FEBRUARY 22, 2023

ROADMAP FOR CO2 TRANSPORT FUNDAMENTAL RESEARCH WORKSHOP

DUBLIN, OH

Argonne NATIONAL LABORATORY GREET LIFE-CYCLE MODEL

Leveraging ongoing Hydrogen pipeline R&D for CO_2

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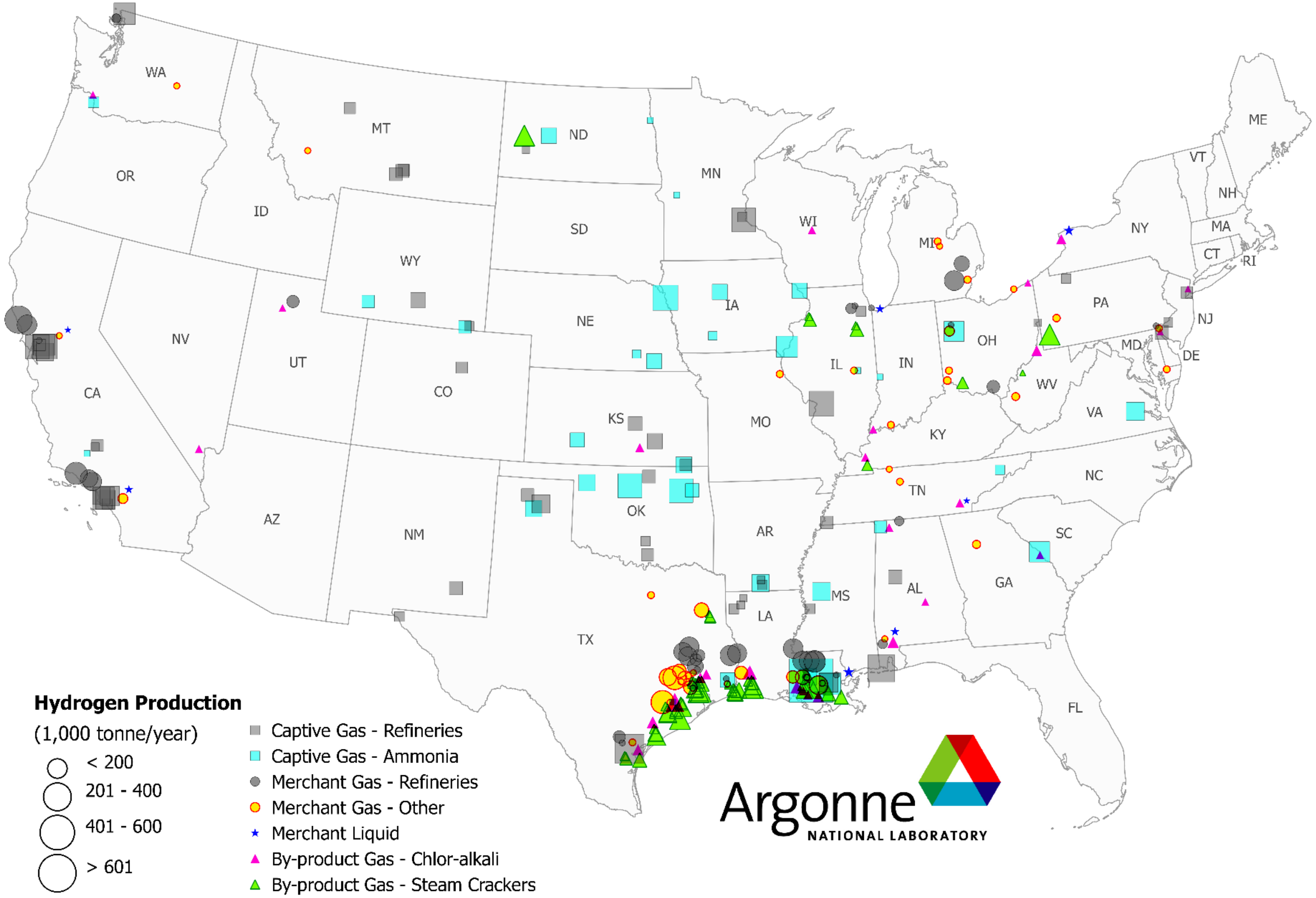
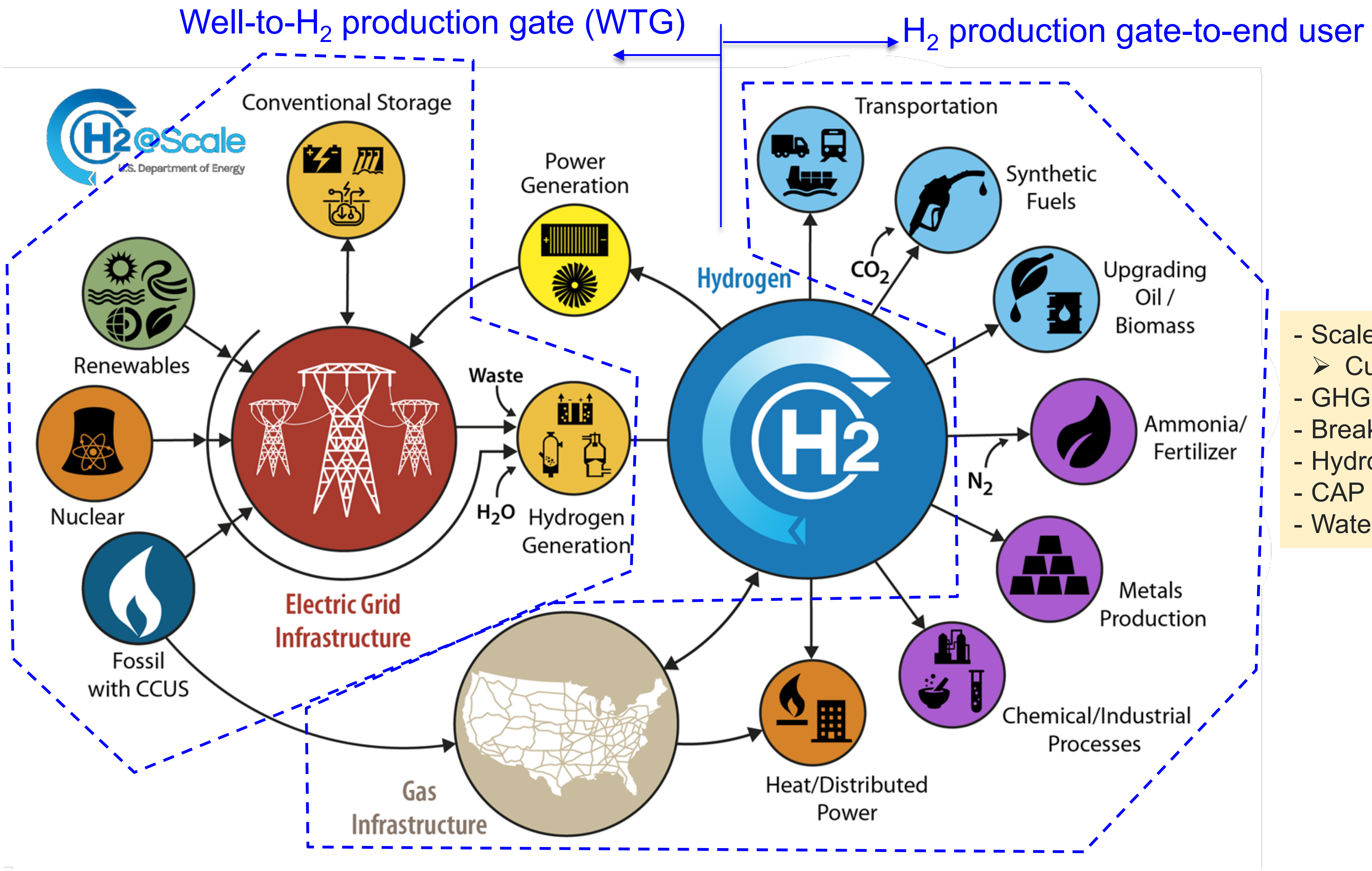
Today, more than 10M metric tons of hydrogen are produced in the U.S. annually, mainly from SMR of natural gas



H2@Scale: a DOE initiative for a hydrogen economy



- Scale of H_2 demand by end use
  - ➢ Current and potential future
- GHG emissions reduction → LCA
- Breakeven H_2 price ($/kg)→ TEA
- Hydrogen infrastructure
- CAP emissions
- Water analysis

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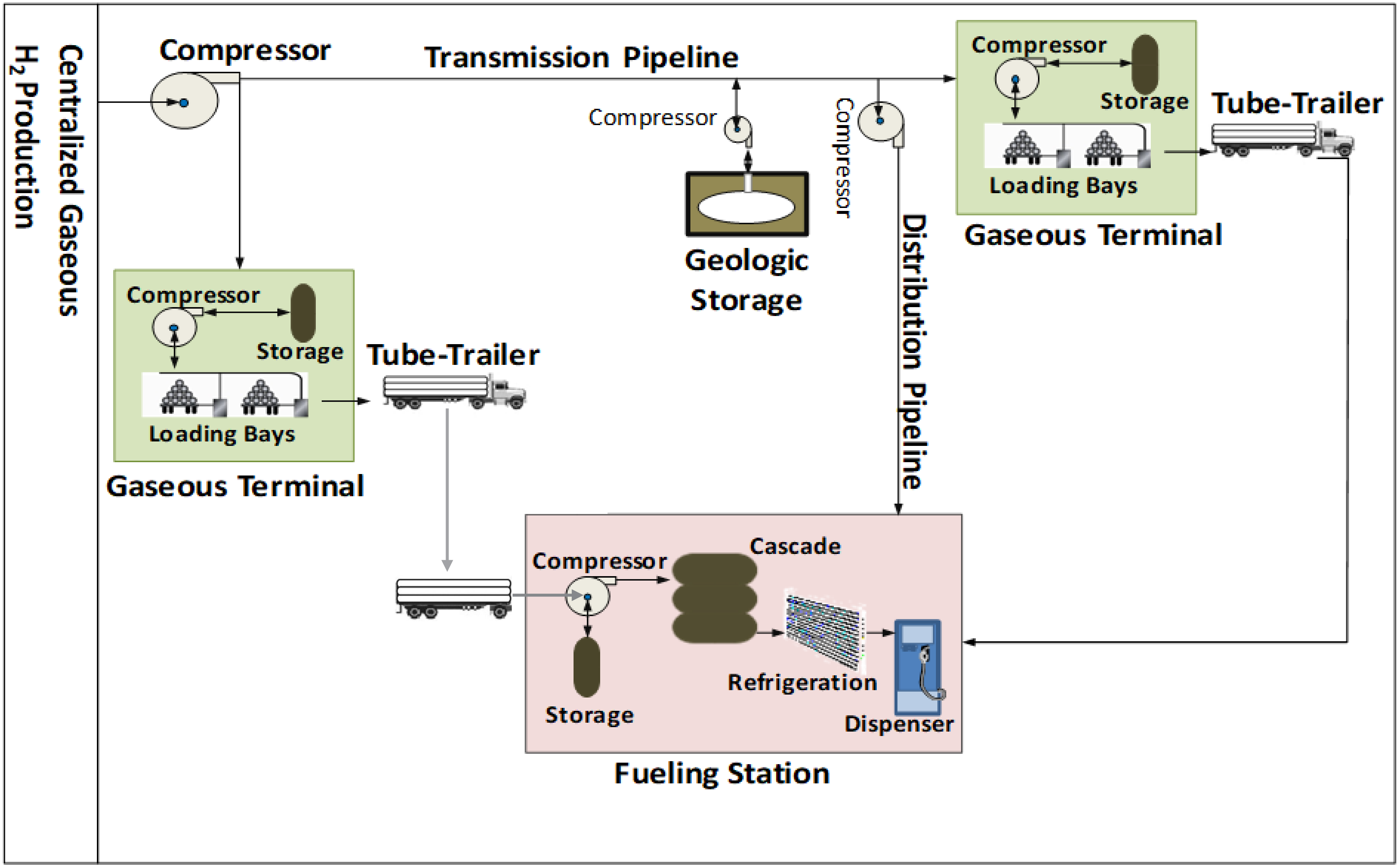
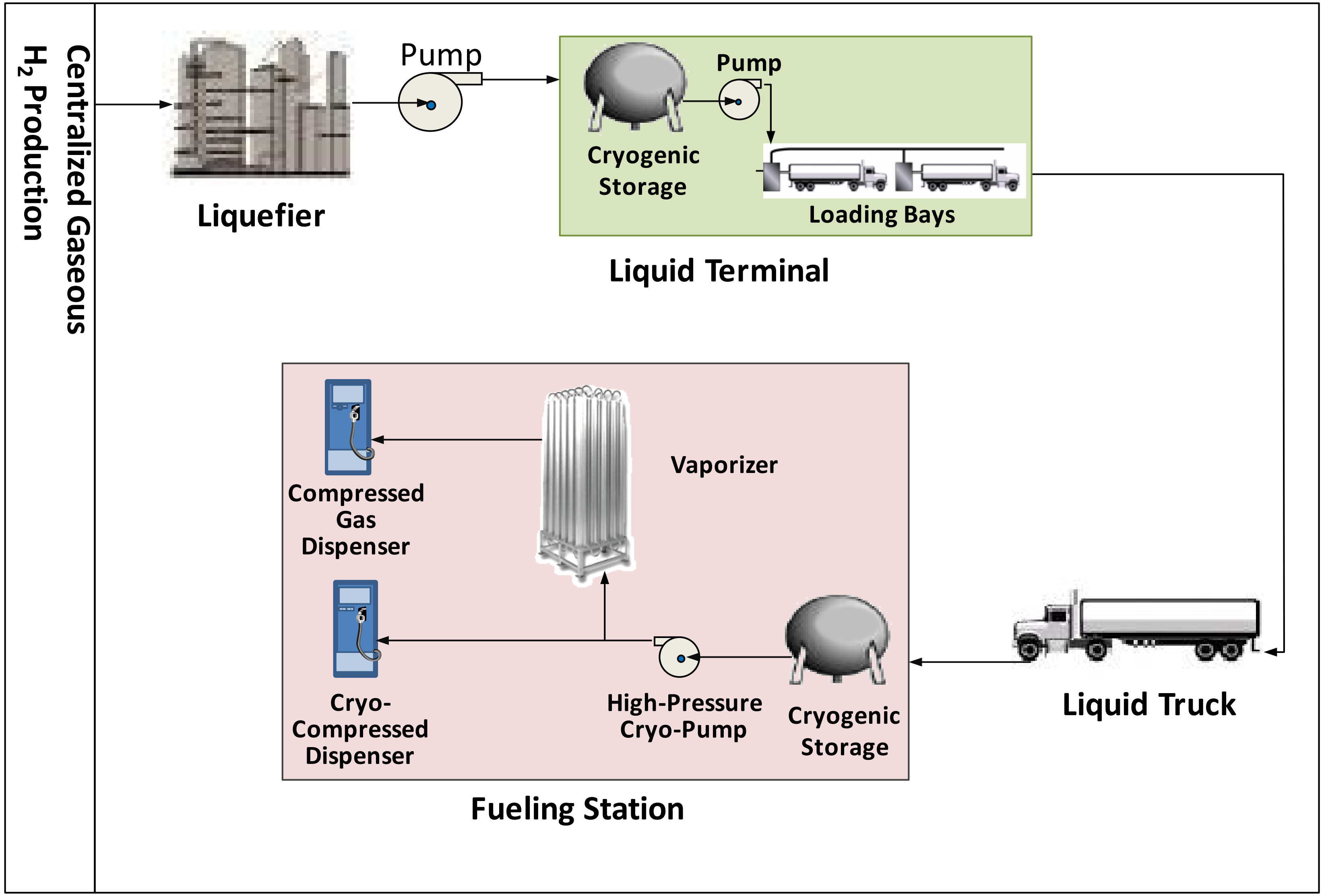
Infrastructure of gaseous hydrogen delivery



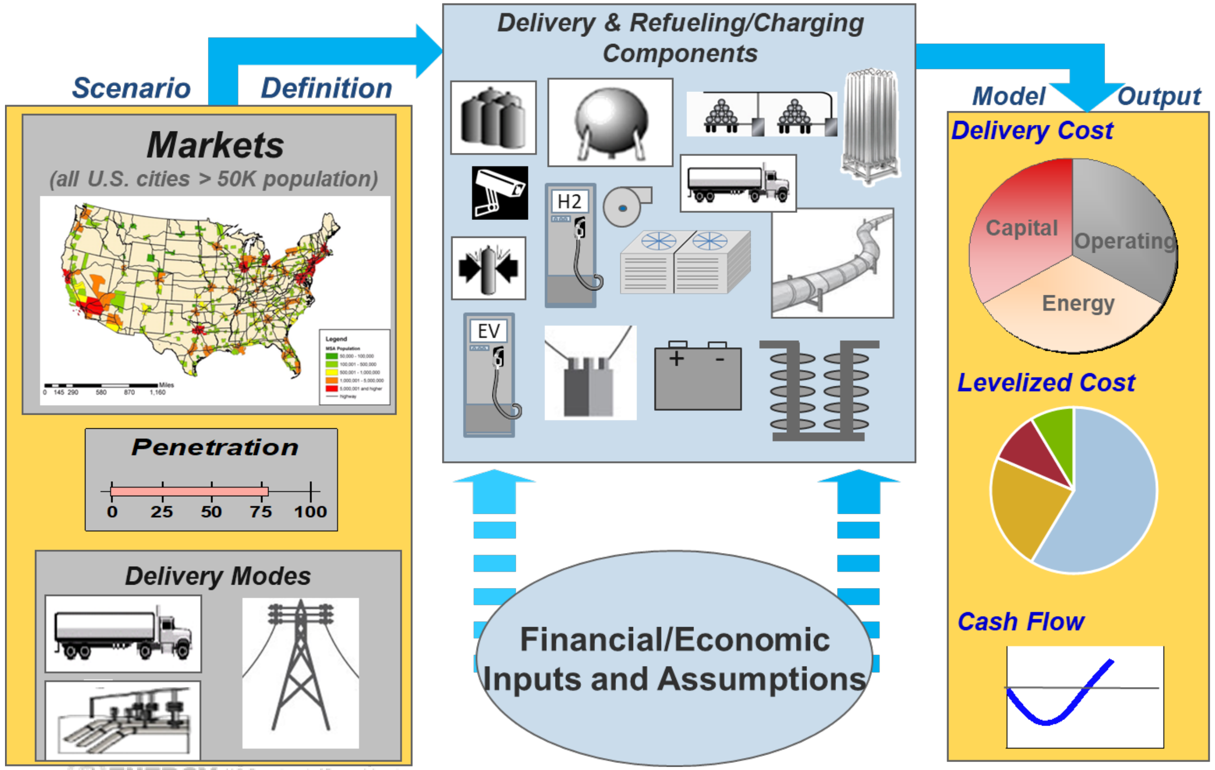
Infrastructure of liquid hydrogen delivery



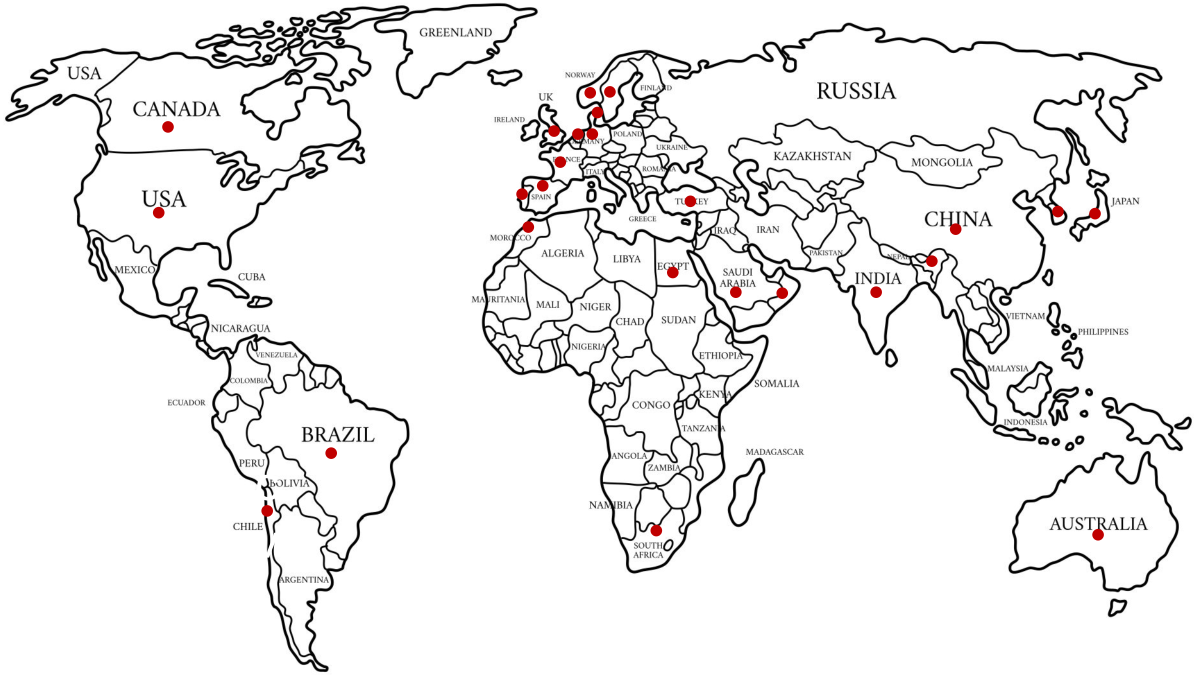
Hydrogen Delivery Scenario Analysis suite of Models (HDSAM)

Argonne's HDSAM and its derivatives evaluate the economic performance and market acceptance of hydrogen delivery technologies and fueling infrastructure for FCEVs

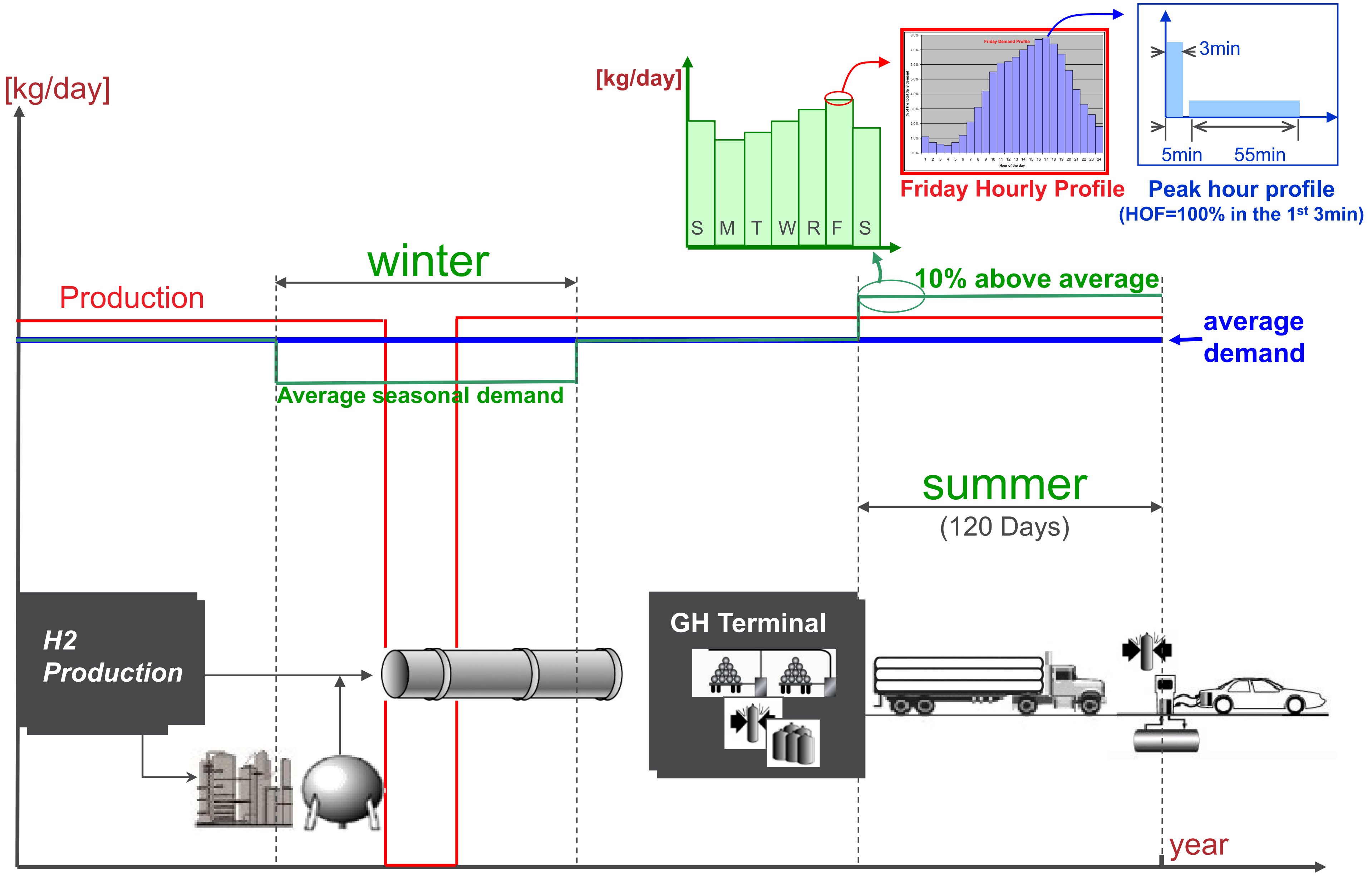
- Publicly available with >5,000 users, including major gas and energy companies, in more than 25 countries
- Supported by U.S. Department of Energy's Hydrogen and Fuel Cell Technologies Office (HFTO) since 2004



https://hdsam.es.anl.gov/

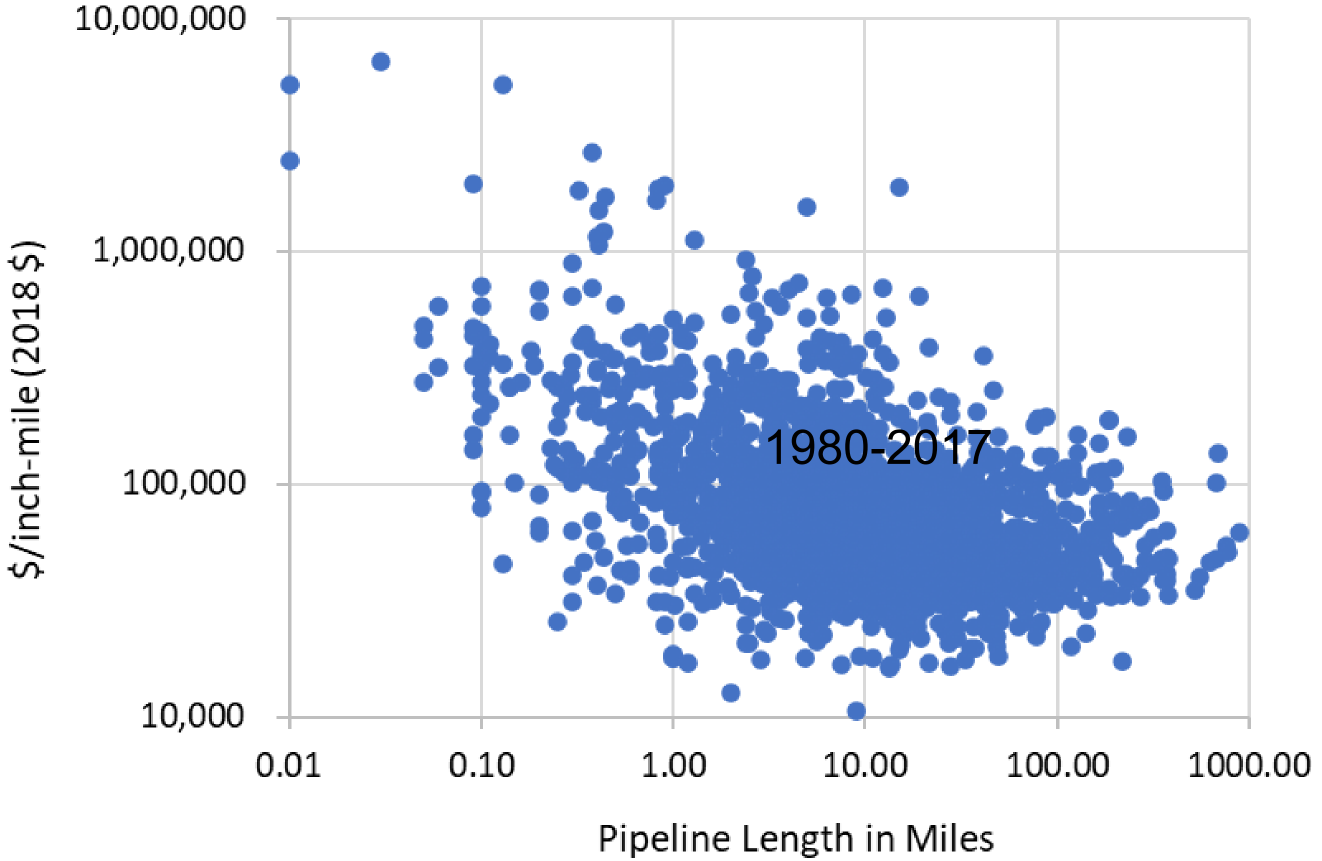


Demand/supply profiles for storage sizing



NATURAL GAS PIPELINE COST: IMPACT OF PIPE LENGTH
→ used as a surrogate for hydrogen pipeline cost

Normalized natural gas pipeline cost vs. length of the pipeline

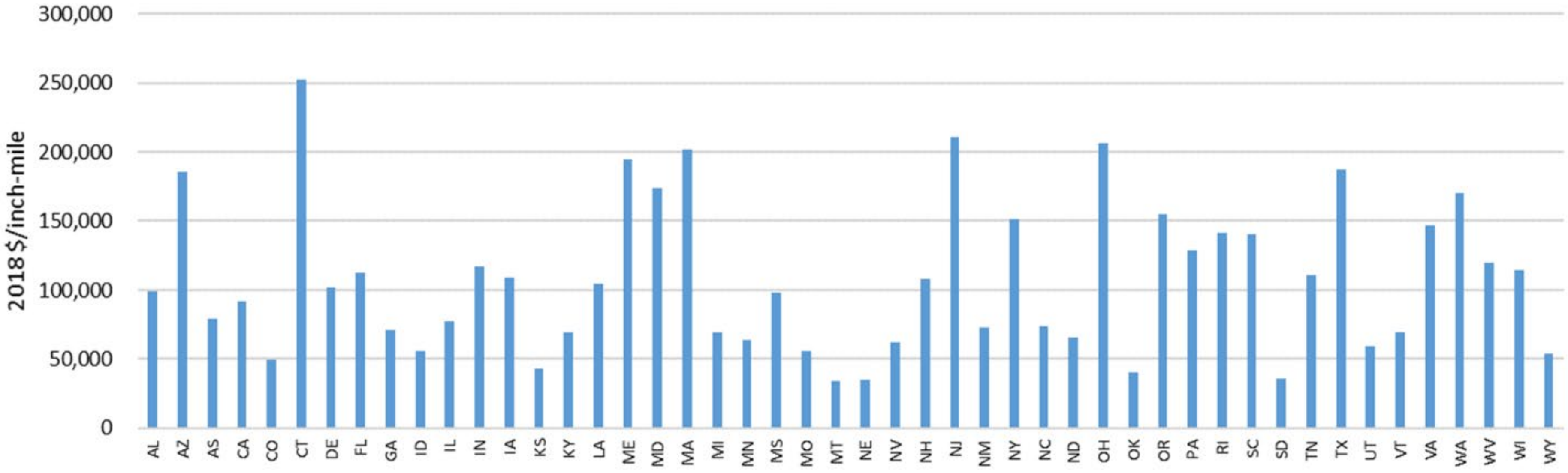


https://www.sciencedirect.com/science/article/pii/S0360319922034048

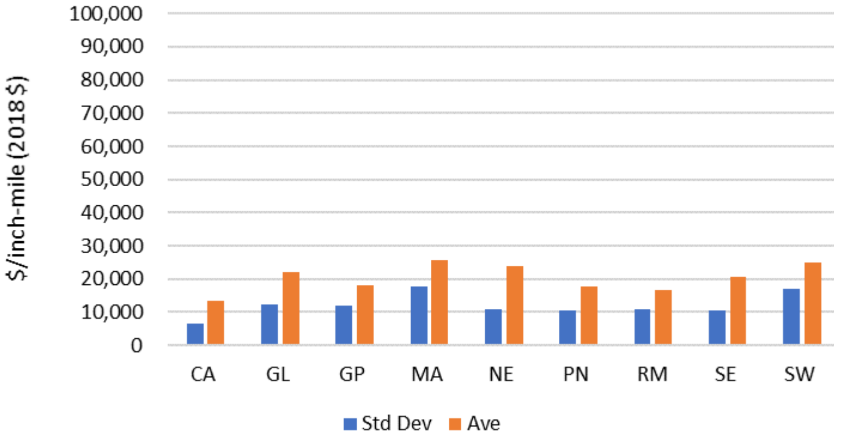
PIPELINE COST: IMPACT OF REGION

Regions	States Included
New England (NE)	ME, NH, VT, MA, CT, RI
Mid-Atlantic (MA)	PA, NY, NJ, WV, MD, DE, VA
Southeast (SE)	KY, TN, NC, SC, GA, FL, AL, MS, LA, AS
Great Lakes (GL)	MI, OH, IN, IL, WI
Great Plains (GP)	ND, SD, NE, KS, OK, MN, IA, MO
Rocky Mountain (RM)	ID, MT, WY, UT, CO, NM, NV
Pacific Northwest (PN)	OR, WA
Southwest (SW)	AZ, TX
California (CA)	CA

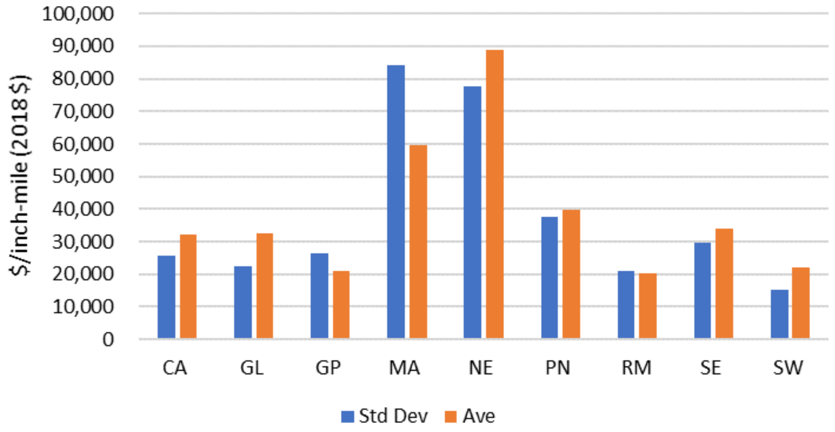
Normalized natural gas pipeline cost by state



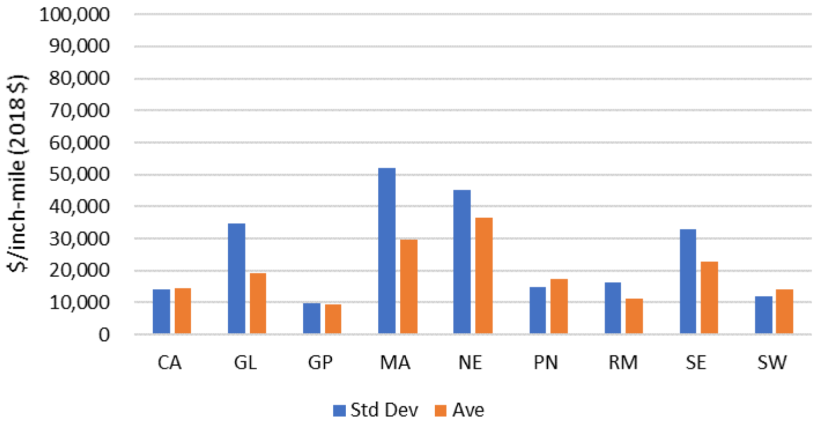
ITEMIZED COST CONTRIBUTION AND VARIATION BY REGION



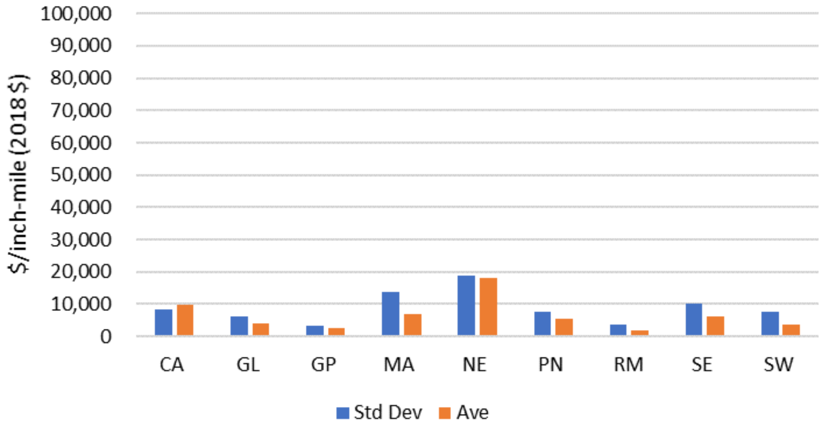
Normalized **material** cost



Normalized **labor** cost



Normalized **miscellaneous** cost



Normalized **right-of-way** costs

https://www.sciencedirect.com/science/article/pii/S0360319922034048

HDSAM incorporates pipeline cost by region, by class location, and by material, labor, misc. and ROW

Regions	States Included
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Great Plains	ND, SD, NE, KS, OK, MN, IA, MO
Rocky Mountain	ID, MT, WY, UT, CO, NM, NV
Pacific Northwest	OR, WA
Southwest	AZ, TX
California	CA

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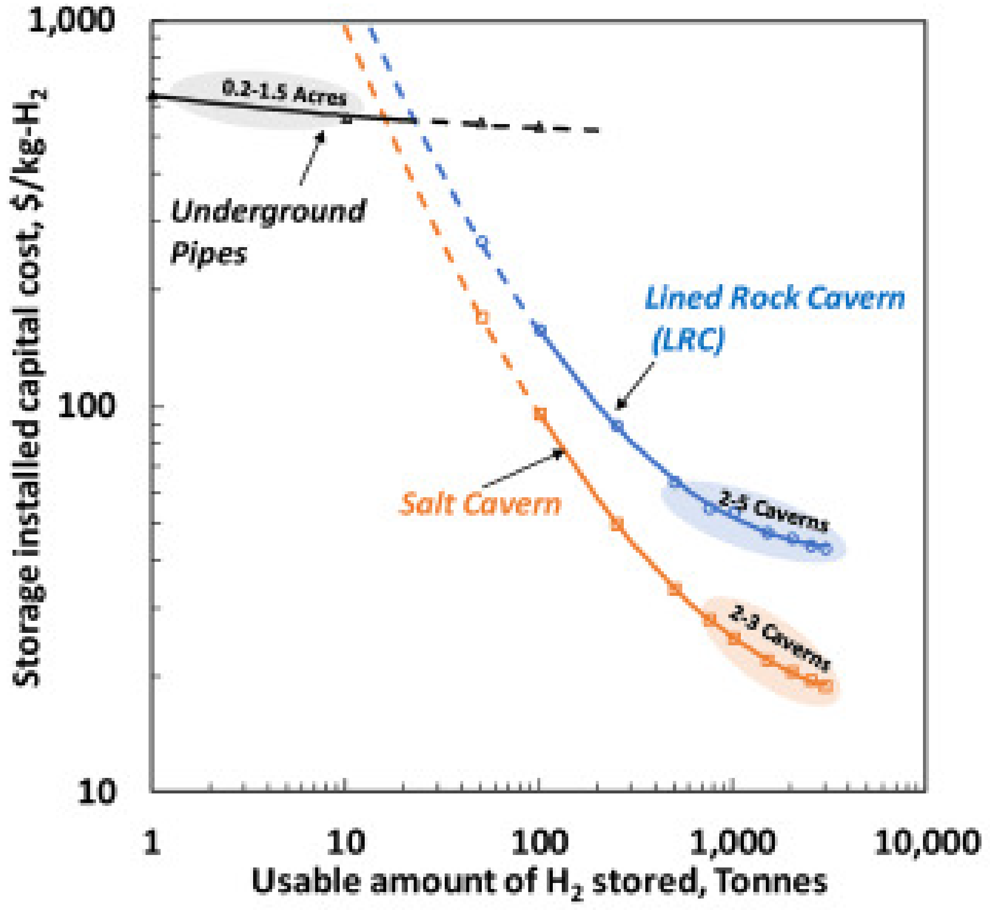
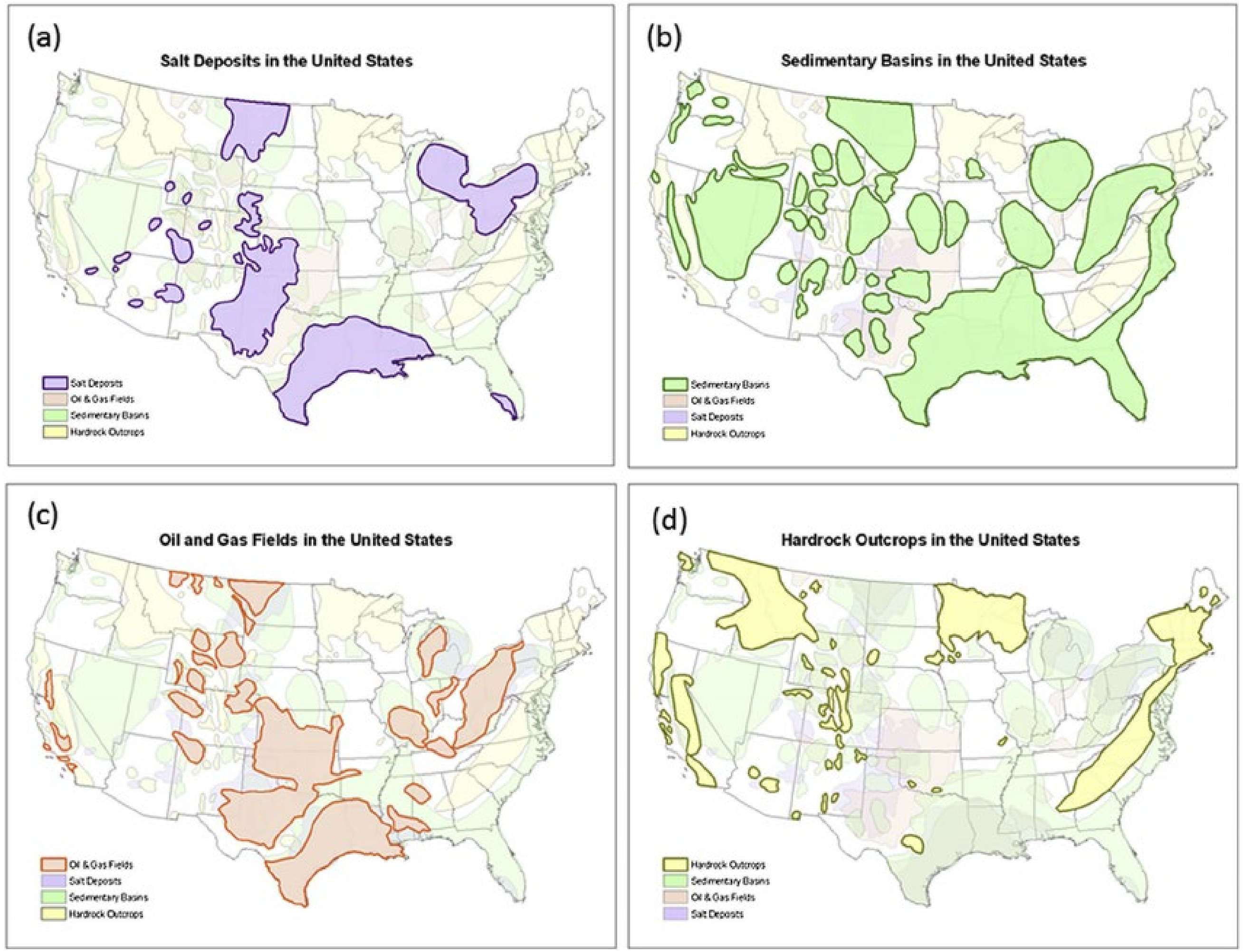
Cavern storage cost

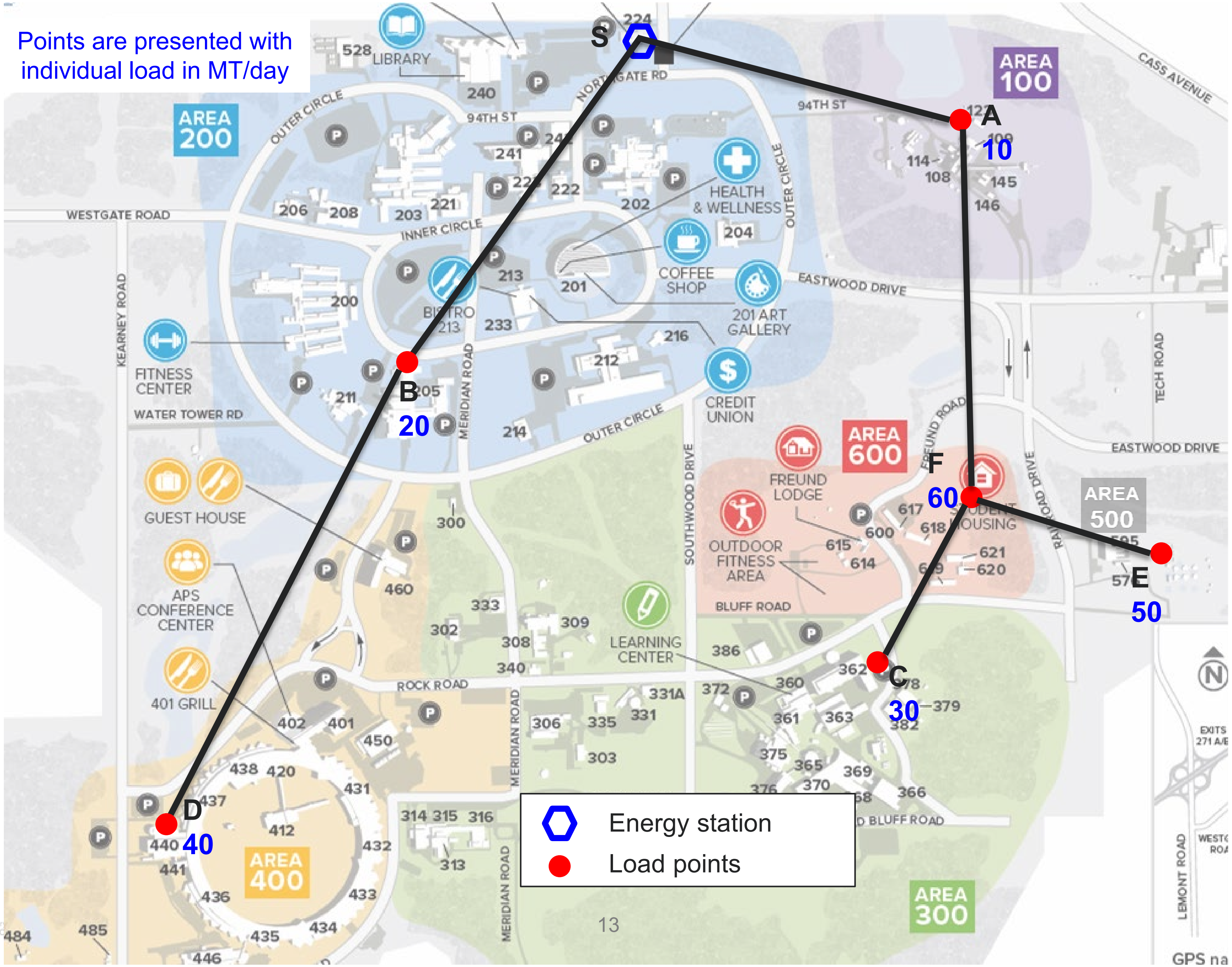


https://doi.org/10.1016/j.ijhydene.2021.08.028



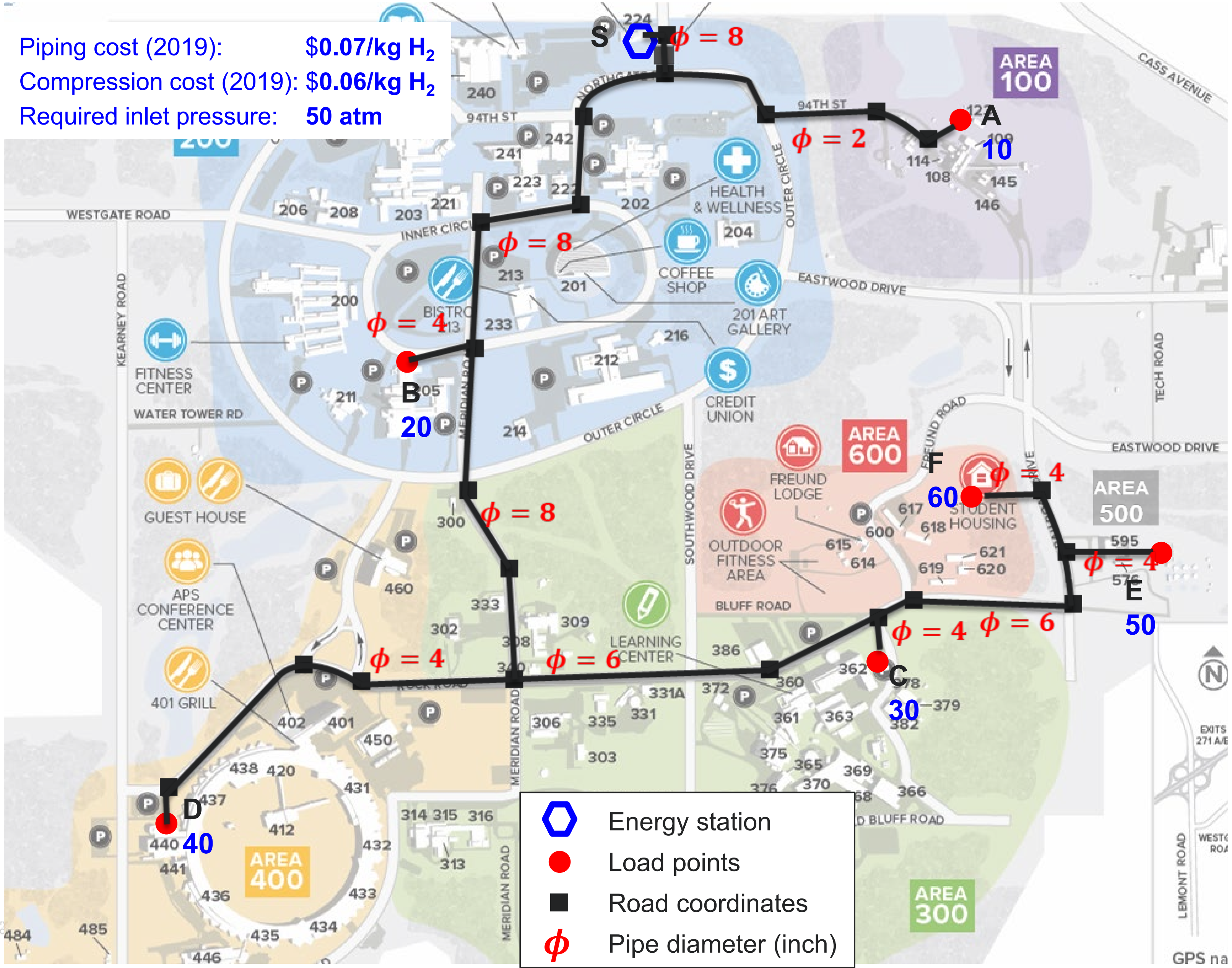
https://www.osti.gov/servlets/purl/1029761

PIPING NETWORK MODEL (ARGONNE)

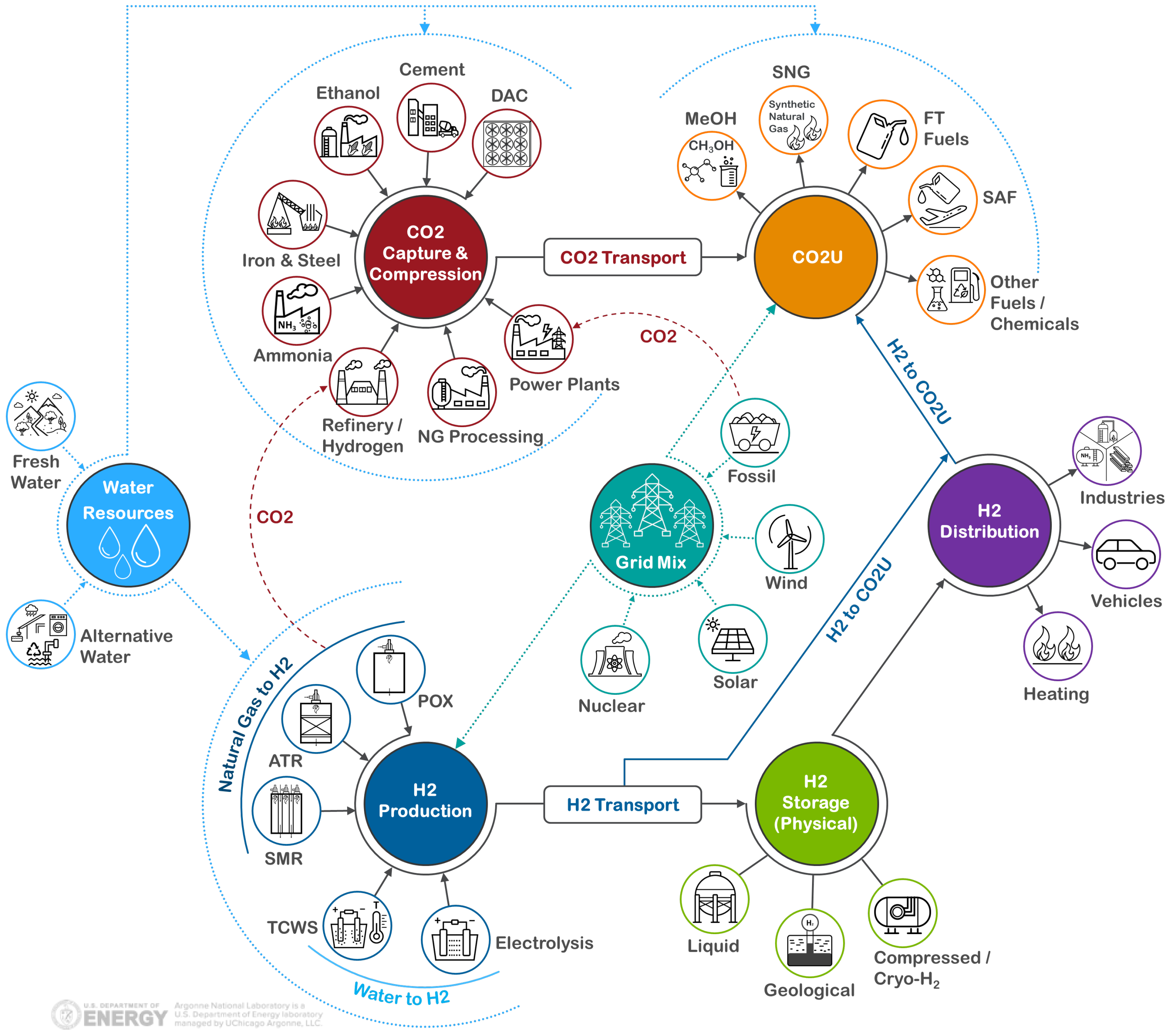


PIPING NETWORK MODEL (ARGONNE)

Piping cost (2019): **$0.07/kg H_2**
Compression cost (2019): **$0.06/kg H_2**
Required inlet pressure: **50 atm**



CCU Research Activities at Argonne



CCU Topics	Current Research
CO2 Capture & Compression	• Process Modeling, TEA and LCA of CC technologies
CO2 Transport	• CO_2 pipeline transportation cost
CO2 Utilization	• Process modeling, TEA and LCA of CO2U
H2 Production	• H_2 production technologies and market analysis • TEA and LCA
H2 Transport	• TEA and LCA of H_2 liquefaction, compression, delivery and fueling infrastructure
H2 Storage	• TEA and LCA of H_2 storage
Electricity Supply	• TEA and LCA of electric power supply by technology and region
Water Resources	• Regional water availability, footprint, and stress of CO2U technology deployment

Analysis Tools

- GREET
- HDSAM
- Aspen Plus
- Aspen Process Economic Analyzer
- WATER (AWAREUS)
- CO2 pipeline cost model

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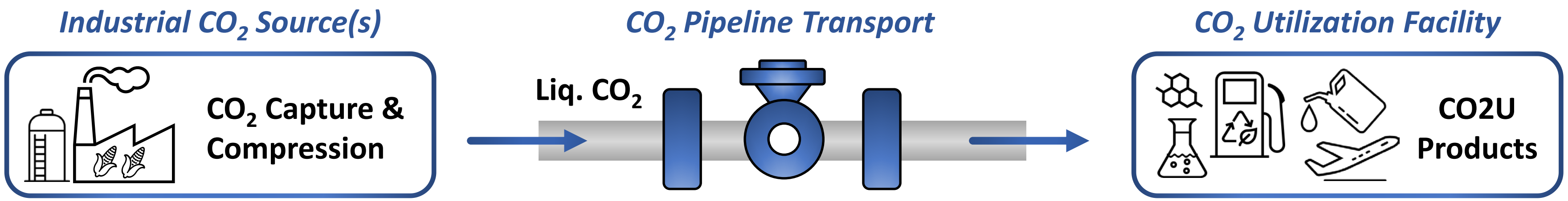
Publications:

- https://pubs.acs.org/doi/10.1021/acs.est.0c08237
- https://www.osti.gov/biblio/1868524
- https://doi.org/10.1016/j.jcou.2022.102212
- https://www.osti.gov/biblio/1845408
- https://doi.org/10.1021/acs.est.0c08674
- https://doi.org/10.1021/acs.est.0c08237
- https://doi.org/10.1021/acs.est.0c05893
- https://doi.org/10.1016/j.jcou.2021.101459

CO_2 Pipeline Transport Model – Cost Analysis for Compression and Transport



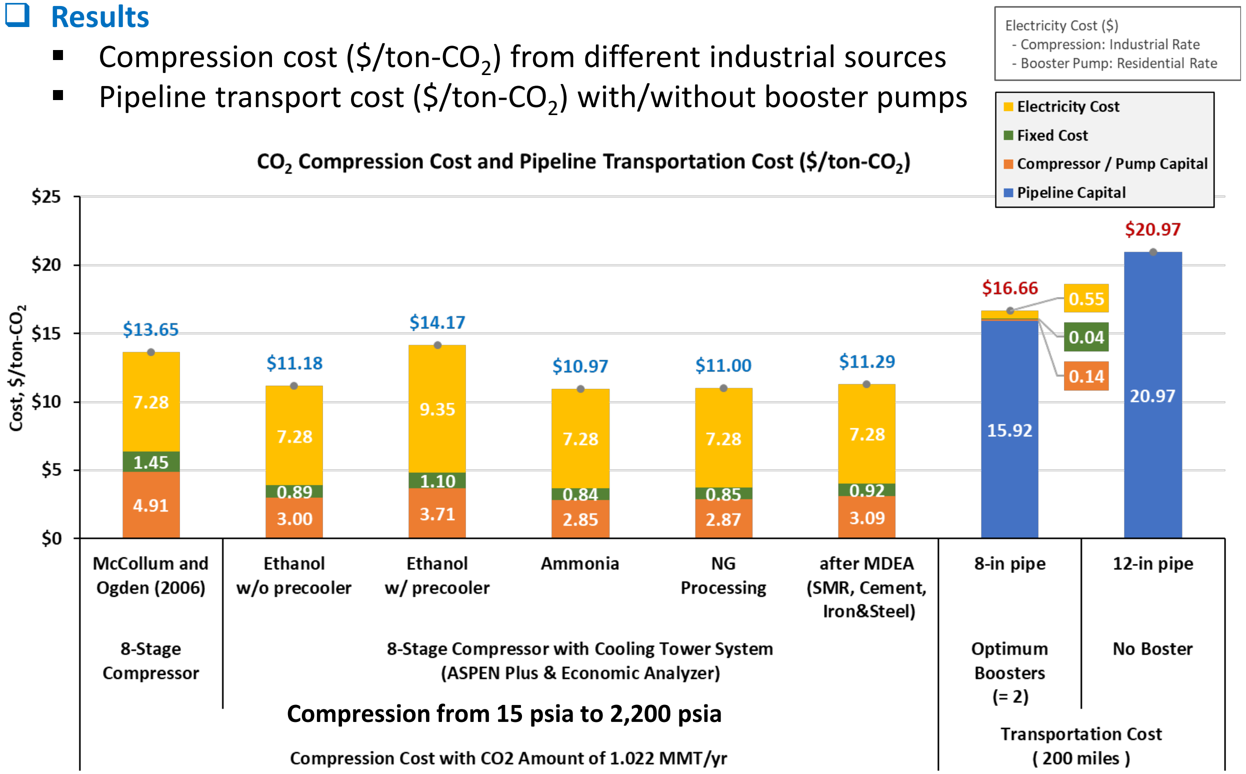
- **CO_2 Compression Cost Analysis (\$/ton-CO_2)**
  - Compression after capture, before pipeline transmission
  - As a function of (CO_2 throughput, pressure, and temperature)
  - Provide CO_2 compression cost
  - Calculation Methods: Literature, ASPEN Economic Analyzer, and Modified HDSAM model (*on-going*)

- **CO_2 Pipeline Transport Cost Analysis (\$/ton-CO_2)**
  - As a function of (CO_2 throughput, distance, pressure, and temperature)
  - Up-to-dated data for pipe material, labor, booster pump, and so on
  - Minimize the total cost by adjusting the number of booster pumps
  - Regional cost application (*on-going*)
  - Optimize CO_2 pipeline network (*on-going*)

CO_2 Pipeline Transport Model Results (Example)

Conditions
- CO_2 transport = 1 million metric ton /year, Pipeline distance = 200 miles
- T = 25°C / Pressures: 2,200 psia (upstream), 1,500 psia (downstream)

Results
- Compression cost (\$/ton-CO_2) from different industrial sources
- Pipeline transport cost (\$/ton-CO_2) with/without booster pumps



Thank You!

aelgowainy@anl.gov

Our models and publications are available at:

https://hdsam.es.anl.gov/