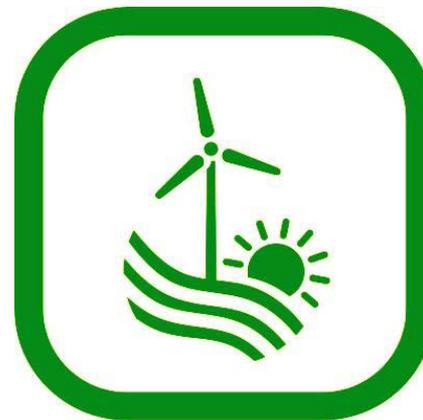


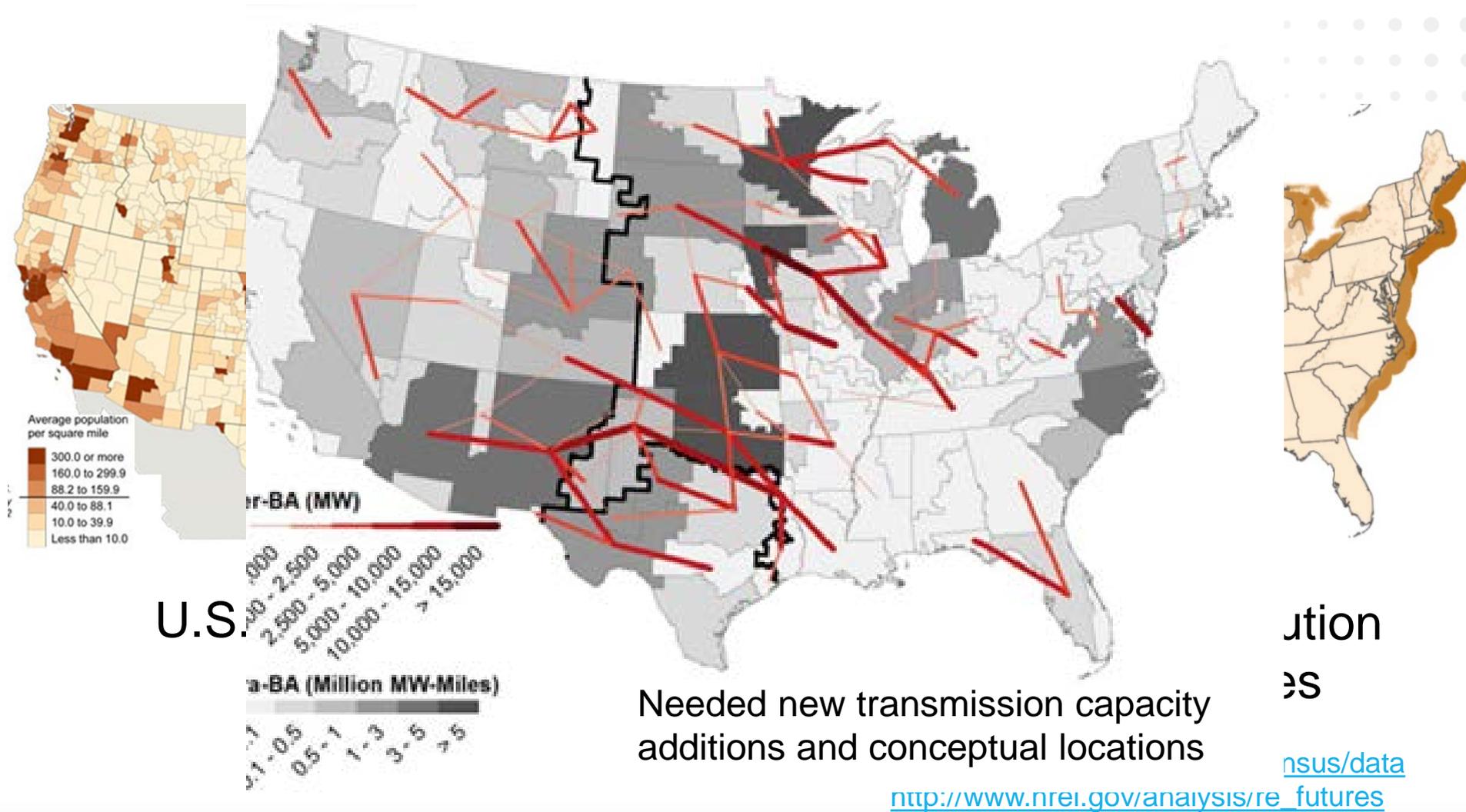
Energy-Dense Liquid Fuels: The Storage Solution for Renewable Energy

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Where is renewable energy?

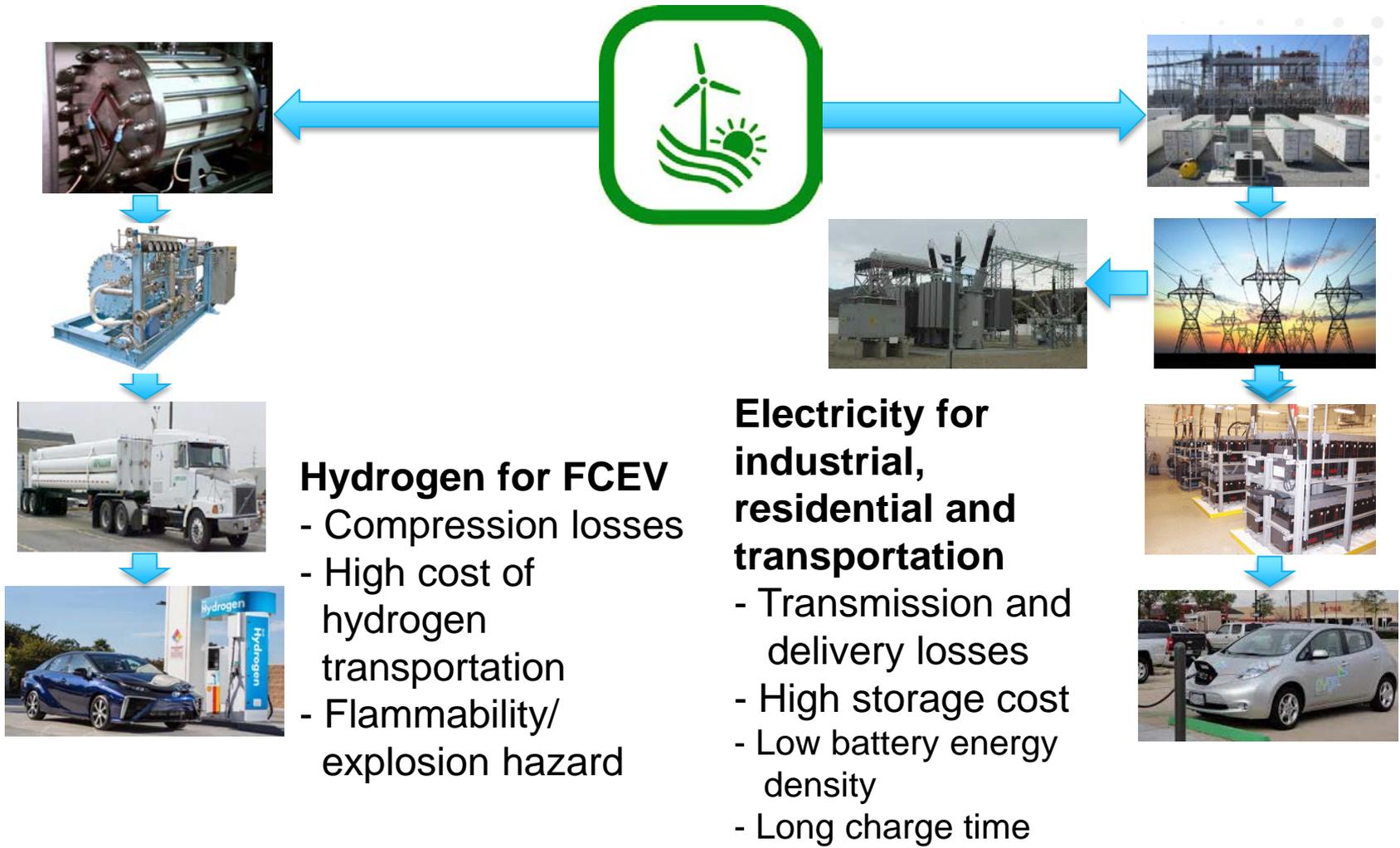


How to increase penetration of renewable energy?

Critical needs

- Remote renewable power generation separated from local energy consumption (electricity + transportation fuels)
- Wide spread of intermittent renewables requires bulk energy storage
- Infrastructure for renewable power transmission and distribution needs to be build and will be expensive

Current renewable energy delivery systems

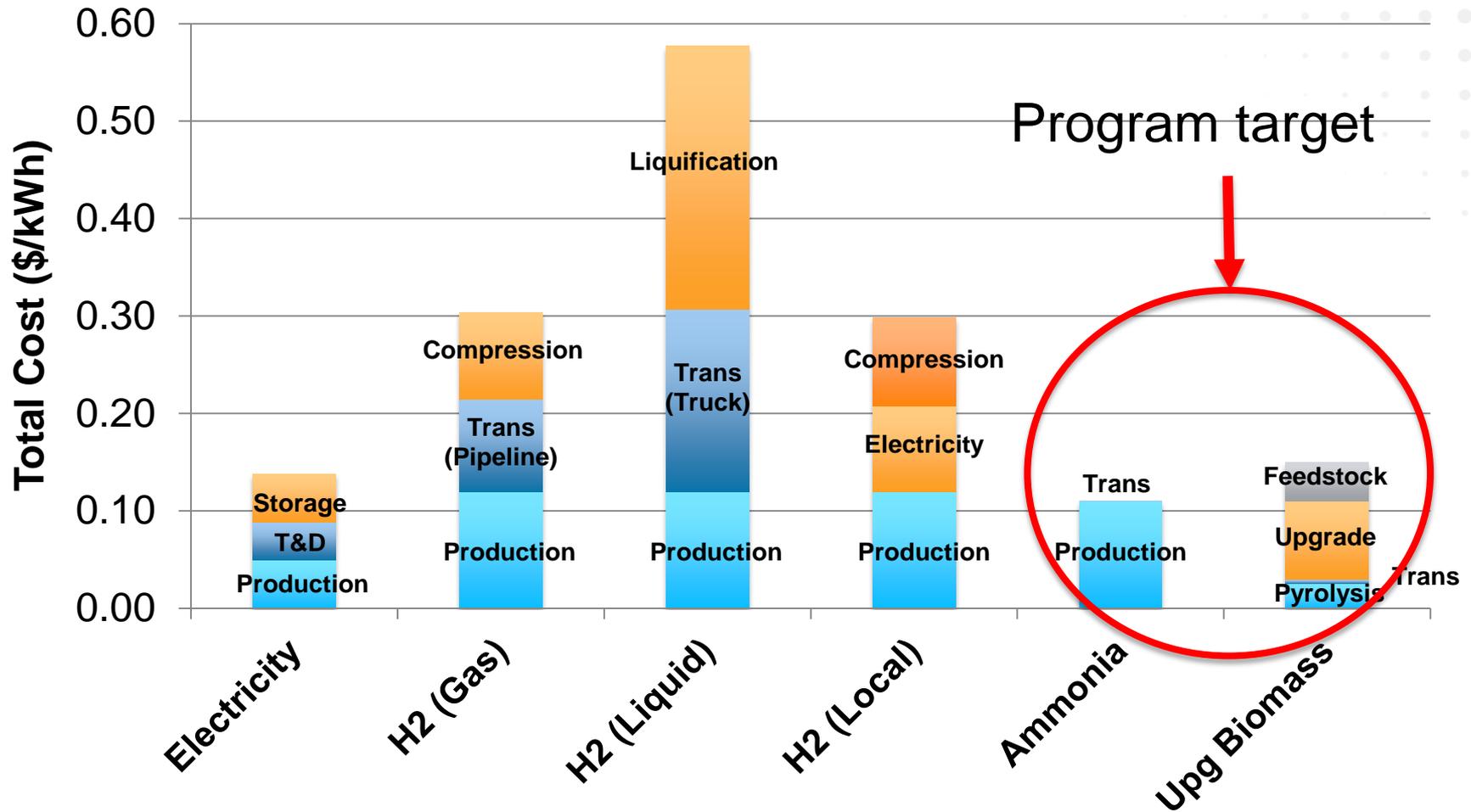


Proposed solution: deliver energy using carbon-neutral regenerable fuels

Combine energy transportation and storage and use the existing infrastructure via:

- i) conversion of renewable power, water and air into hydrogen-rich carbon-neutral liquid fuels,
- ii) transportation of liquids, and
- iii) energy generation at the end point using direct (electrochemical) or indirect (via intermediate hydrogen extraction) fuel cells

Energy transportation (2000 km) and storage cost



Liquid fuels for energy storage



30,000 gallon underground tank
with liquid ammonia contains 200 MWh
(plus 600 MMBTU CHP heat)

Footprint 516 sq.ft underground
Capital cost ~\$100K

=



204 MWh NGK battery in Japan

Footprint 51,000 sq.ft (15' high)
Capital cost \$50,000 - 100,000K

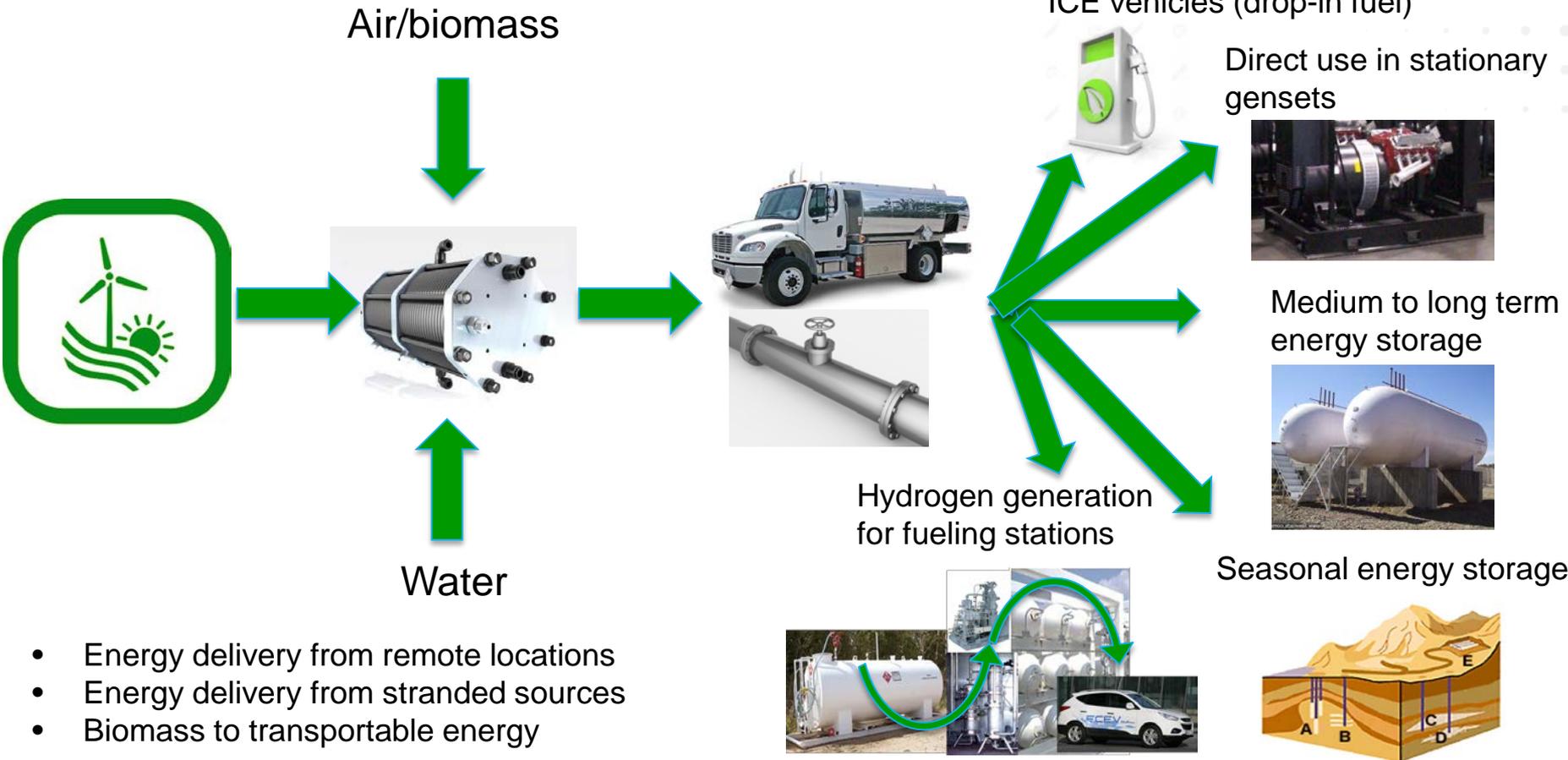
Liquid fuels provide smallest footprint and CAPEX

Renewable energy delivery via liquid fuels – application space

Synthesis of liquid fuels

Fuels transportation

Application space



- Energy delivery from remote locations
- Energy delivery from stranded sources
- Biomass to transportable energy

Renewable Energy to Fuels through Utilization of Energy-dense Liquids (REFUEL)

Program goals

- Develop small to medium scale direct conversion of renewable energy to high energy density liquid fuels
- Develop cost effective methods for fuels conversion to electricity or H₂

Project targets

- Competitive cost of delivered energy
- Demonstration of fuel synthesis and conversion in a bench scale prototype

Potential program benefits

- Reduced transportation losses
- Providing long-term energy storage with low cost/footprint
- Use of existing liquid fuel infrastructure
- Enabling fuel cell car fueling stations
- Reduced CO₂ emissions and oil imports