https://hydrogenenergysupplychain.com/
https://www.toyota.com/mirai/fcv.html

Potential Roles of Hydrogen as an Energy Carrier

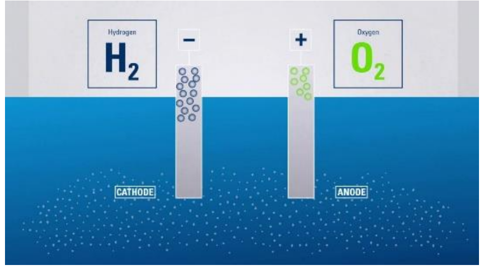
- Power-gas-Power for longer duration storage



- Power-to-gas for end-use fuel demand



Many potential H_2 applications in a low-carbon energy system: Uncertain where value will emerge



- Production of hydrogen: “**green**” vs. “**blue**”
  - Electrolysis interactions with power system are complex
  - Production from NG with CCS could be more cost effective with low GHGs

- Storage and distribution: significant challenges
  - Underground storage is limited, above-ground storage is expensive
  - Delivery infrastructure requires new pipelines, safety management
  - Conversion to ammonia or other molecule could make handling easier
  - Distributed electrolysis (“H_2 by wire”) is another option

- End-use demand: competition with other low-carbon fuels
  - Electricity where possible, bioenergy where a molecule is needed

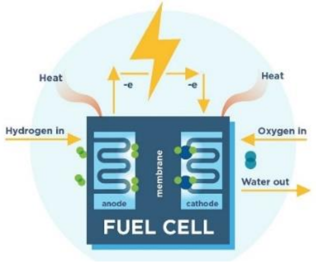


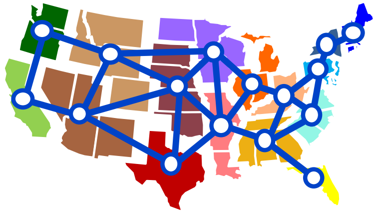
Image sources: https://www.omv.com/en/blog/hydrogen-an-element-bursting-with-energy https://www.sciencedirect.com/topics/engineering/salt-cavern http://www.fchea.org/fuelcells

Key research questions for hydrogen: Modeling needed!

- How does electrolysis interact with the power system?
- What is the most cost-effective delivery pathway?
- What are the limits of (direct) electrification?
- Low-carbon molecules: H_2 (or H_2-derived) vs. Bioenergy?

How does electrolysis interact with the power system?

- Insights from US-REGEN model analysis:

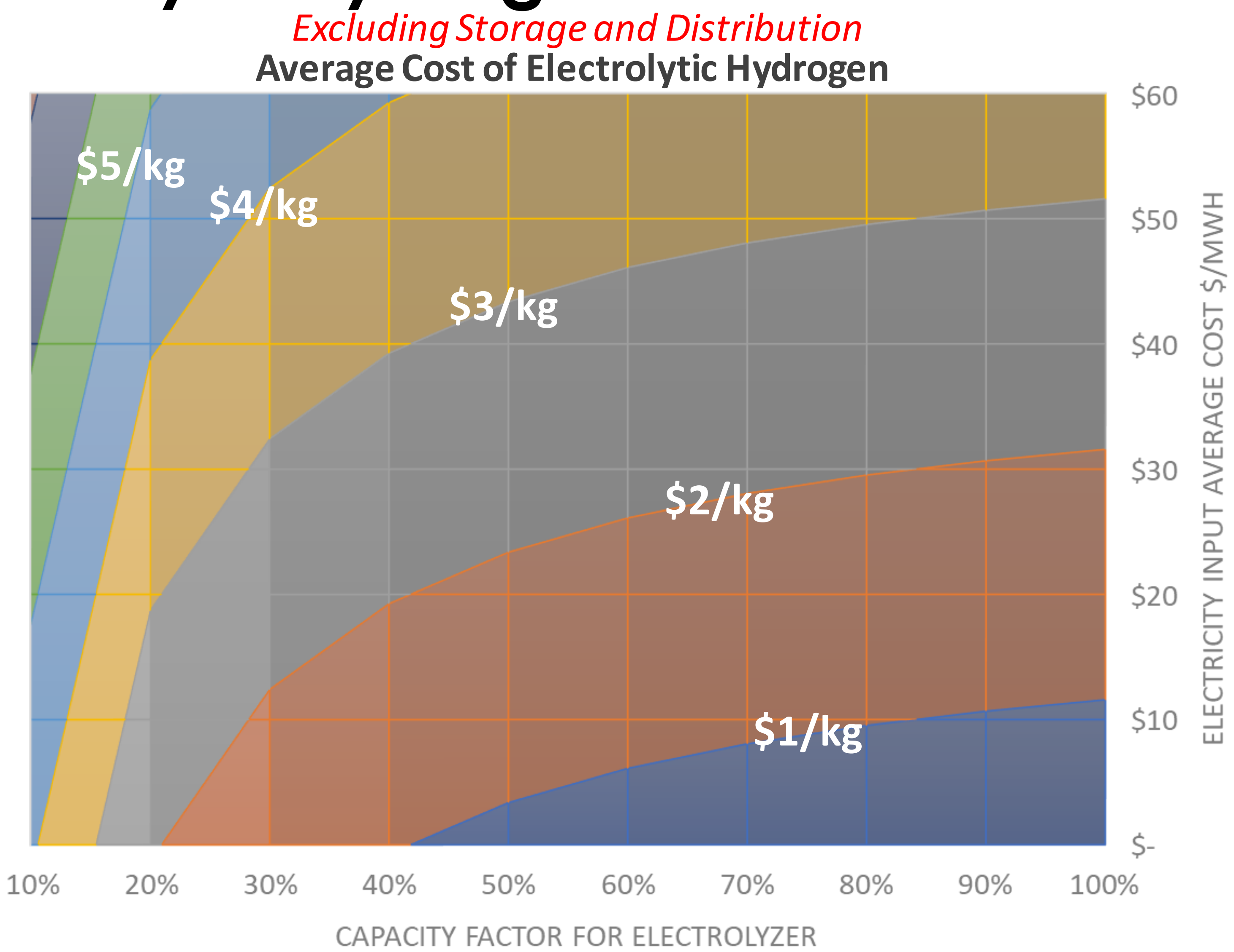


  - Power-gas-power storage only plays an economic role under most stringent policy constraints (e.g. zero carbon or 100% renewables)
  - While power-to-gas for end-use is potentially synergistic with electric generation (i.e. flexibility value), it competes with/drives up the cost of power-gas-power storage
  - Power-to-gas (i.e. "green" hydrogen) will need to compete economically with other low-GHG hydrogen pathways (e.g. "blue" hydrogen via SMR or ATR + CCUS)

- Technology development for electrolysis is a key uncertainty: modeling can inform targets for future R&D

Equilibrium price of electrolytic hydrogen

- Cost structure of electrolytic hydrogen depends on system mix: capacity factor vs. electricity price
- Grid-integrated electrolysis could take advantage of low-price hours of high renewable generation – but how many?



Based on $1000 per kg/day and 50 KWh/kg = $480/kW @ 70% efficiency

Equilibrium price of electrolytic hydrogen

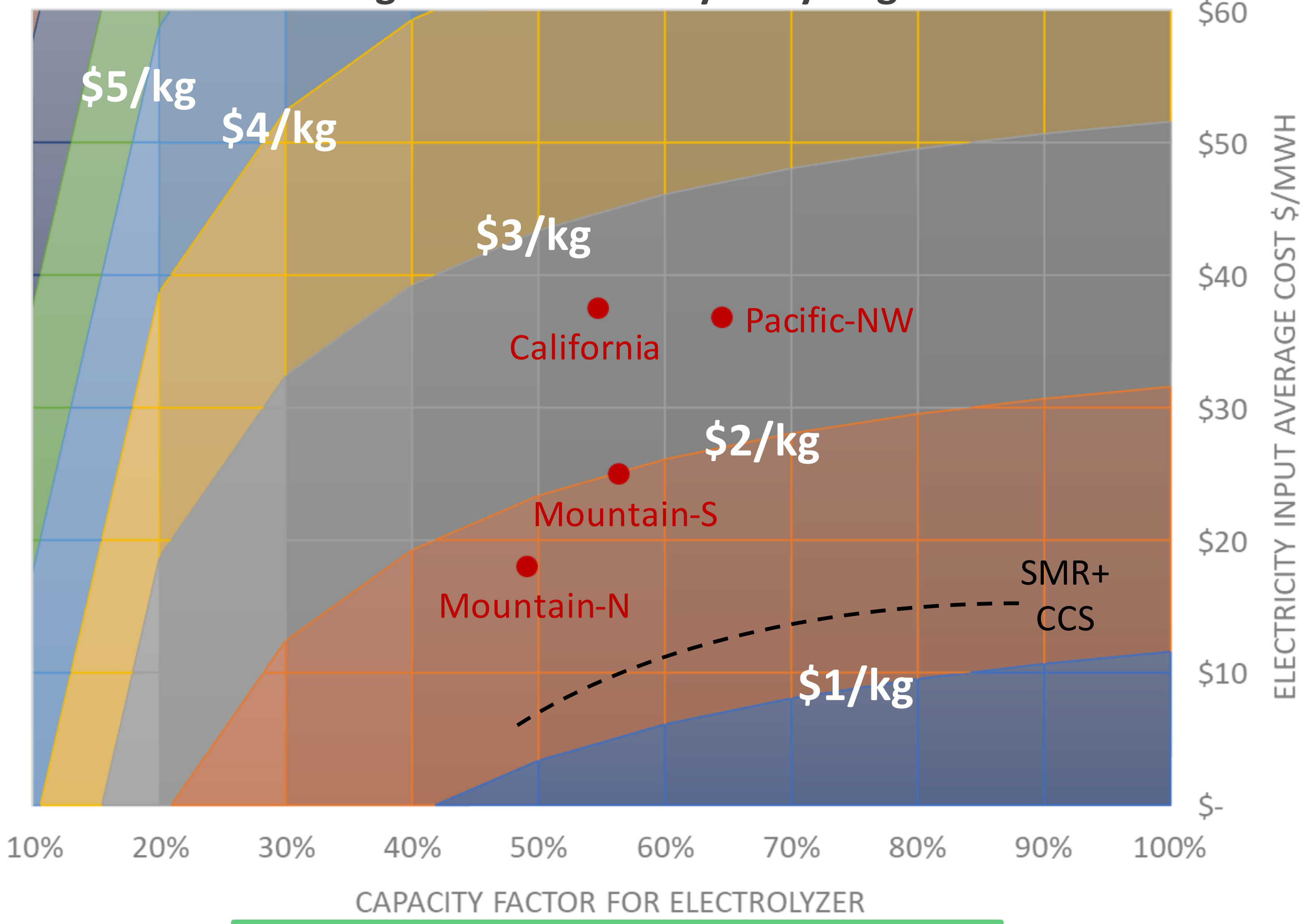
- Cost structure of electrolytic hydrogen depends on system mix: capacity factor vs. electricity price
- Grid-integrated electrolysis could take advantage of low-price hours of high renewable generation – but how many?

US-REGEN scenario results:

● Indicates regional CF/price combinations for electrolysis with 100% renewables plus ~1 EJ end-use H_2 demand in WECC

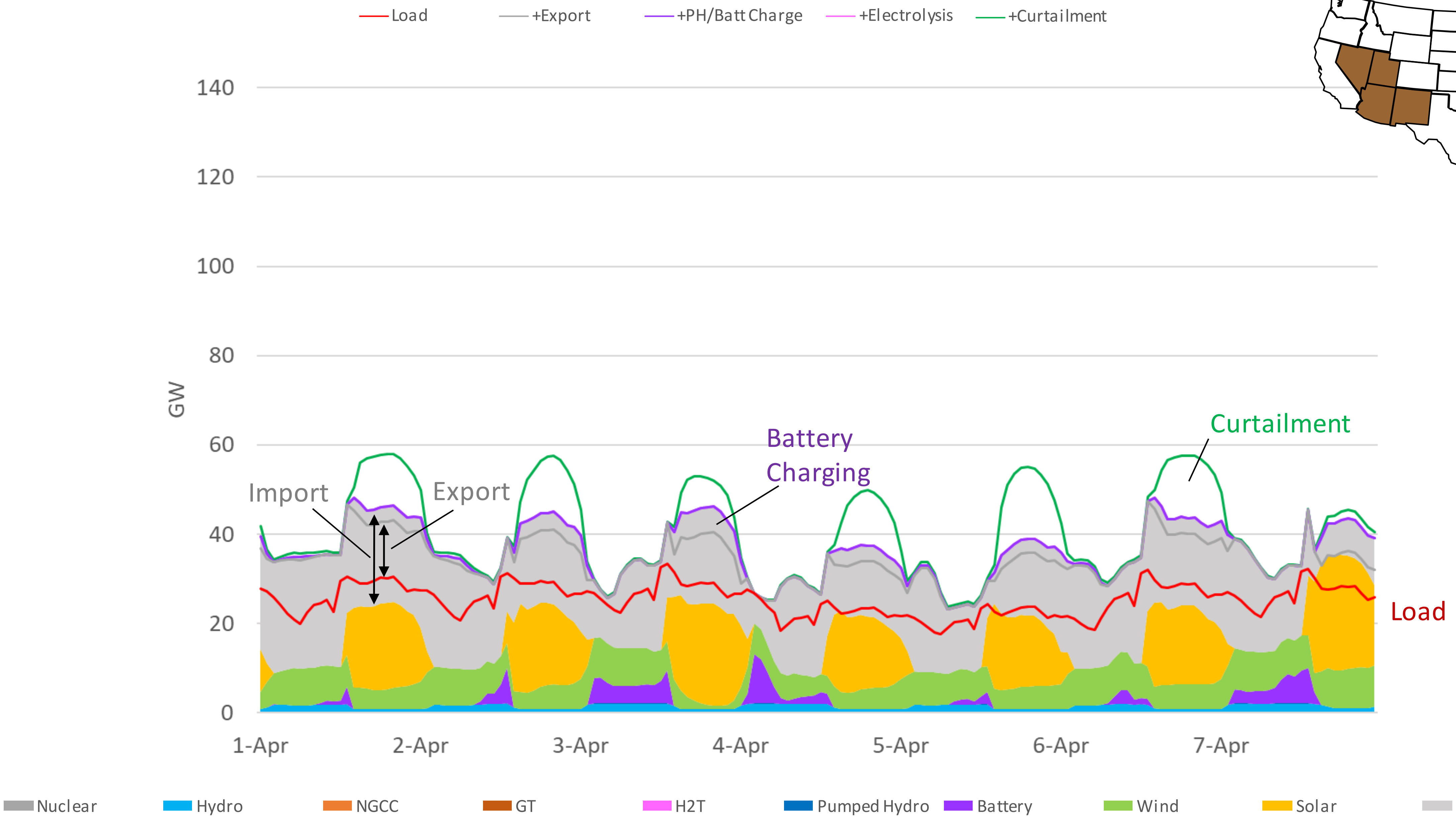
Excluding Storage and Distribution

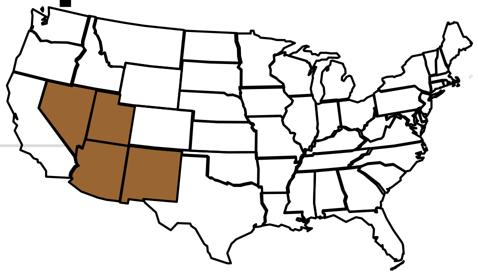
Average Cost of Electrolytic Hydrogen



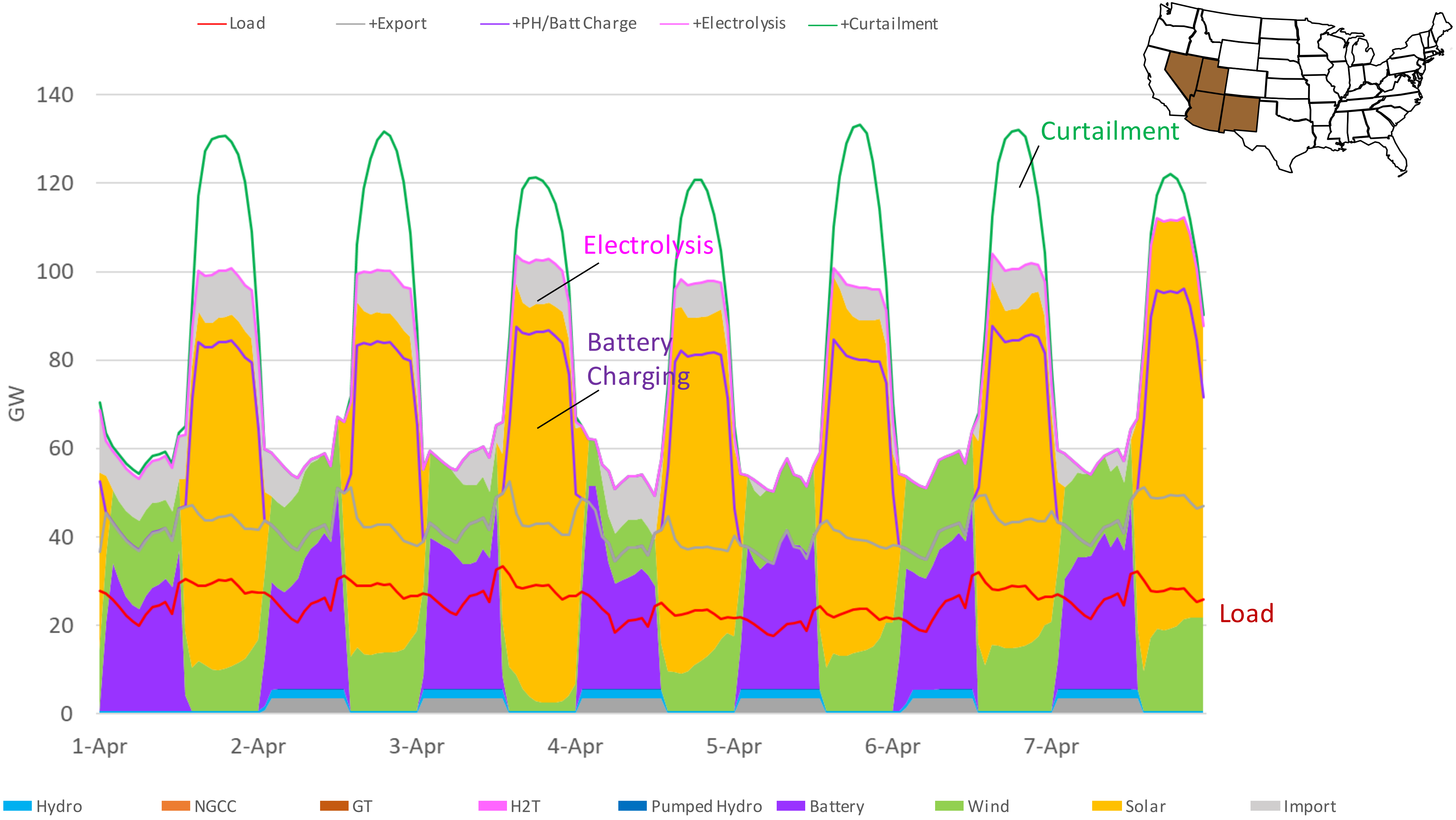
Based on $1000 per kg/day and 50 KWh/kg = $480/kW @ 70% efficiency

Mountain-South $100/tCO2 Scenario Example Dispatch

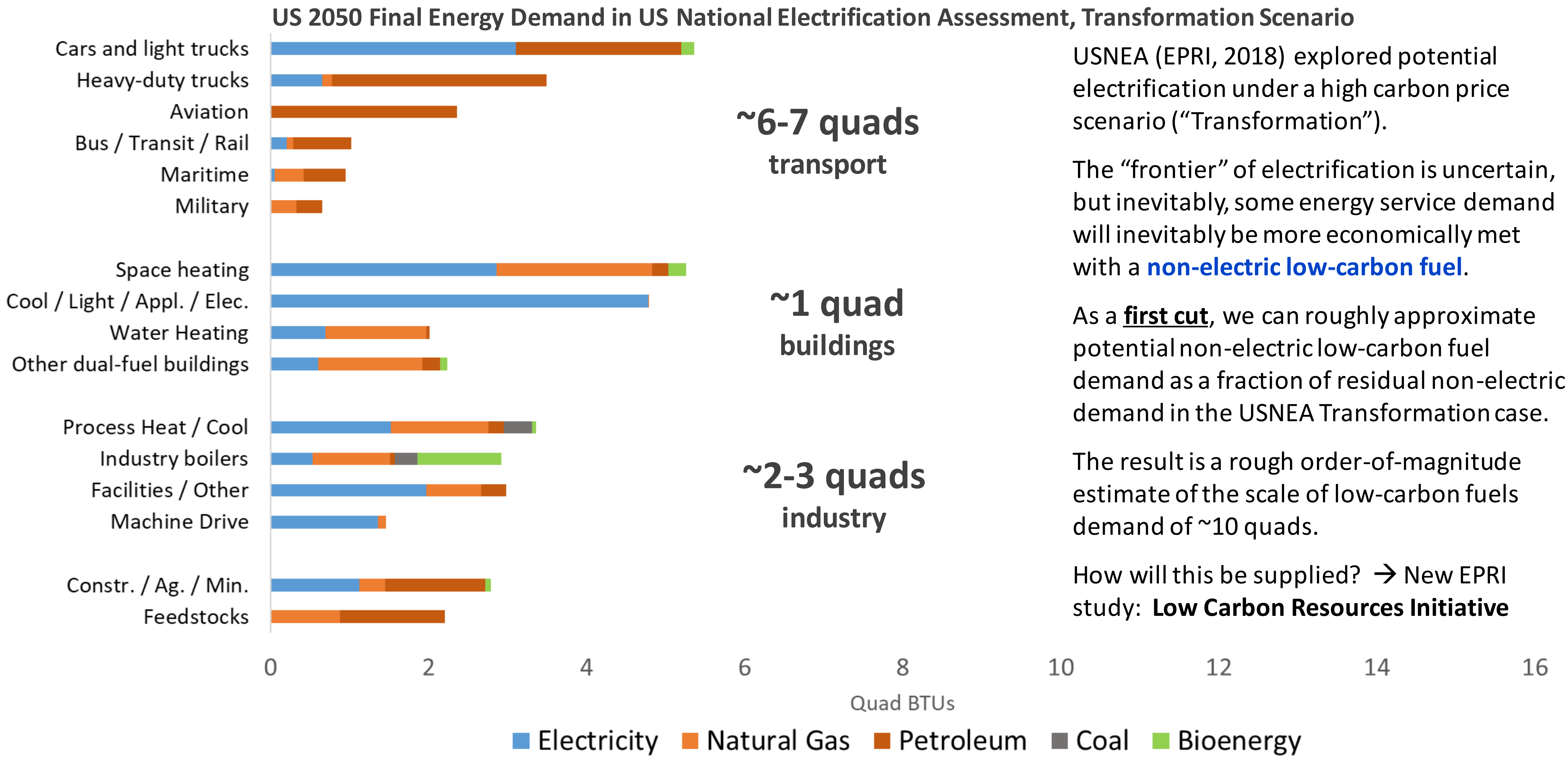




Mountain-South $100/tCO2 + Nele H2 Demand



What are the limits of (direct) electrification?



USNEA (EPRI, 2018) explored potential electrification under a high carbon price scenario ("Transformation").

The "frontier" of electrification is uncertain, but inevitably, some energy service demand will inevitably be more economically met with a **non-electric low-carbon fuel**.

As a **first cut**, we can roughly approximate potential non-electric low-carbon fuel demand as a fraction of residual non-electric demand in the USNEA Transformation case.

The result is a rough order-of-magnitude estimate of the scale of low-carbon fuels demand of ~10 quads.

How will this be supplied? → New EPRI study: **Low Carbon Resources Initiative**

Low-Carbon Resources Initiative

The **Low-Carbon Resources Initiative** (LCRI) is a five-year, focused R&D commitment to develop the pathways to advance low-carbon technologies for large-scale deployment. This initiative is jointly led by EPRI and GTI. The goal of the initiative is to enable a risk-informed understanding of options and technologies enabling significant economy-wide decarbonization through global partnerships and demonstrations, applied engineering developments, and technology acceleration of the most promising options.

WHY

- **Enable infrastructure** for future low-carbon fuel options
- **Decarbonize sectors** such as bulk transportation, large industries, and heating networks in cold climates
- **Large-scale** clean power utilizing combustion turbines

Hydrogen and related, low-carbon resources

Low-Carbon Power Generation
Advanced Nuclear and Renewables | CCUS

Low-Carbon Resource Production
Hydrogen | Biofuels

End Use
Industrial | Buildings | Hydrogen Turbines | Heavy Duty-Transportation

Transmission, Delivery, and Storage
Existing and New Infrastructure | Pipeline Blending

VALUE

- **Individual commitment** to environmental, social, and governance (ESG) efforts
- **Increase optionality** of low-carbon solutions
- **Leverage investments** across relevant sectors
- **Enable resiliency and affordability** of low-carbon energy system

Together…Shaping the Future of Electricity