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STATISTICS, ANALYTICS, AND GIS IN ENERGY CONFERENCE

August 13-14, 2025 | Des Plaines, Illinois

Clean Energy Network Analysis (CENA)

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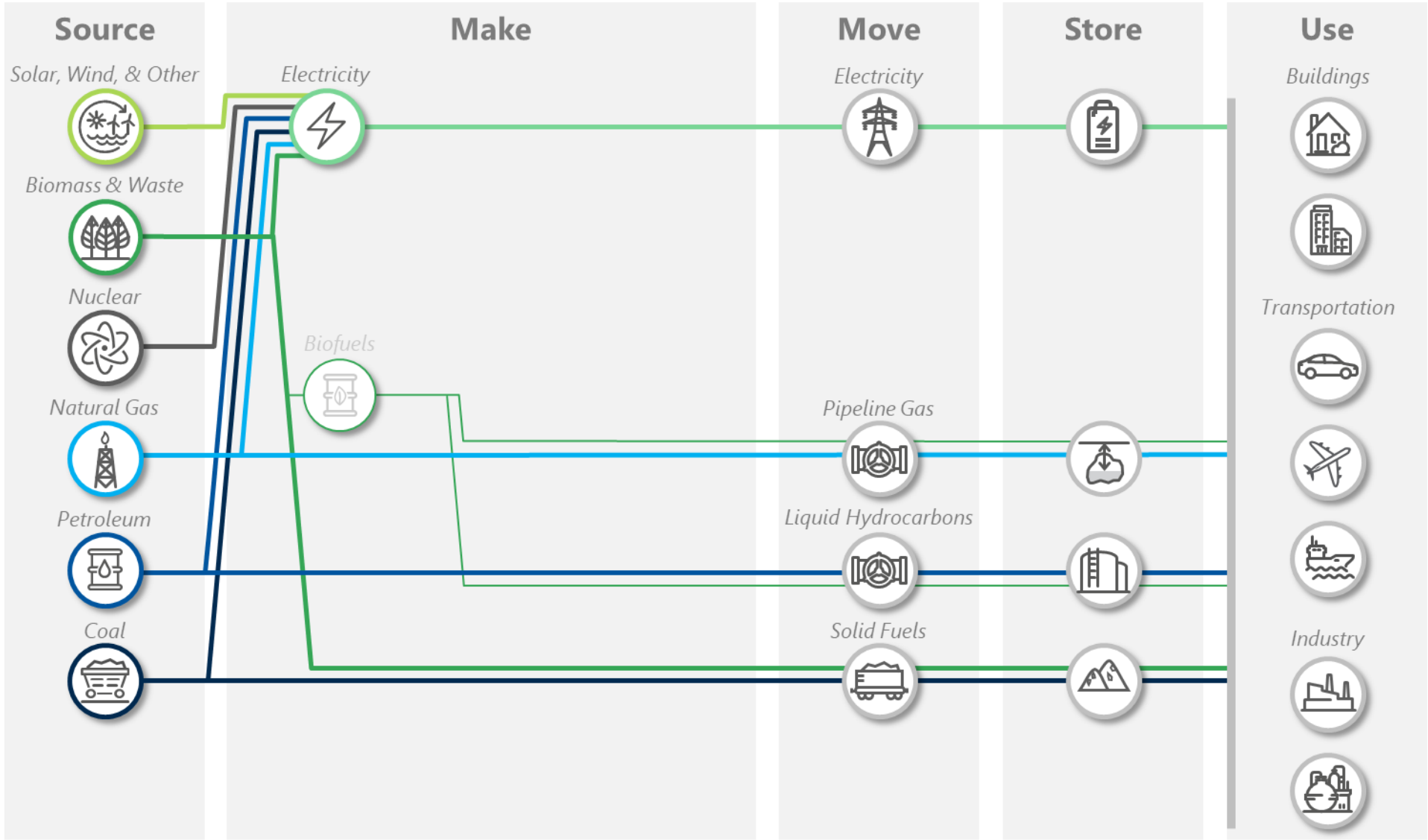
Today's Energy Systems



Electricity

Conventional molecules

Existing infrastructure

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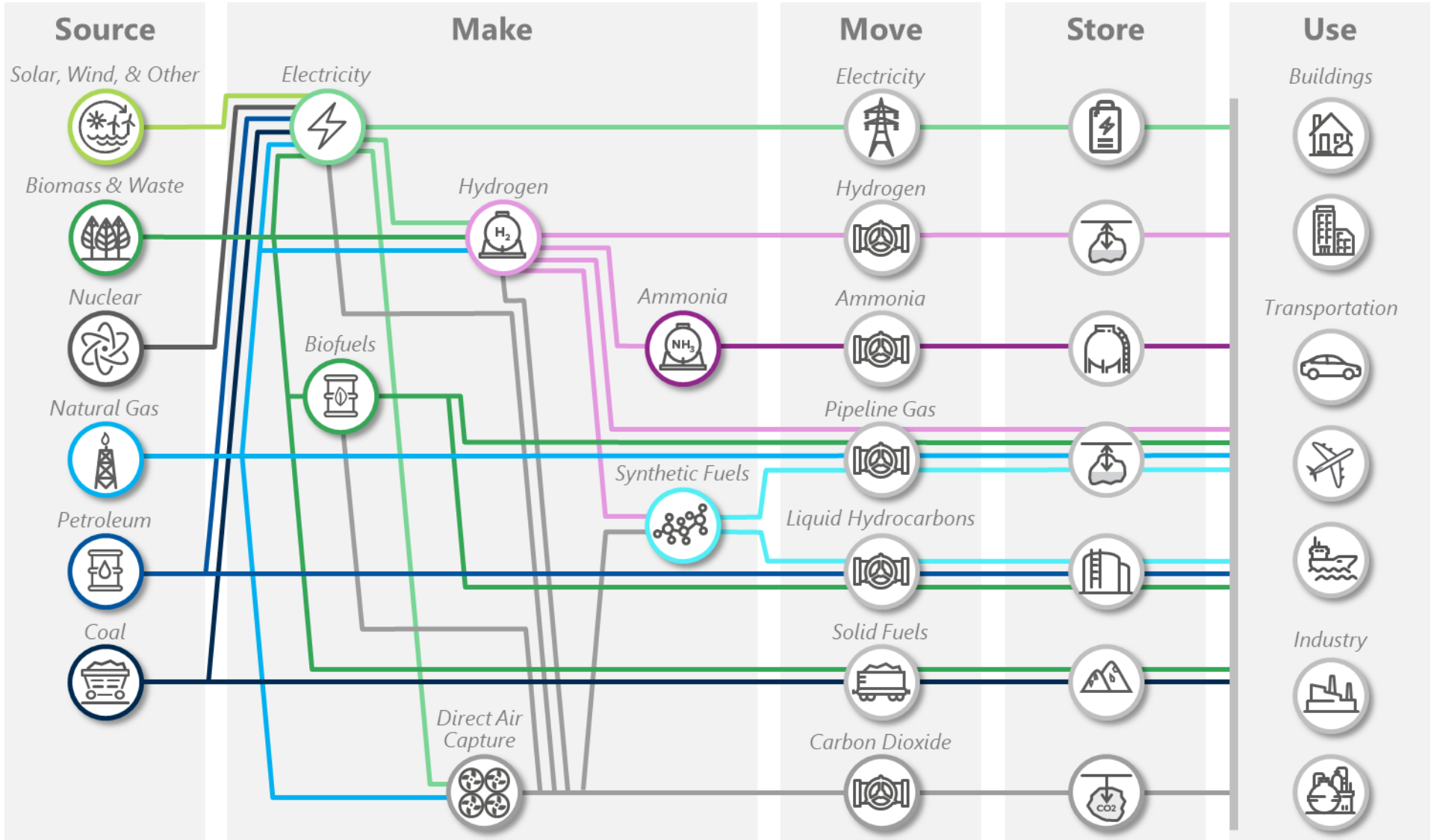
Net-Zero Energy Systems



Electricity

Conventional molecules

Existing infrastructure

New molecules

New infrastructure

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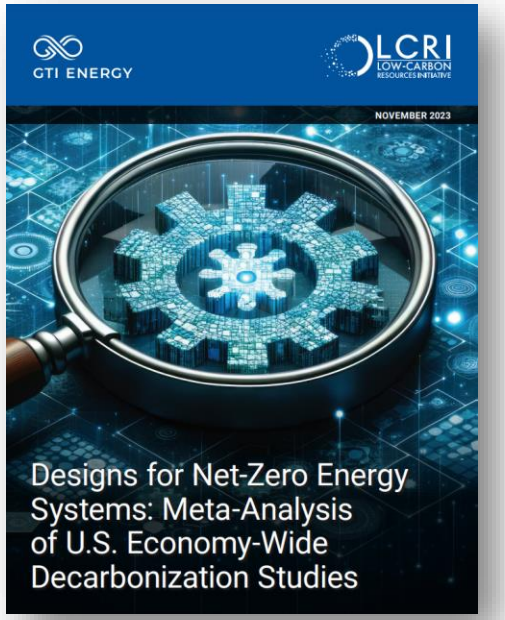
Meta NZ Study



report available at
gti.energy/meta-nz/

Meta-Analysis of U.S. Economy-Wide, Net-Zero Studies

1. Low Carbon Resources Initiative (*EPRI, GTI Energy*)
2. Open Energy Outlook (*Carnegie Mellon University, NC State*)
3. Evolved Energy Research
4. Princeton University
5. Decarb America (*Bipartisan Policy Center, Clean Air Task Force, Third Way*)

5 leading independent U.S. economy-wide studies

23 scenarios for least-cost pathways to net-zero

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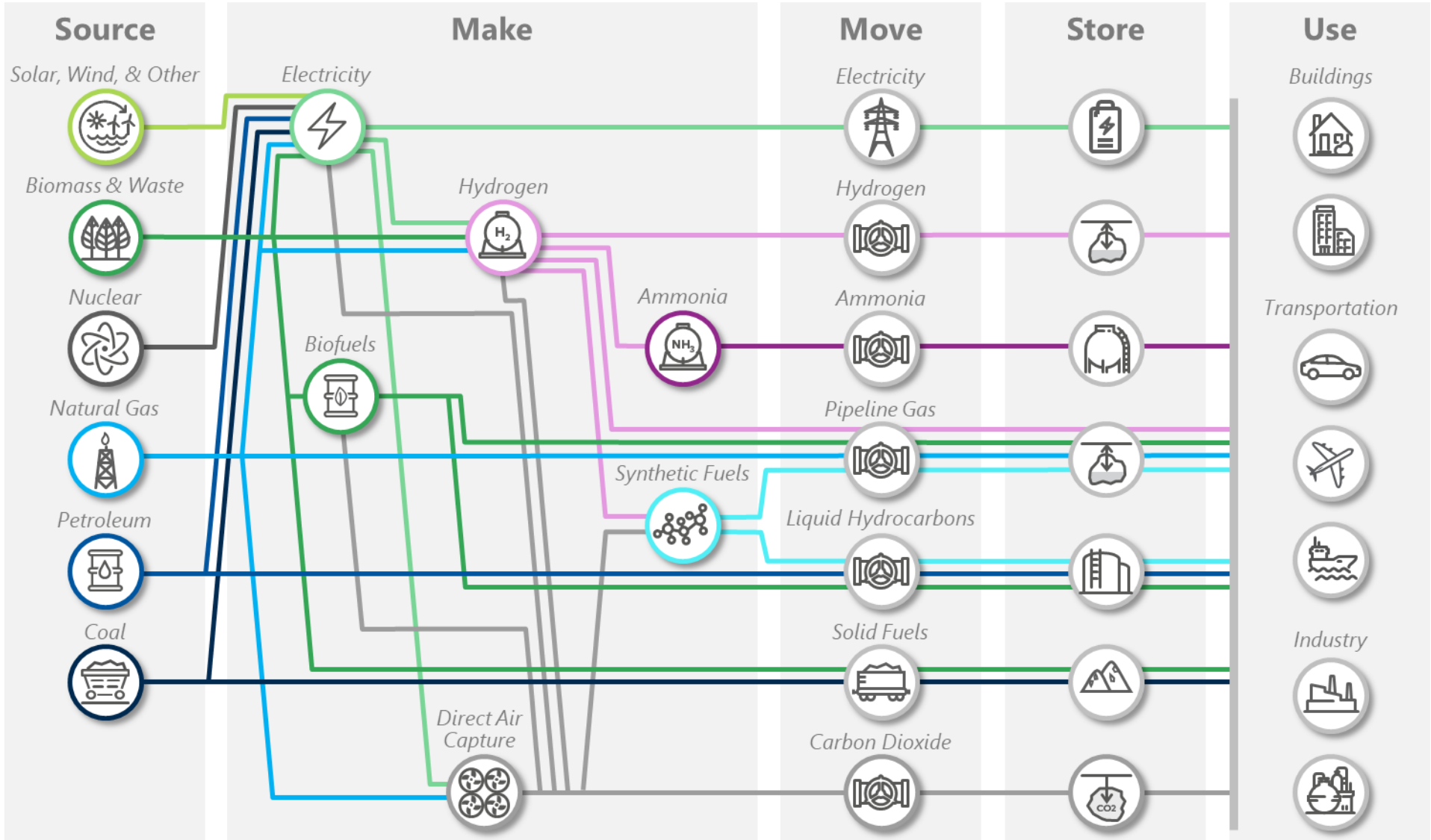
Net-Zero Energy Systems



Electricity

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New infrastructure

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Clean Energy Network Analysis (CENA)

What could the co-optimized deployment of gas infrastructure (NG/RNG/SNG, H2, CO2) look like in a net-zero future?

How can we answer regional questions using data from national net-zero studies?	What is the role of existing gas infrastructure in net-zero energy systems?	How do we optimize building new infrastructure to move these new molecules?

First-of-a-kind analysis that performs a **simultaneous cost-based co-optimization of CO2 and H2 infrastructure relative to NG infrastructure**

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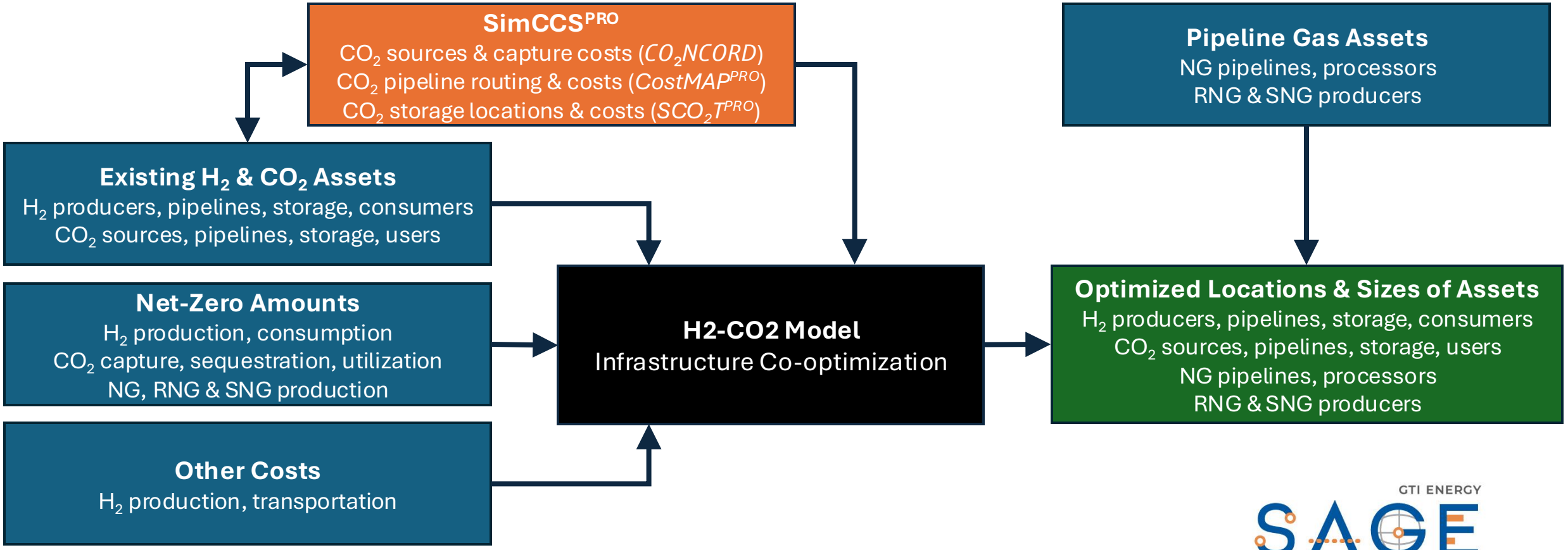
Modeling Framework



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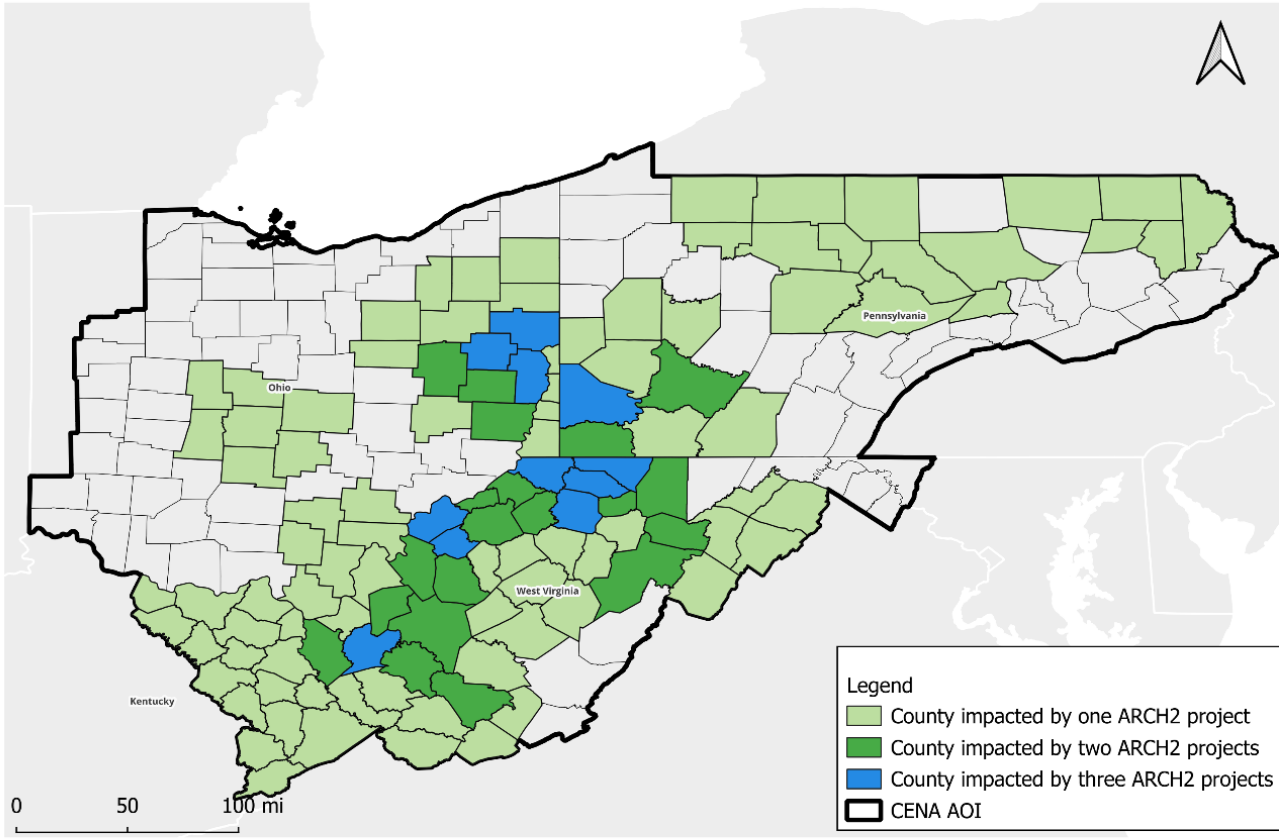
Area of Interest (AOI): Appalachia

- Important energy-producing region for over a century
- Plentiful NG to produce H2
- Iron & steel industry that could use H2
- Large sources of CO2 to capture from
- Existing gas infrastructure & workforce
- ARCH2 hub



Selected counties in four states: KY, OH, PA, WV

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Data Disaggregation: Net-Zero Scenarios

US

- How much hydrogen is produced via electrolysis in the US in 2050 under net-zero conditions?

Depending on available data

Region/State

- How much hydrogen is produced via electrolysis in the Ohio River Valley or in Pennsylvania in 2050 under net-zero conditions?

County-level data: population, GDP, truck stops

AOI

- How much hydrogen is produced via electrolysis in CENA's area of interest in 2050 under net-zero conditions?

Data Disaggregation: Net-Zero Scenarios

Low Carbon Resources Initiative (LCRI)

1. LCRI Opt-Tech
   Optimistic assumptions for CO2 transport and storage, electrolysis, and bioenergy
2. LCRI Lim-CCS Opt-Nuc
   Optimistic assumptions for electrolysis, reference assumptions for bioenergy, and no CO2 storage

Evolved Energy Research (EER)

1. EER Central
   Least-cost pathway for achieving net zero by 2050
2. EER Low Land
   Limits the amount of land available for building energy infrastructure due to environmental and societal constraints

Net-Zero 2050 Values	LCRI Opt-Tech	LCRI Lim-CCS Opt-Nuc	EER Central	EER Low Land
H2 consumption total [Mt/yr]	0.13	0.63	2.43	2.88
Green H2 production total [Mt/yr]	0.00	0.63	1.38	1.77
Blue H2 production total [Mt/yr]	0.13	0.00	1.04	1.11
CO2 capture total [Mt/yr]	92.01	4.91	21.15	32.67
CO2 sequestration total [Mt/yr]	92.01	0.00	18.59	29.40
CO2 utilization total [Mt/yr]	0.00	0.00	2.56	3.27
RNG production total [EJ/yr]	0.02	0.03	0.07	0.09
SNG production [EJ/yr]	0.00	0.00	0.00	0.00
NG production total [EJ/yr]	3.71	0.04	3.71	4.99

Data Gathering: NG, RNG & SNG

Natural Gas (NG)

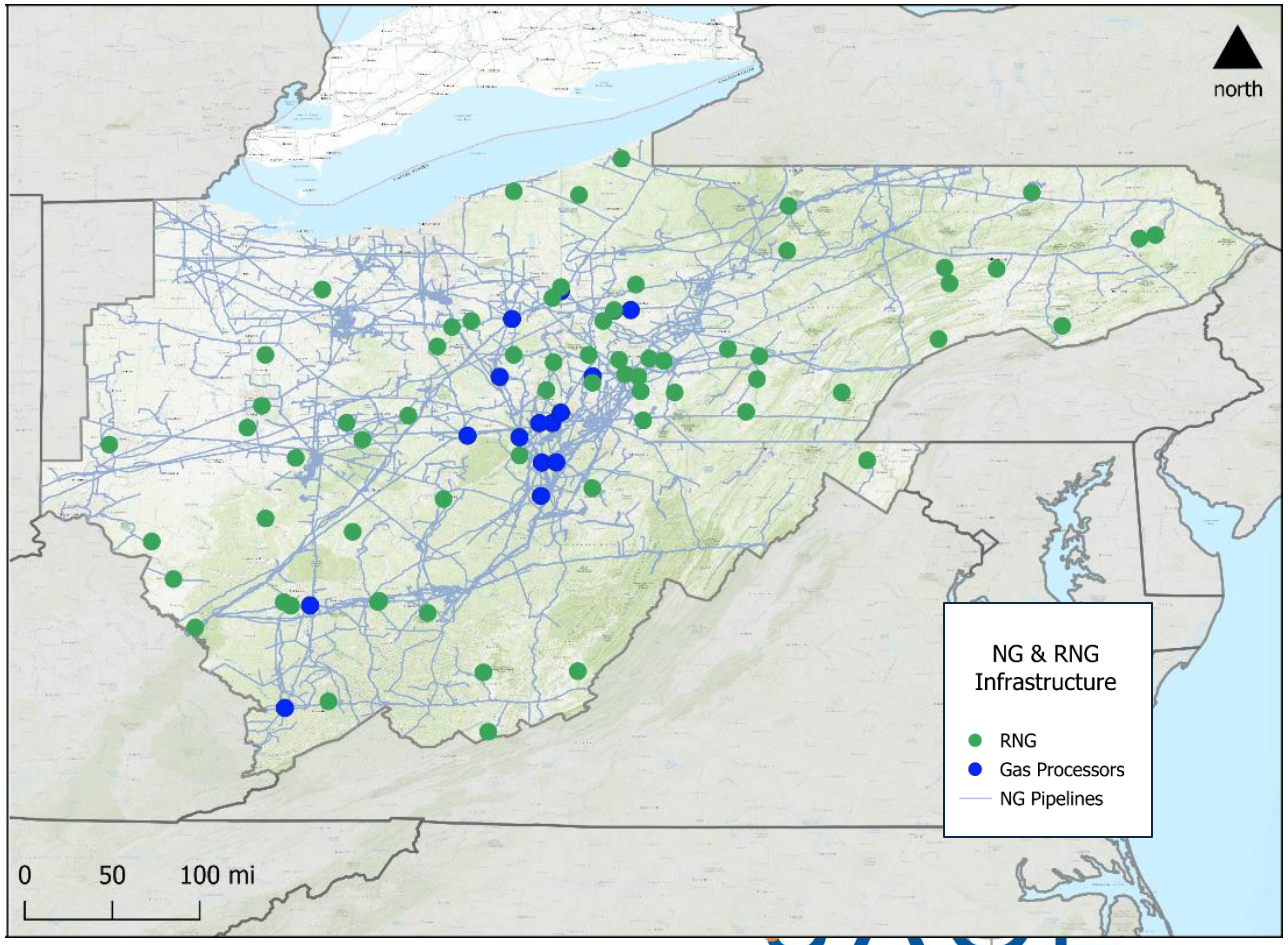
- Production: Gas processors > 50 MMcfd
- Transportation: ~73,000 km Pipelines

Renewable Natural Gas (RNG)

- 18 existing and 48 new RNG facilities
- Potential RNG production capacity of ~160,000 scfm

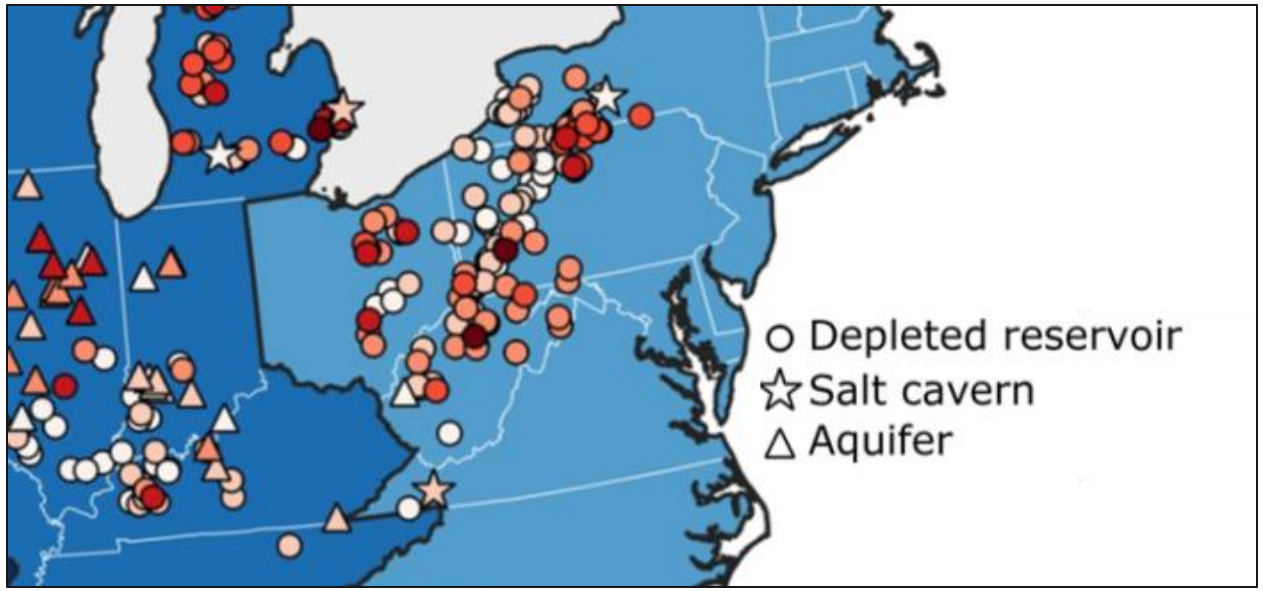
Synthetic Natural Gas (SNG)

- None

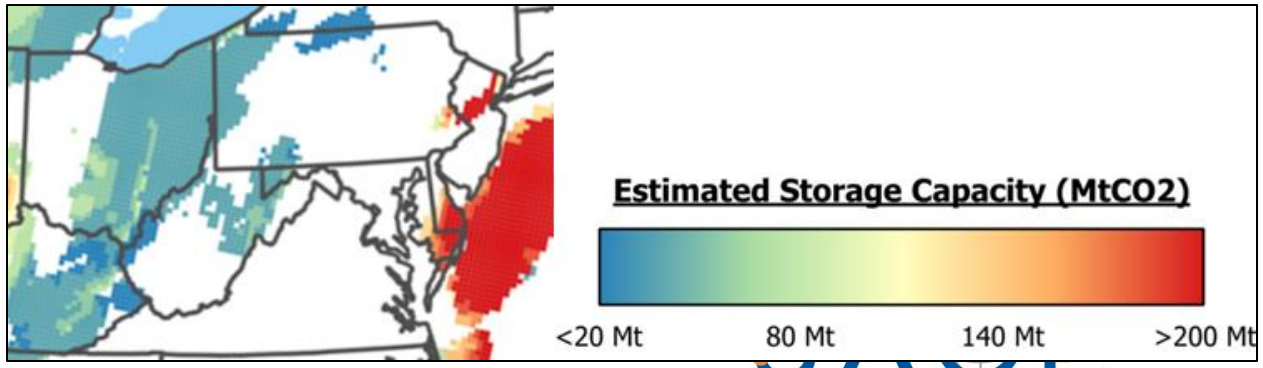


Data Gathering: H2 & CO2

H2 production	• NGR+CC, electrolysis, BG+CC
H2 transportation	• Pipelines
H2 storage	• Subsurface depleted gas reservoirs
H2 consumption	• Iron & steel, cement, ammonia, synthetic fuels, MHDVs, refineries
CO2 capture	• H2 production, power plants, cement/lime, ethanol
CO2 transportation	• Pipelines
CO2 sequestration	• Geologic subsurface
CO2 utilization	• Synthetic fuels



Adapted from Lackey et al.



Adapted from Carbon Solutions

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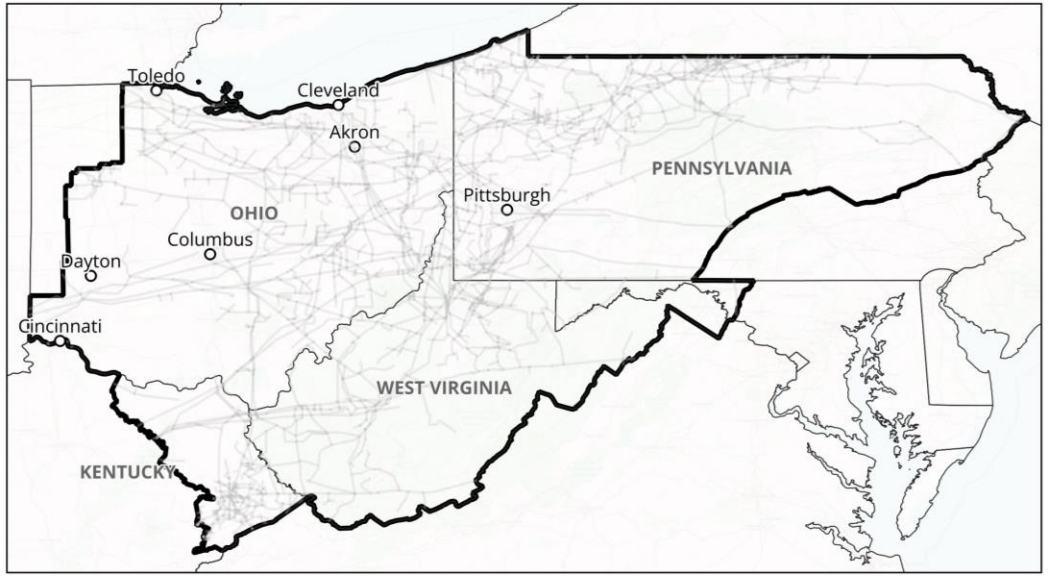
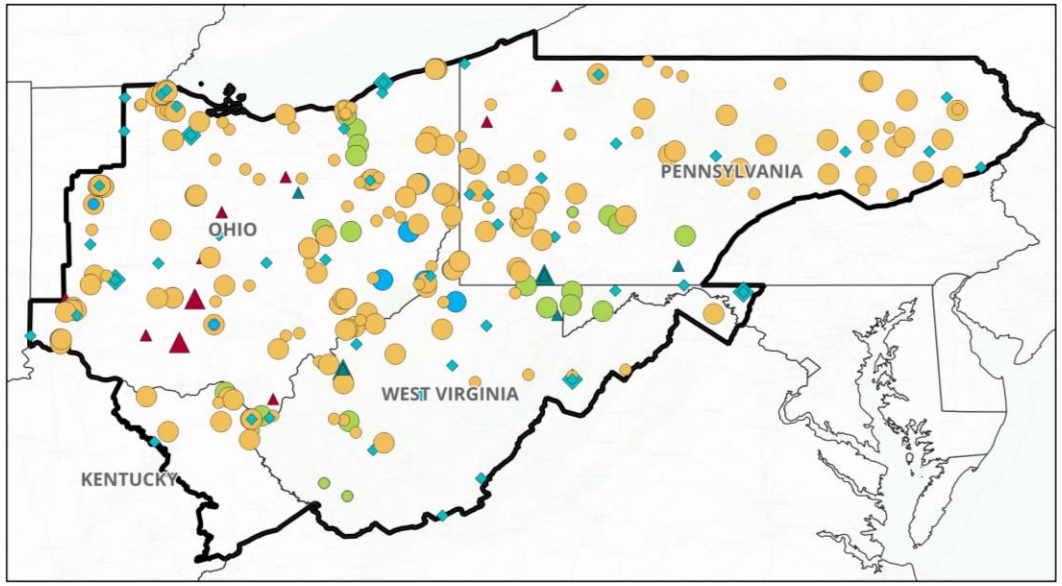
Infrastructure Available for Optimization

Existing Natural Gas Pipelines



Potential H_2 & CO_2 Assets



H2
H2_Producers
≤ 0.1 MtH2/yr
> 0.1 MtH2/yr
NGR/BG +CC
Electrolysis
H2_Storage
≤ 1.0 MtH2/yr
> 1.0 MtH2/yr

H2_Consumers
≤ 0.1 MtH2/yr
> 0.1 MtH2/yr
H2_Pipelines
≤ 0.5 MtH2/yr
0.5–3.0 MtH2/yr
> 3.0 MtH2/yr

CO2
CO2_Sources
≤ 0.1 MtCO2/yr
> 0.1 MtCO2/yr
CO2_Storage
≤ 25 MtCO2
> 25 MtCO2

CO2_Users
≤ 0.1 MtCO2/yr
> 0.1 MtCO2/yr
CO2_Pipelines
≤ 0.5 MtCO2/yr
0.5–3.0 MtCO2/yr
> 3.0 MtCO2/yr

Existing Natural Gas Transmission Pipelines
Major Cities
CENA AOI

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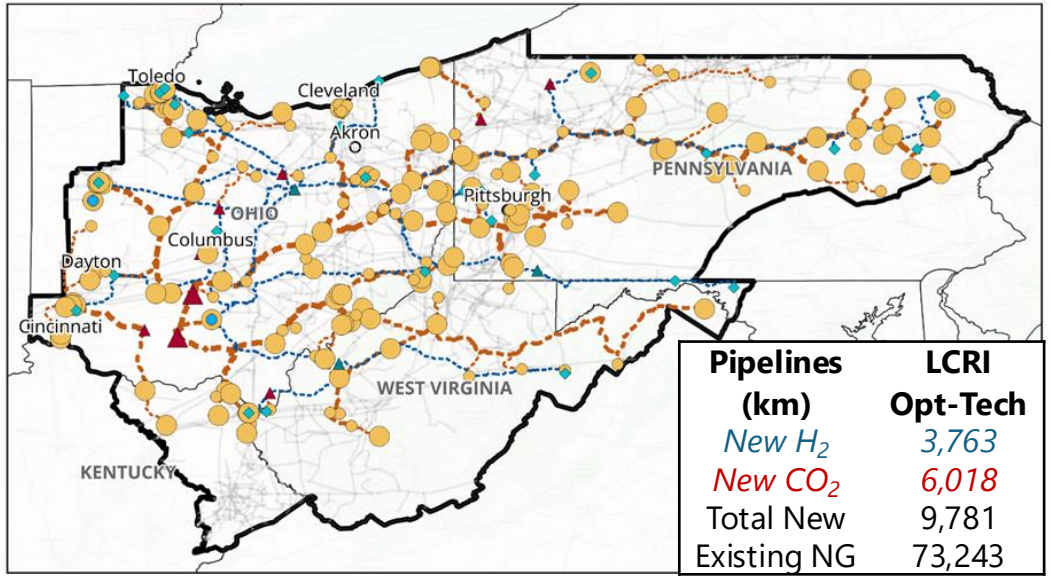
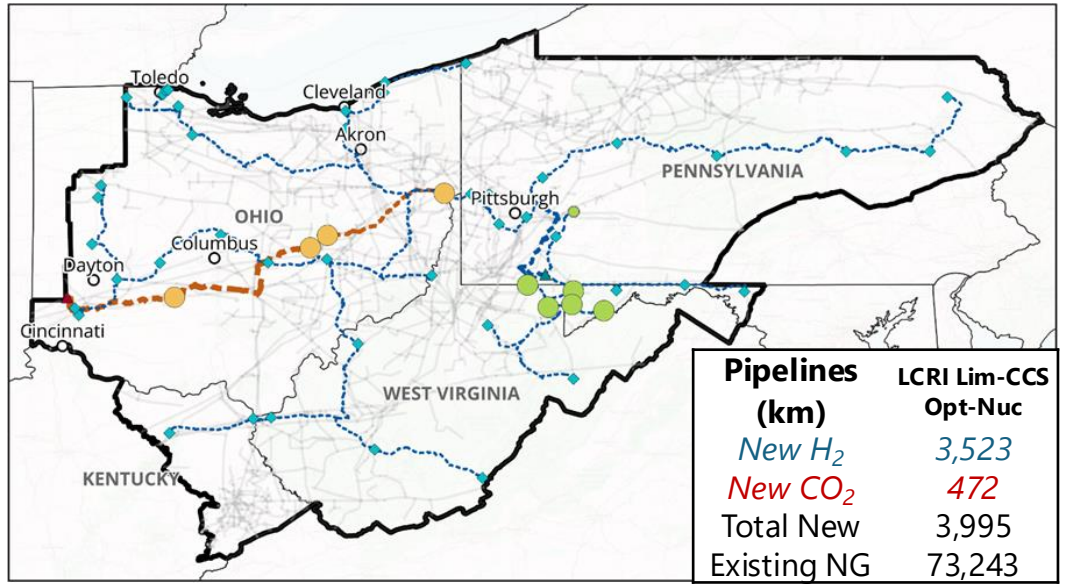
Results of Net-Zero LCRI Scenarios

LCRI Opt-Tech



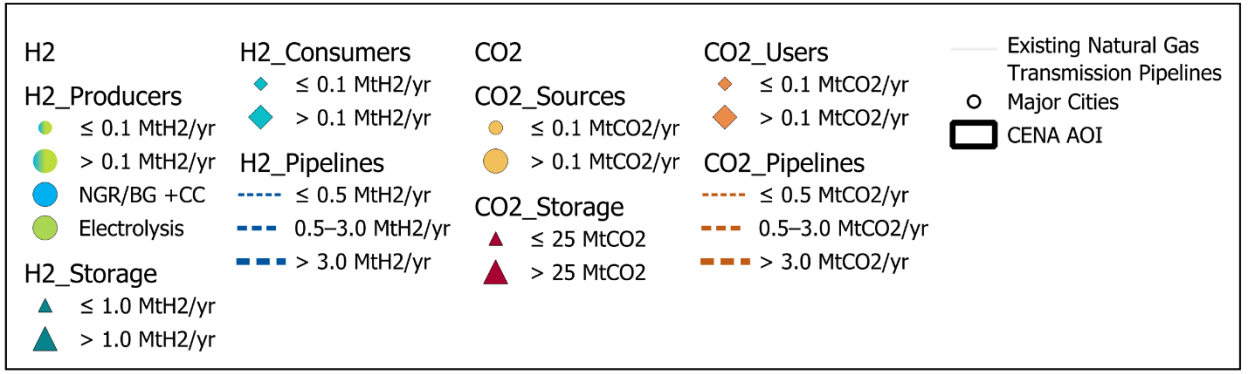
Pipelines (km)	LCRI Opt-Tech
New H_2	*3,763*
New CO_2	*6,018*
Total New	9,781
Existing NG	73,243

LCRI Lim-CCS Opt-Nuc



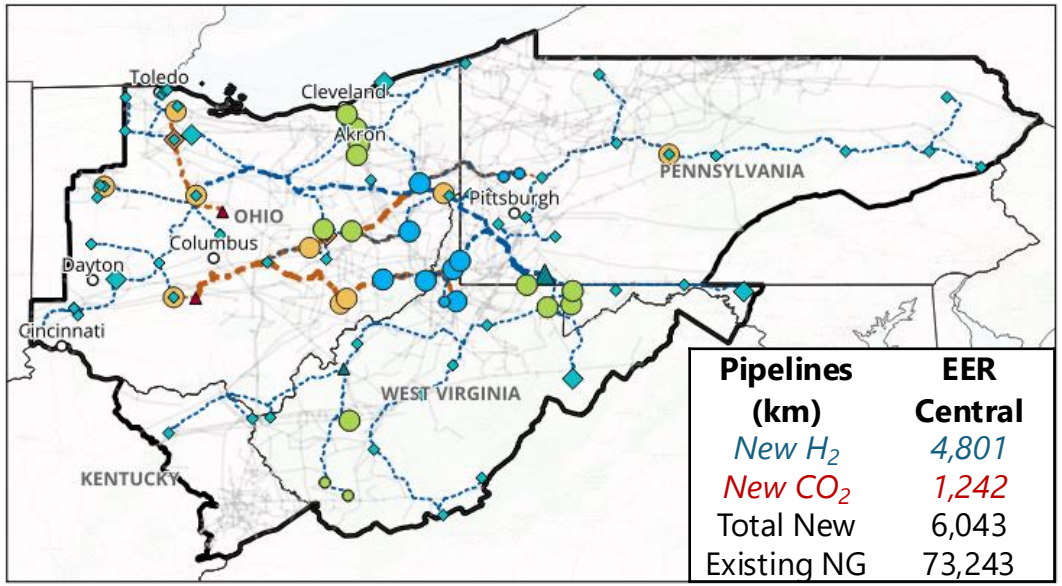
Pipelines (km)	LCRI Lim-CCS Opt-Nuc
New H_2	*3,523*
New CO_2	*472*
Total New	3,995
Existing NG	73,243

Amount	Opt-Tech	Lim-CCS Opt-Nuc
Green H_2 [Mt/yr]	0.00	0.63
Blue H_2 [Mt/yr]	0.13	0.00
CO_2 capture [Mt/yr]	92.01	4.91



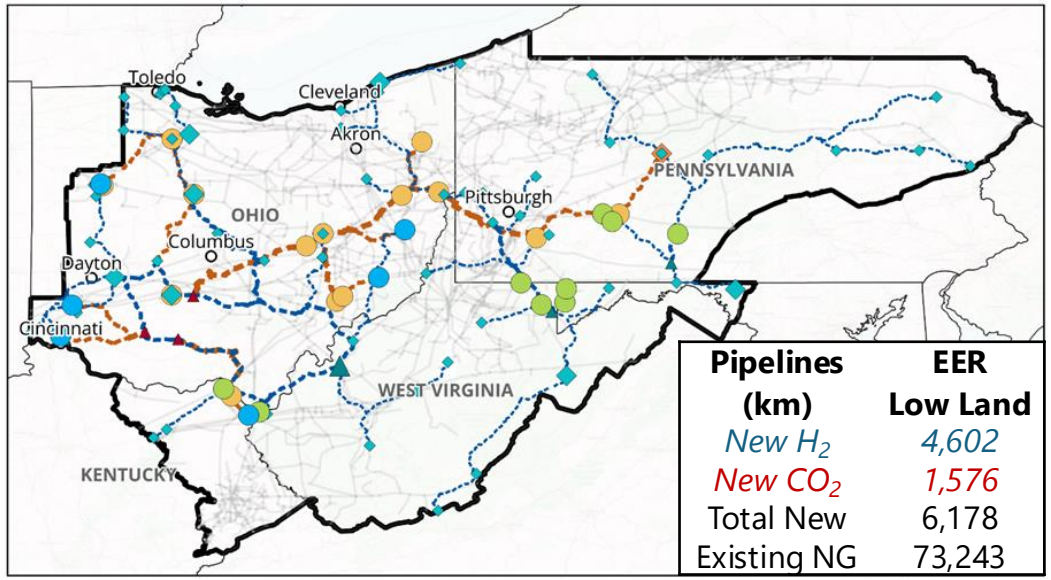
Results of Net-Zero EER Scenarios

EER Central



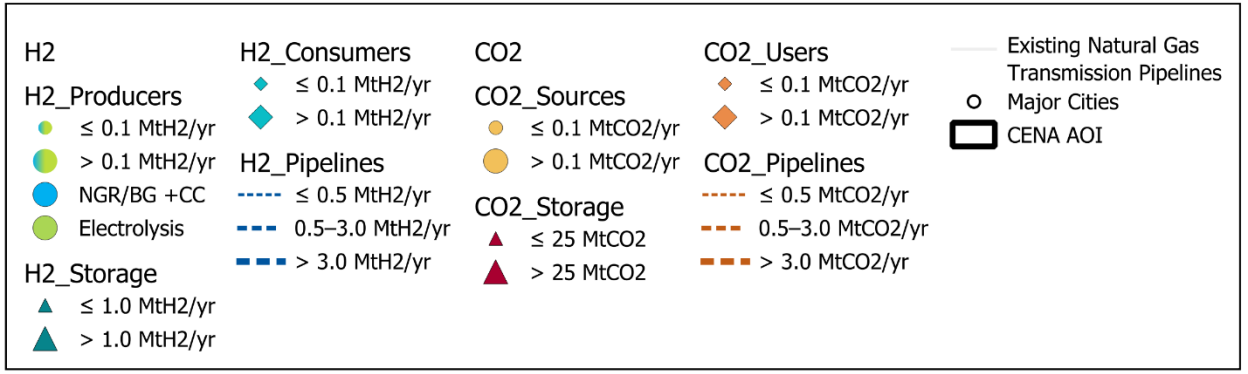
Pipelines (km)	EER Central
New H_2	*4,801*
New CO_2	*1,242*
Total New	6,043
Existing NG	73,243

EER Low Land



Pipelines (km)	EER Low Land
New H_2	*4,602*
New CO_2	*1,576*
Total New	6,178
Existing NG	73,243

Amount	Central	Low Land
Green H_2 [Mt/yr]	1.38	1.77
Blue H_2 [Mt/yr]	1.04	1.11
CO_2 capture [Mt/yr]	21.15	32.67



Can we build it?

Pipelines (km)	LCRI Opt-Tech	LCRI Lim-CCS Opt-Nuc	EER Central	EER Low Land
New H_2 Pipelines	*3,763*	*3,523*	*4,801*	*4,602*
New CO_2 Pipelines	*6,018*	*472*	*1,242*	*1,576*
Total New Pipelines	9,781	3,995	6,043	6,178
Build Rate over 25 Years (km/yr)	391	160	242	247

- Total length of existing NG transmission pipelines in the CENA AOI is 73243 km
- 294 km of natural gas transmission pipelines were installed in WV in 2022
  - This build rate could lead to 7,000 km of new transmission pipelines in WV by 2050

Key Takeaways

- **H_2 and CO_2 infrastructure** are key to least-cost net-zero pathways in the U.S.
- **New modeling tool** enables co-optimized, geospatial planning of these assets
- **High interconnectivity** found, especially in Appalachian region scenarios
- **Project-by-project planning** may miss synergies and lead to inefficiencies
- **Modeling supports broader planning**, beyond immediate hub boundaries
- **Deployment is feasible**—pipeline build rates align with recent NG benchmarks