GTI ENERGY

solutions that transform

Decarbonization Analysis & Technology Opportunities

Dr. Derek Wissmiller, Director of Strategic Analytics

Ryan Kerr, Director of Emerging Technologies

We develop and deploy solutions in the transition to low-carbon, low-cost energy systems

GTI ENERGY

SOURCE MAKE MOVE STORE USE

490+ Employees

TOP WORK PLACES 2019 · 2020 · 2021 · 2022 · 2023 — Chicago Tribune

We work collaboratively to address critical energy challenges impacting gases, liquids, efficiency and infrastructure

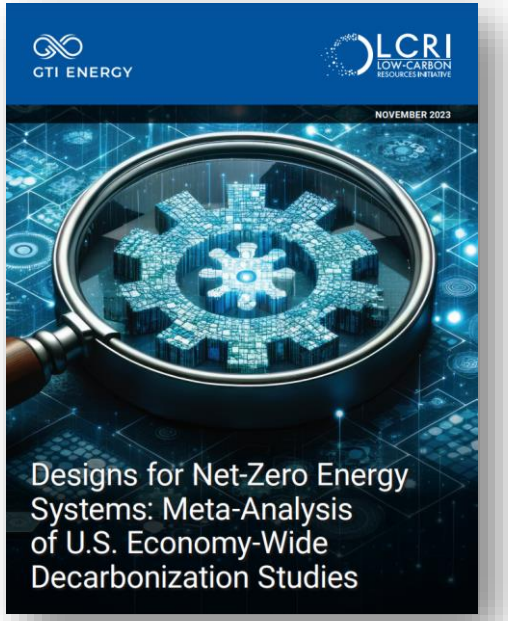
OTD Operations Technology Development

UTD Utilization Technology Development

GTI ENERGY EMERGING TECHNOLOGY PROGRAM (ETP)

LCRI LOW-CARBON RESOURCES INITIATIVE

Meta-NZ Study



report available at
gti.energy/meta-nz/

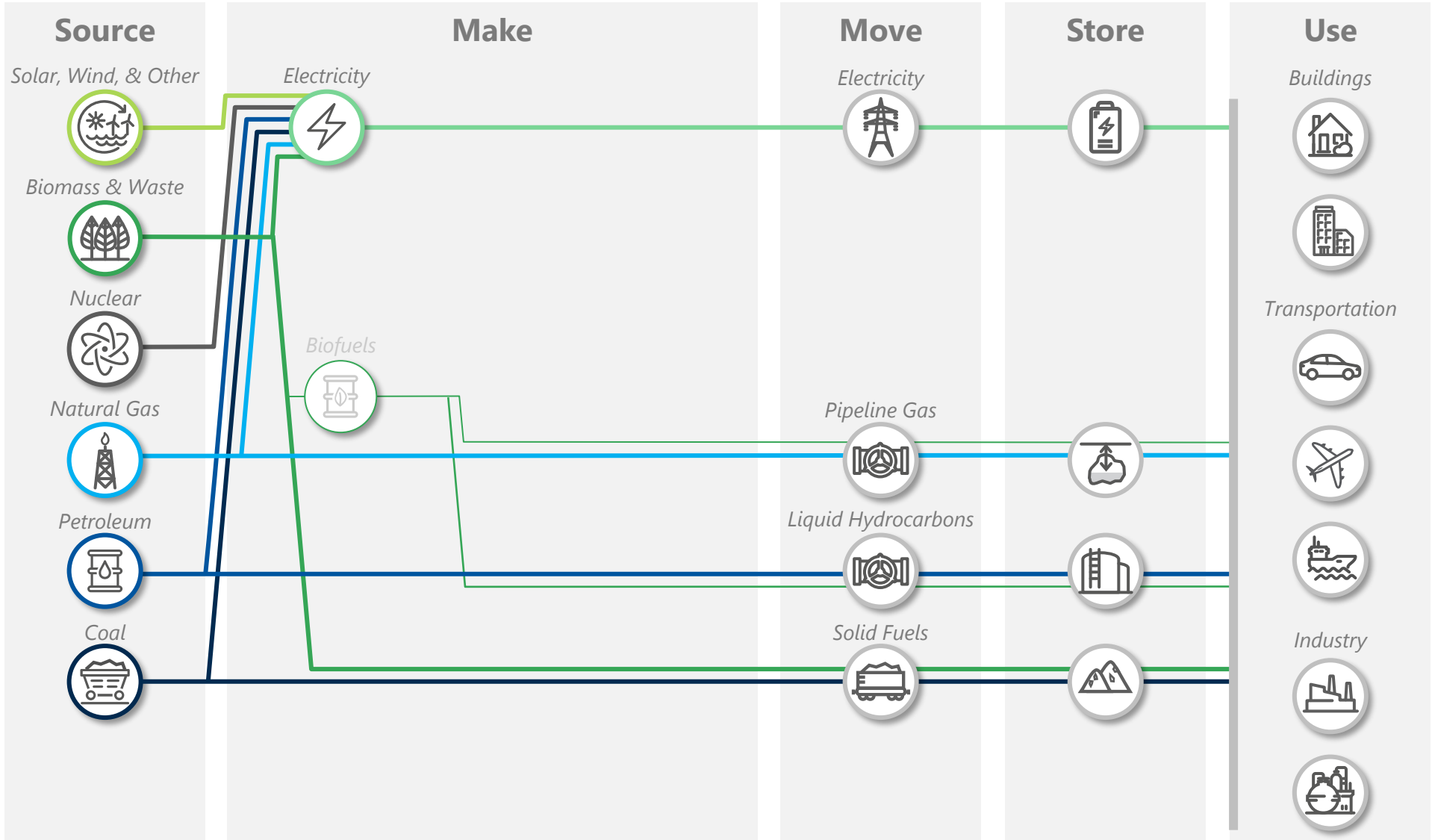
Meta-Analysis of U.S. Economy-Wide, Net-Zero Studies

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*)

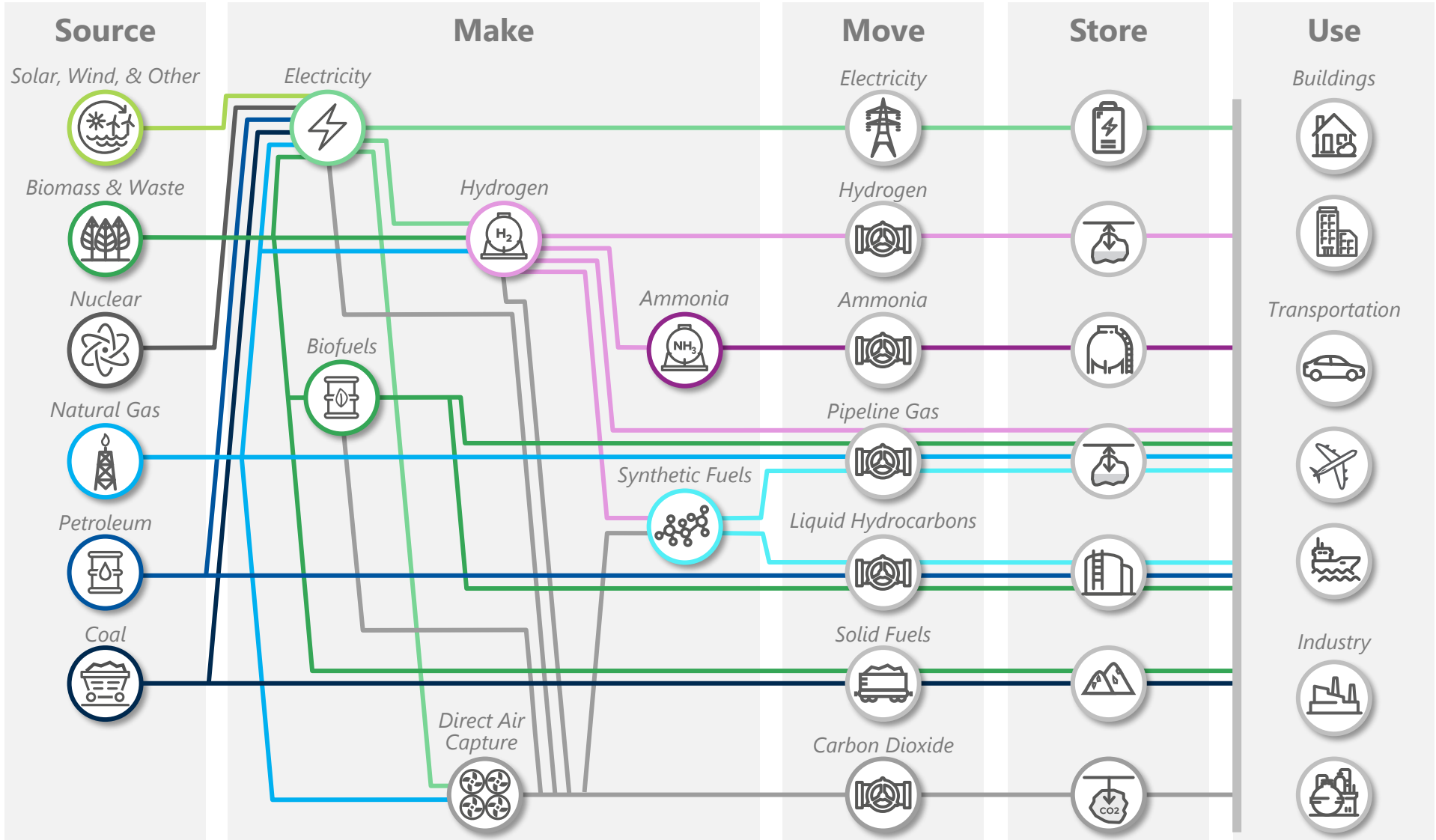
5 leading independent U.S. economy-wide studies

23 scenarios for least-cost pathways to net-zero

Today's Energy Systems



Net-Zero Energy Systems



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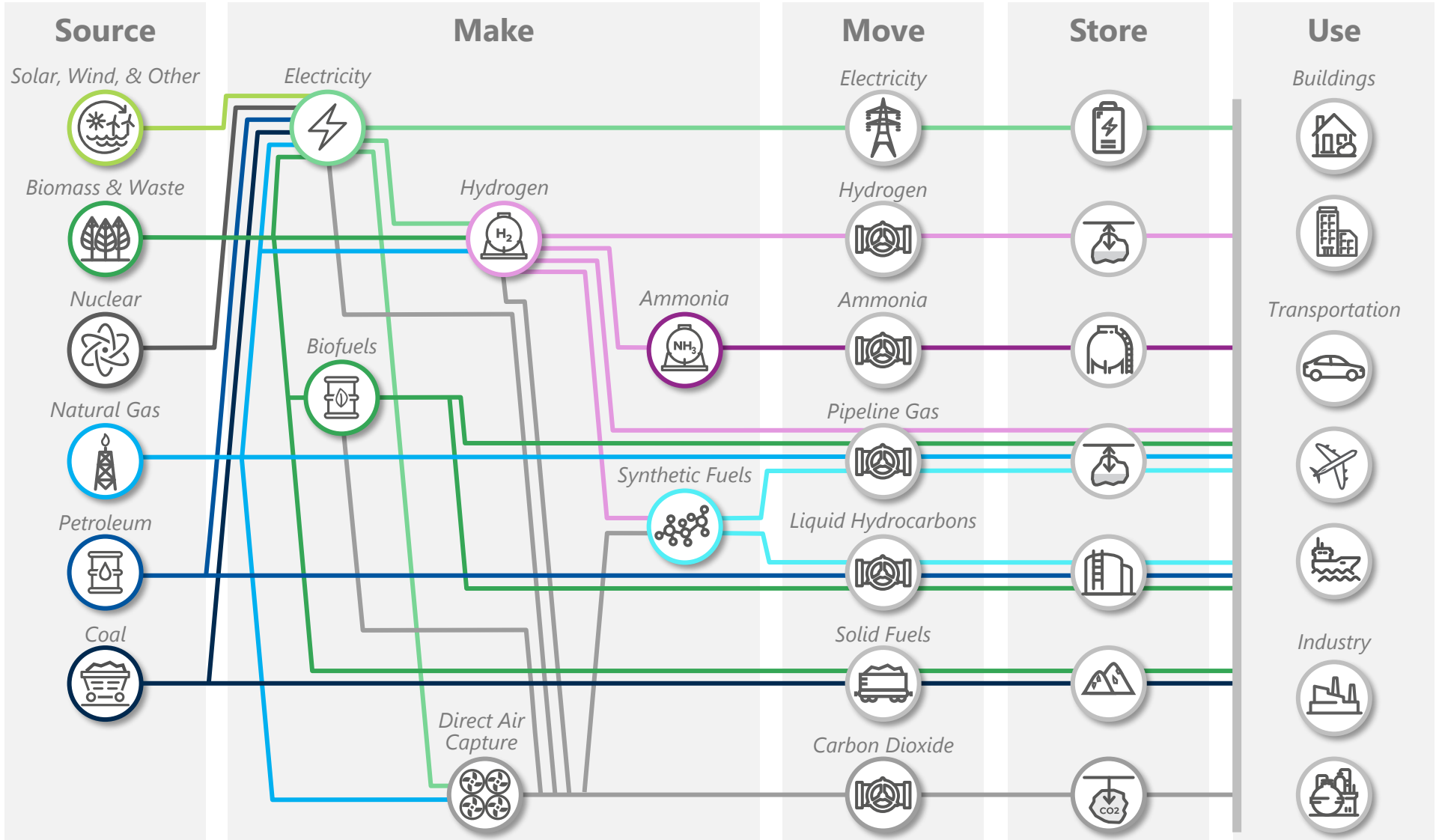
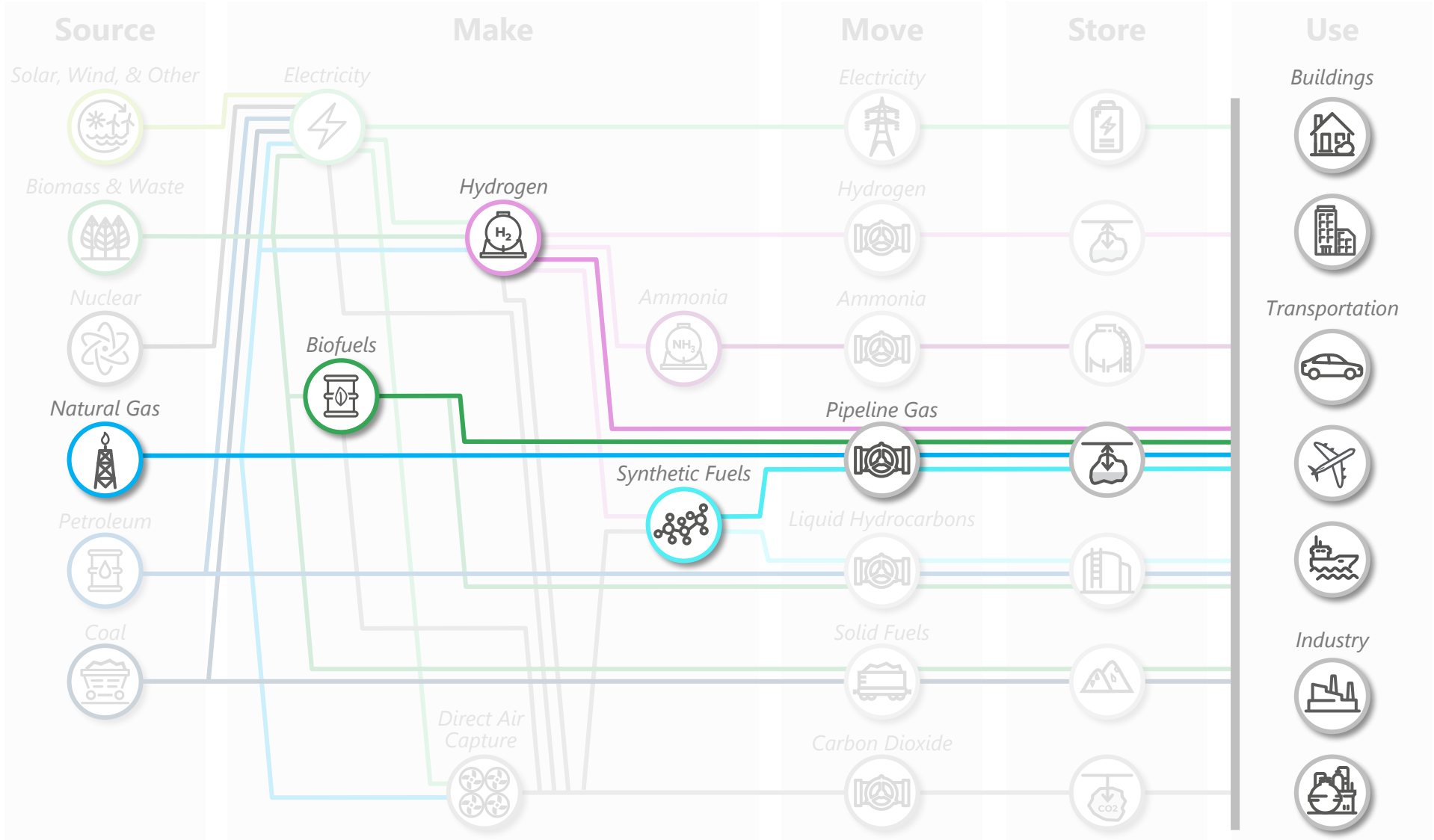


variety
in **electricity**
+
variety
in **fuels**
+
carbon management
+
efficiency

Pipeline Gas



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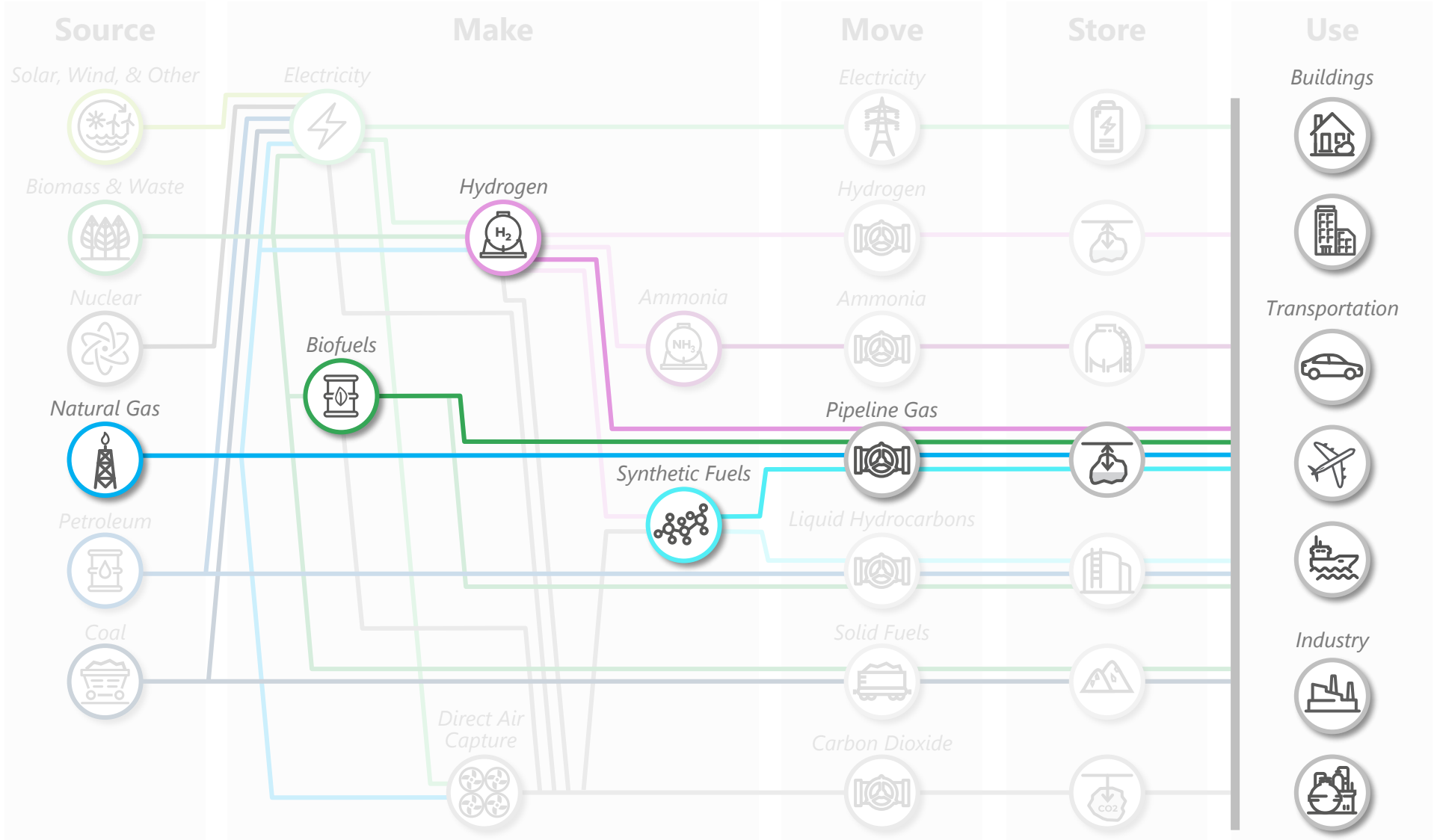
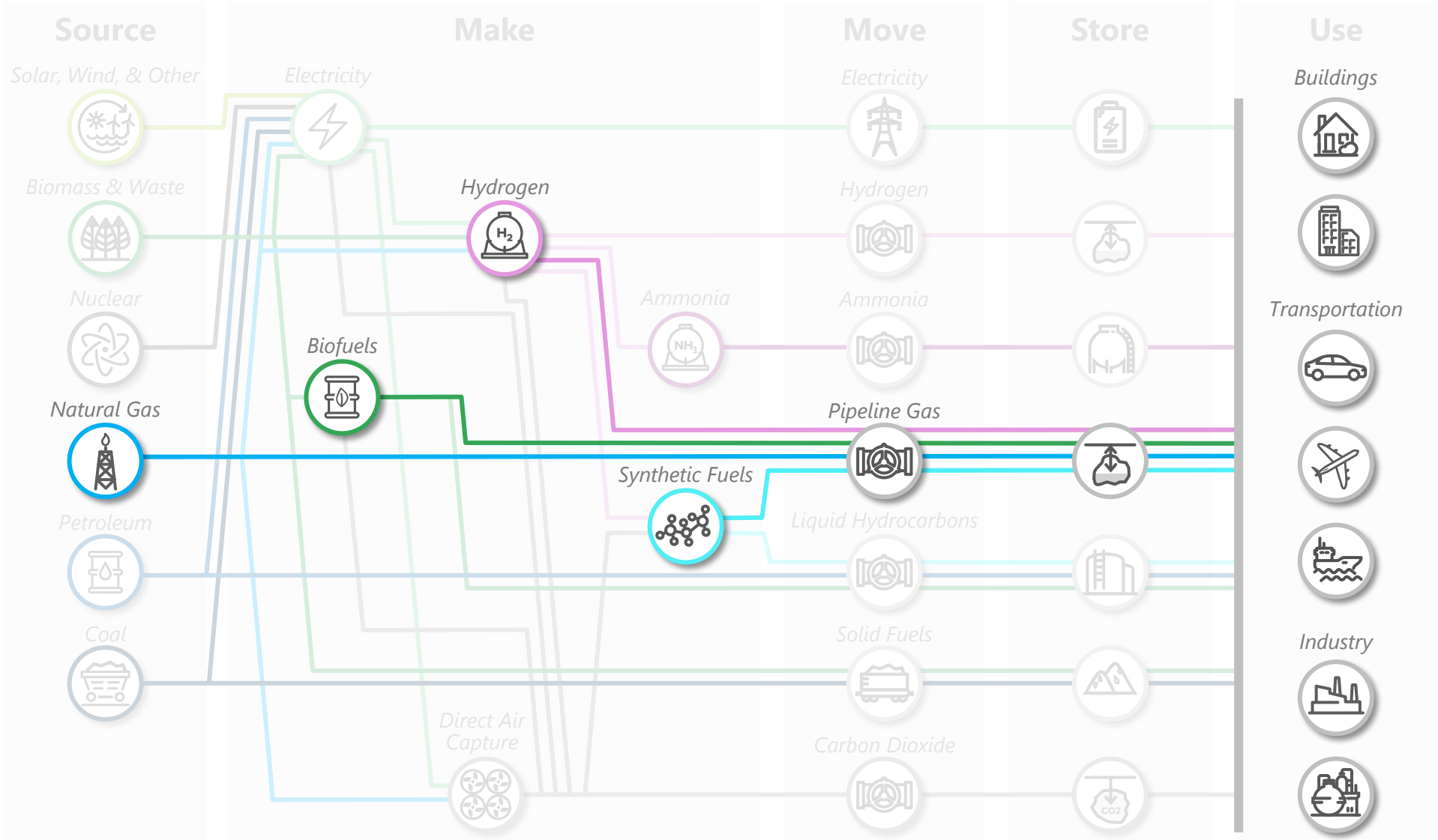


pipeline gas is used in **every** net-zero scenario

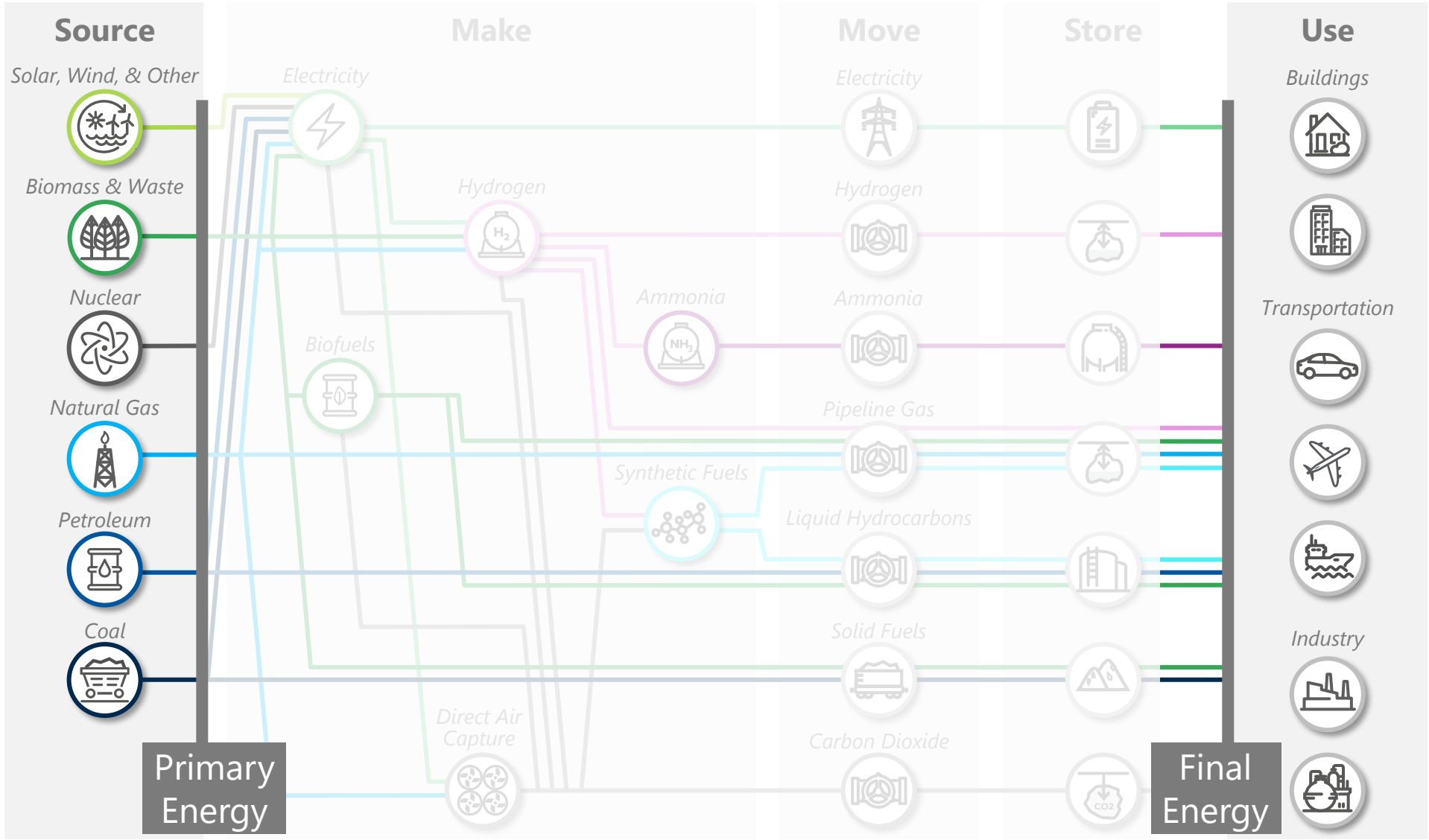
Pipeline Gas



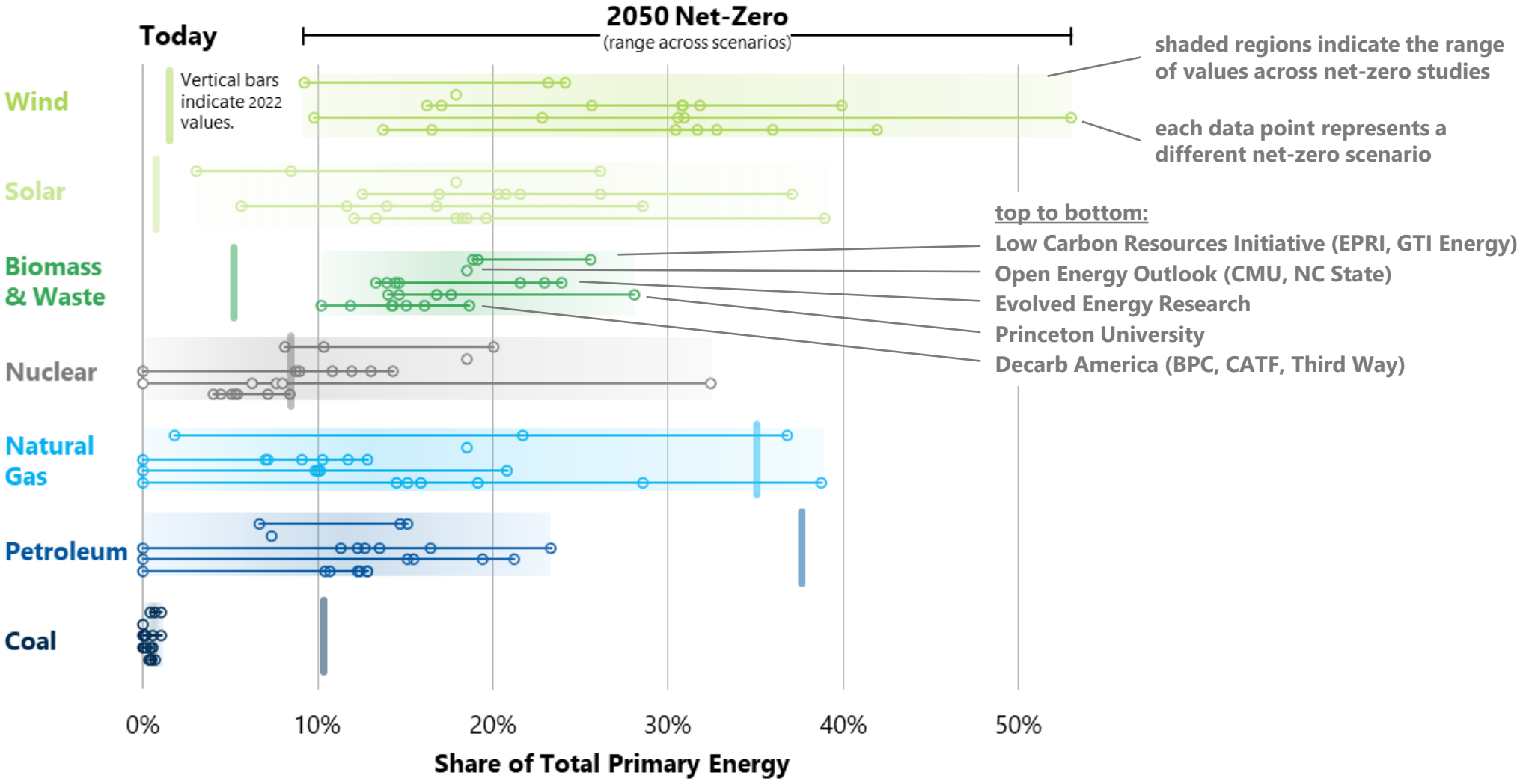
pipeline gas is used in **every** net-zero scenario

gas **infrastructure** peak throughput (Btu/hr) remains

Primary and Final Energy



Primary Energy Consumption (Sources)



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Geothermal and hydro account for <2% of primary energy across net-zero scenarios.

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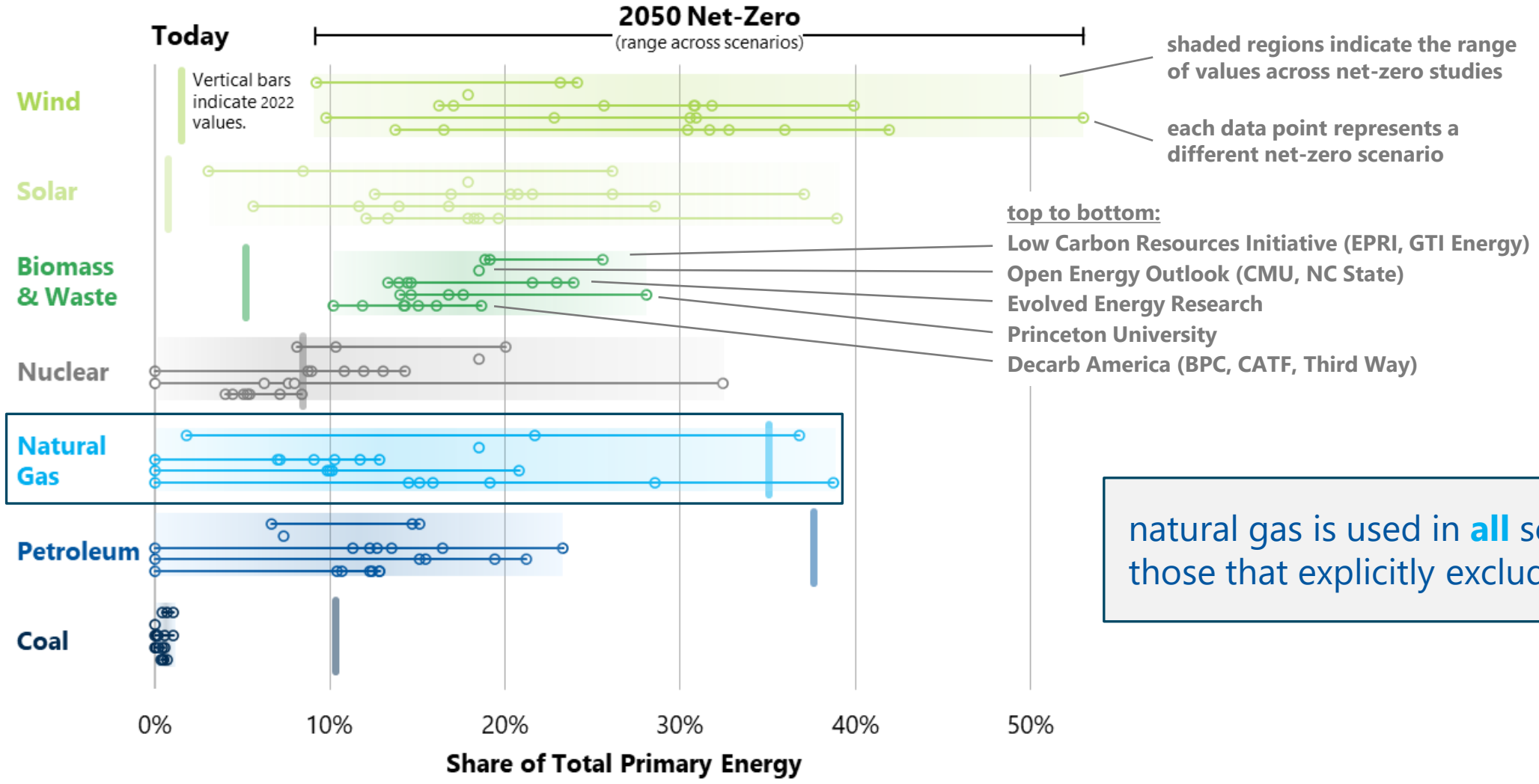

natural gas is used in **all** scenarios, except those that explicitly exclude fossil fuels

report available at gti.energy/meta-nz/

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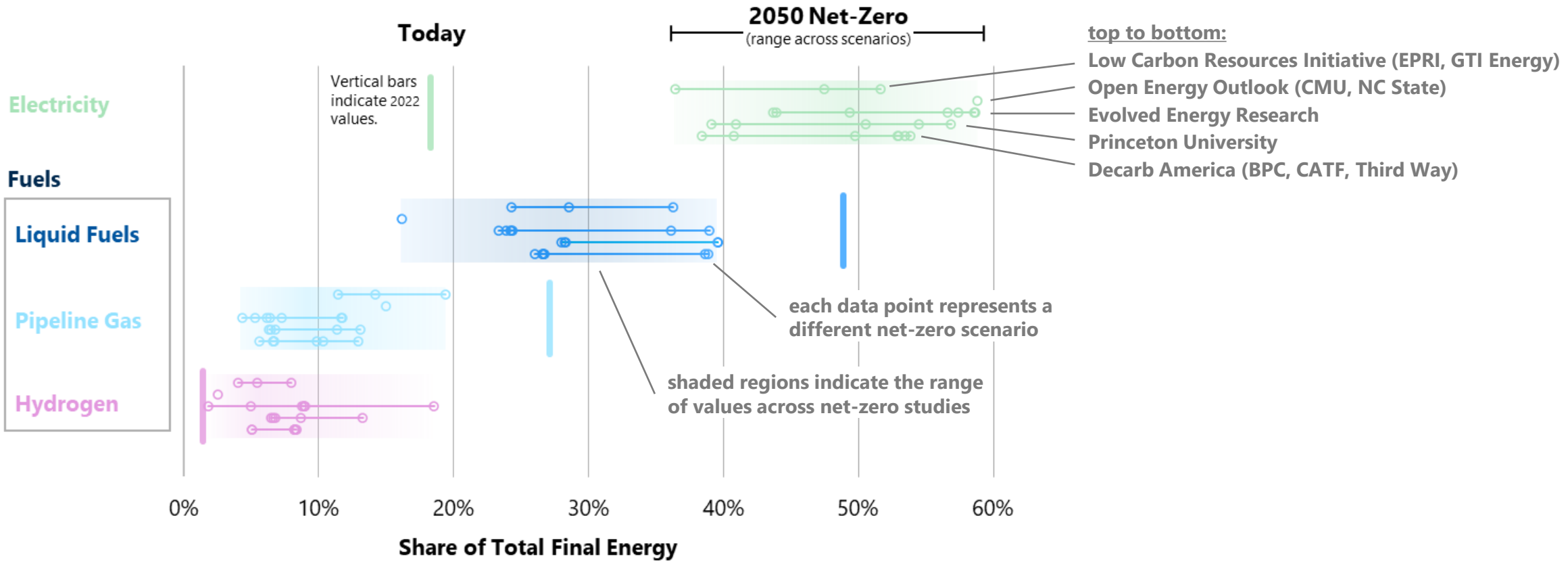
Final Energy Consumption (End-Use)



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Includes non-energy uses of fuels.
Liquid fuels include ammonia and hydrocarbon fuels derived from petroleum, bioenergy, and synthetic pathways.
Pipeline gas includes fossil natural gas, renewable natural gas, synthetic natural gas, and blended hydrogen.
Coal and biomass account for <2% and <4% of final energy across net-zero scenarios, respectively

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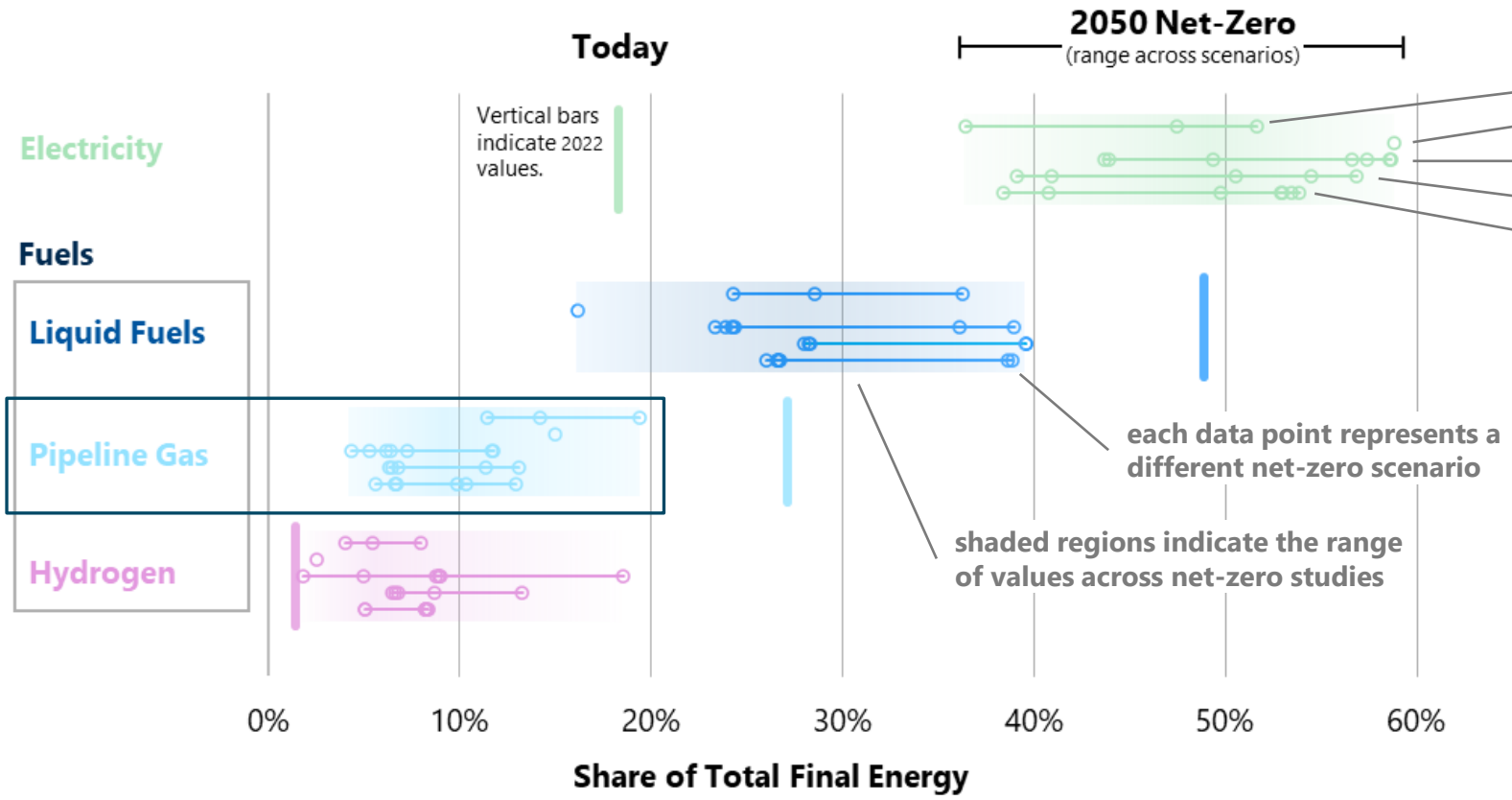

top to bottom:

Low Carbon Resources Initiative (EPRI, GTI Energy)
Open Energy Outlook (CMU, NC State)
Evolved Energy Research
Princeton University
Decarb America (BPC, CATF, Third Way)

pipeline gas is used for **electricity** generation, **industry**, and **buildings** in **every** net-zero scenario

peak gas **infrastructure** throughput (Btu/hr) remains

report available at gti.energy/meta-nz/

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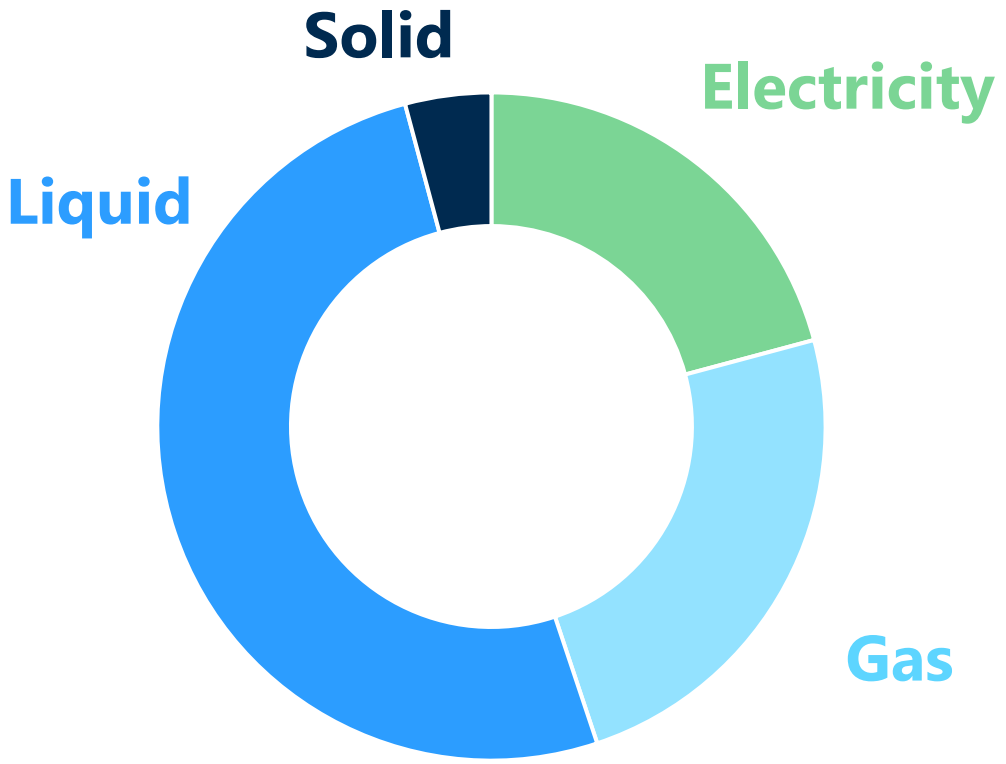
Today's Energy System

U.S. Final End-Use Energy Consumption (2020, Quad Btu)



Based on EIA data
Excludes non-energy uses of fuels

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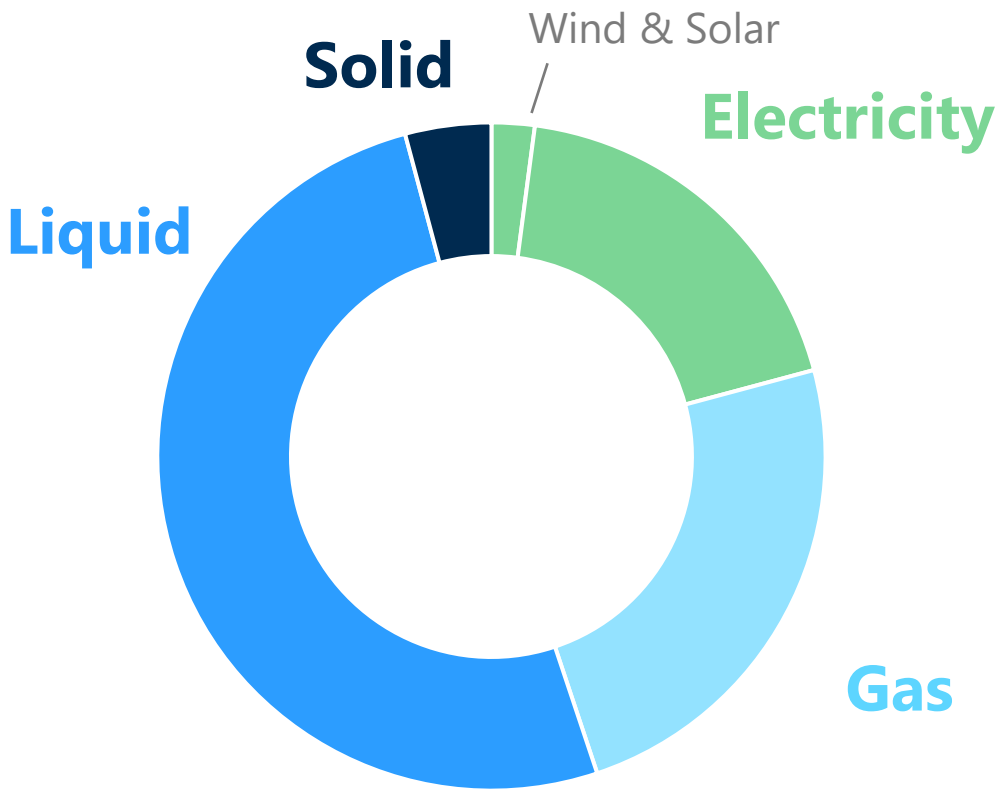

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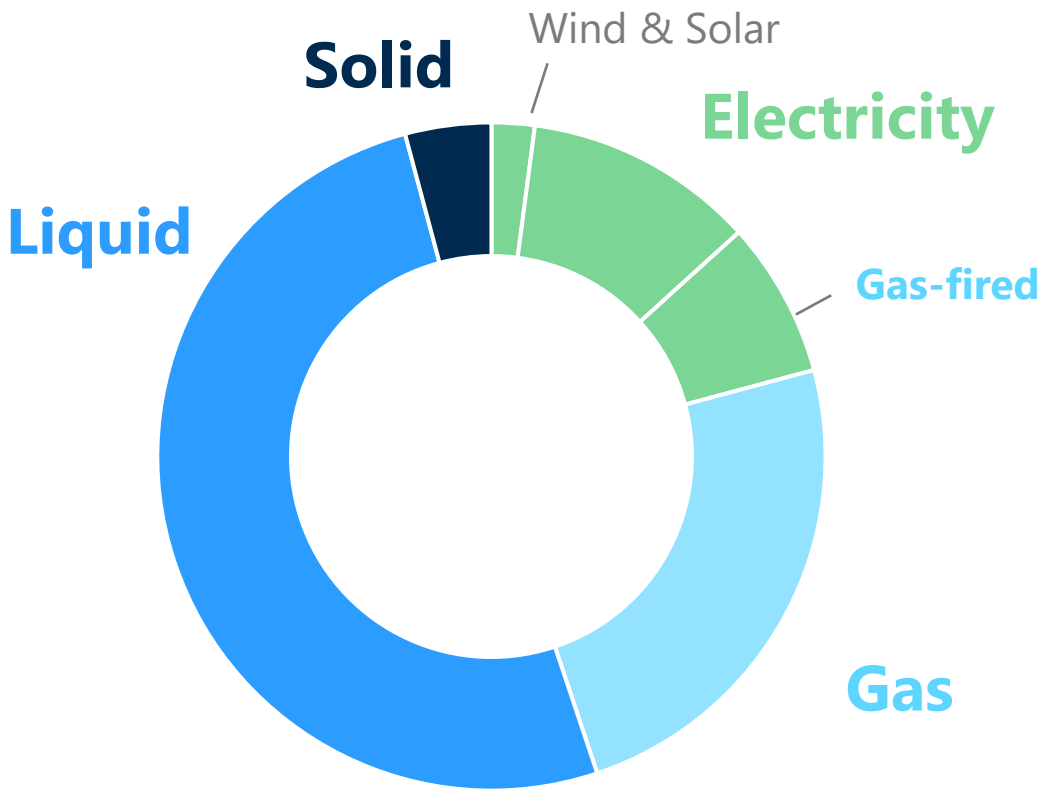

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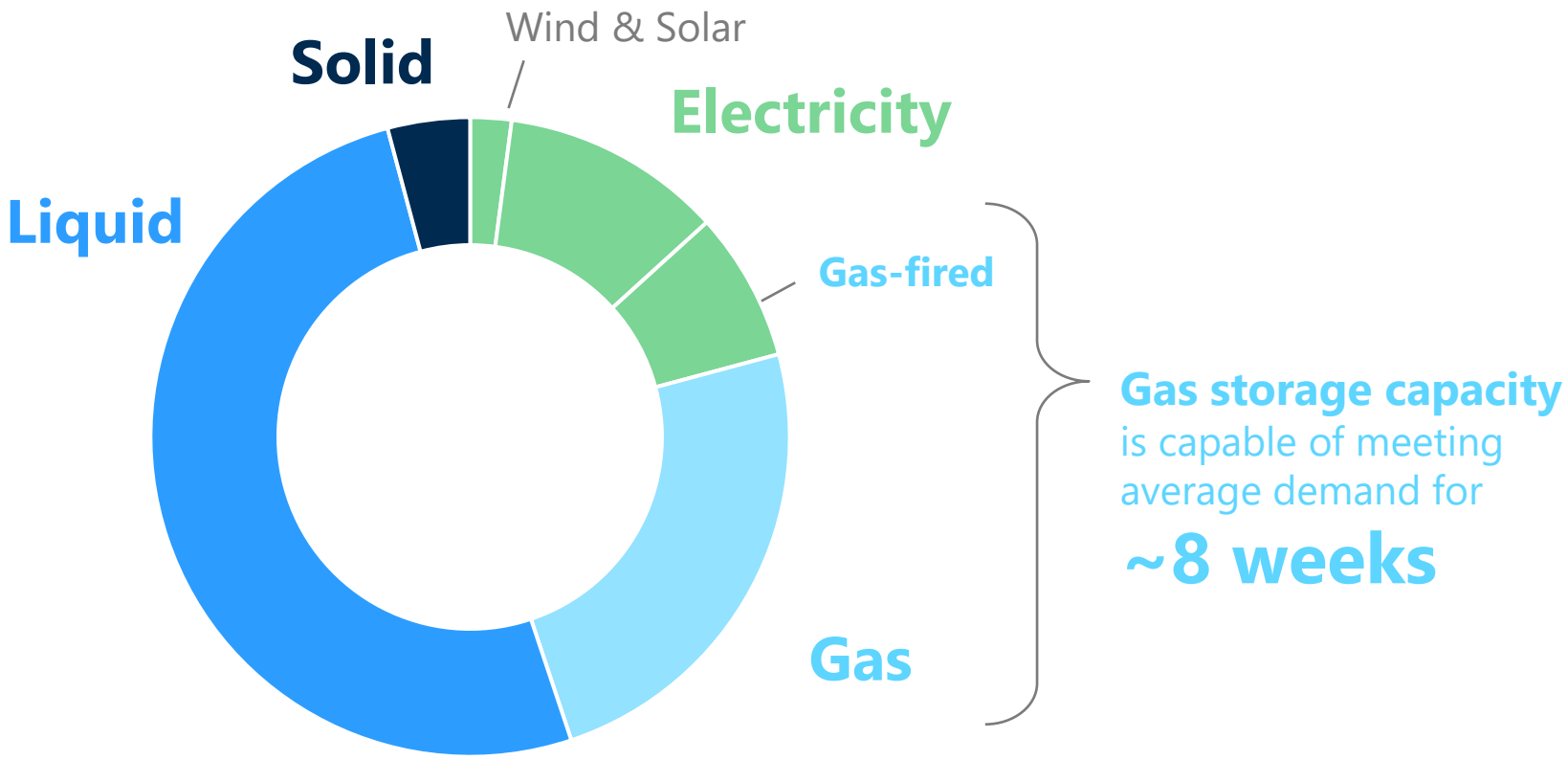

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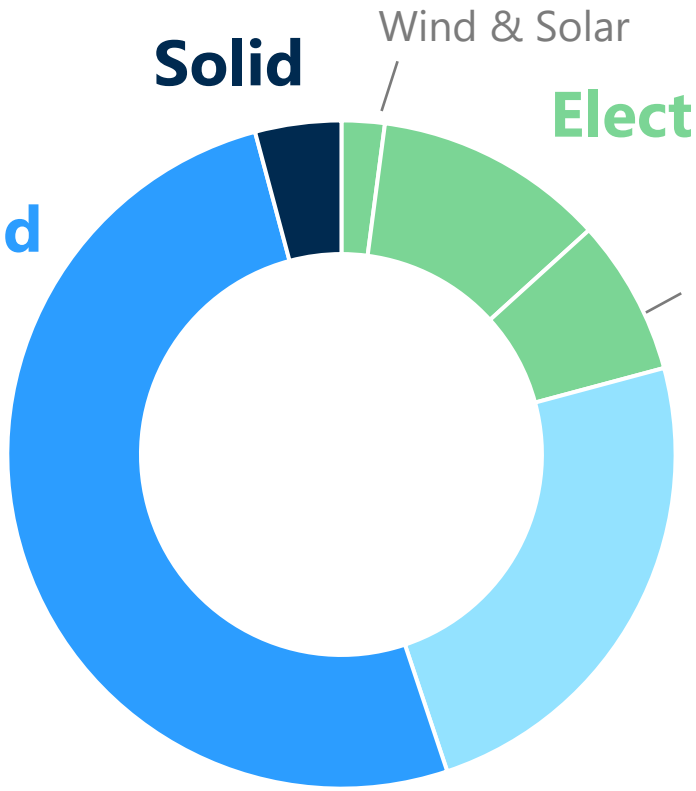

Liquid storage capacity is capable of meeting average demand for **~7 weeks**

Gas storage capacity is capable of meeting average demand for **~8 weeks**

Based on EIA data
Excludes non-energy uses of fuels

TECHNOLOGIES

Residential Space and Water Heating: **Hybrid or Dual Fuel Heat Pumps**

- **"Hybrid" space conditioning systems**

  1. Replace conventional air conditioner with electric heat pump (electric EE programs)

  2. Retain/use high-efficiency gas furnace as appropriate (natural gas EE programs)

  3. Smart thermostat chooses electric or gas space heating depending on outdoor temperature, operating cost, or other factors

- **"Hybrid" space conditioning systems** create opportunities for consumers to improve efficiency and reduce costs and emissions.

Residential Space and Water Heating: **Gas Heat Pumps**

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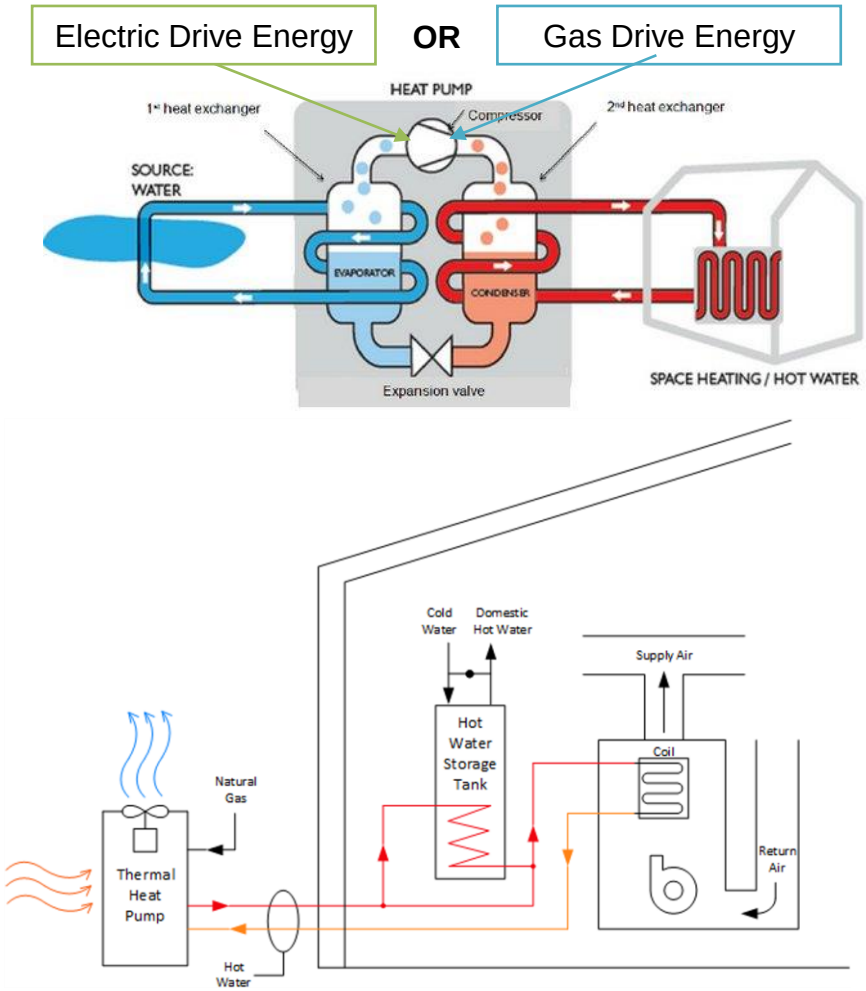
What is a Gas Heat Pump?

- Just like an electric heat pump, it sits outside and extracts heat from the outside air.
- The difference, it uses heat instead of an electric compressor to drive process

Why do we need Gas Heat Pumps?

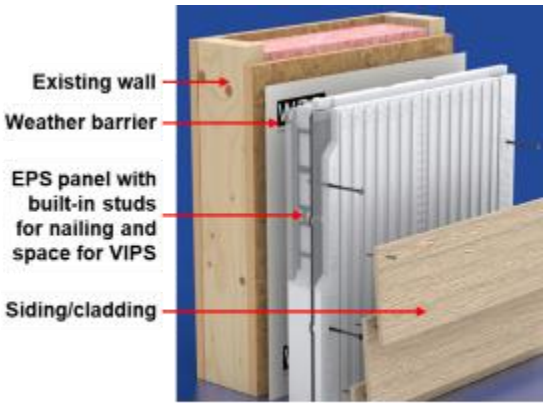
- *Best-in-class operating efficiency*
  - Condensing furnace is 95-98 AFUE vs GHP is 140 AFUE
  - GTI Energy field demos showed 33-46% therm savings (space and water heat)
- Systems operate during the coldest days, meeting the heating load without back-up resistance heating
- Commonly use natural refrigerants with low/no GWP
- 30-50% reduction in operating GHG emissions, with combustion outside



Typical Residential Installation

Image Source: Ninikas, Konstantinos & Hytiris, N & Emmanuel, R & Aaen, Bjorn & McMillan, S. (2014). A renewable heat solution for water ingress in the Glasgow subway tunnel system. 161-171. 10.2495/ESUS140141.

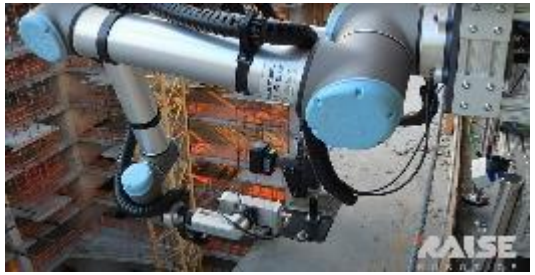
Building Space Conditioning Energy Use: **Envelopes**



Courtesy of InSoFast

Skinny R30 Wall Retrofit Systems - InSoFast

- (NYSERDA, UTD, NEEA)
- Taking existing commercialized ICF panel and fabricating with R-50 VIP inserts for area-weighted R30 in 3.5" thick retrofit
- Advancing from feasibility testing to prototype development; demonstration in NY planned late 2024



Robotics in Deep Energy Retrofits

- NYSERDA, National Fuel
- Increase cost-effectiveness with robotics
- Reduce time for panelized retrofits

Solar Cogeneration

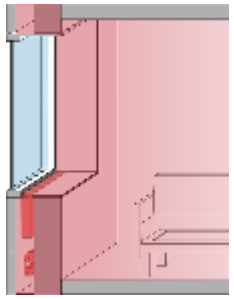
- Solar thermal behind PV (PVT)
- Heat sink improves kWh generation (perhaps ~5% / yr)
- PVT + heat pumps can assist cold-climate capacity
- Capable of nighttime heat rejection for cooling savings

Comm-INDOWS

- Advanced secondary window system (SWS) (CEC, NEEA, SoCalGas)
- Targeting commercial buildings
- Laboratory testing with field validation
- Triple-pane, aerogel, and vacuum glass options
- Alpen, Inovues, AeroShield, V-Glass, LBNL

USACE – Advanced Glazing Systems

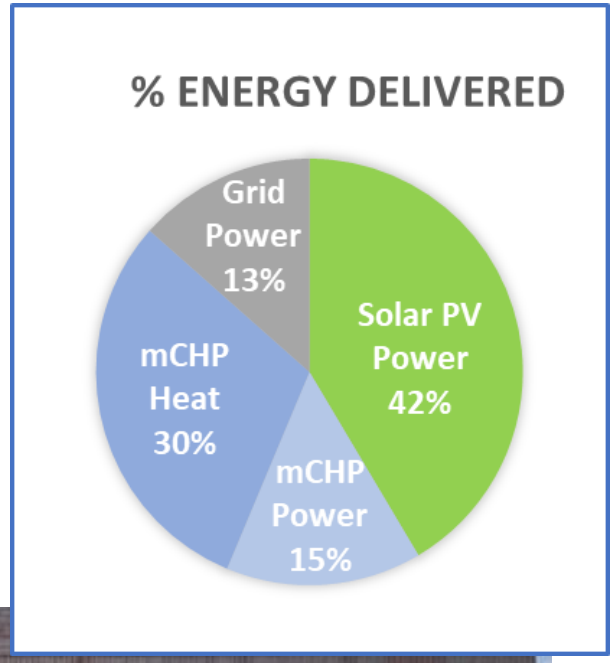
- Evaluating commercialized products working with Alpen and Inovues
- Testing both double-pane and vacuum glass

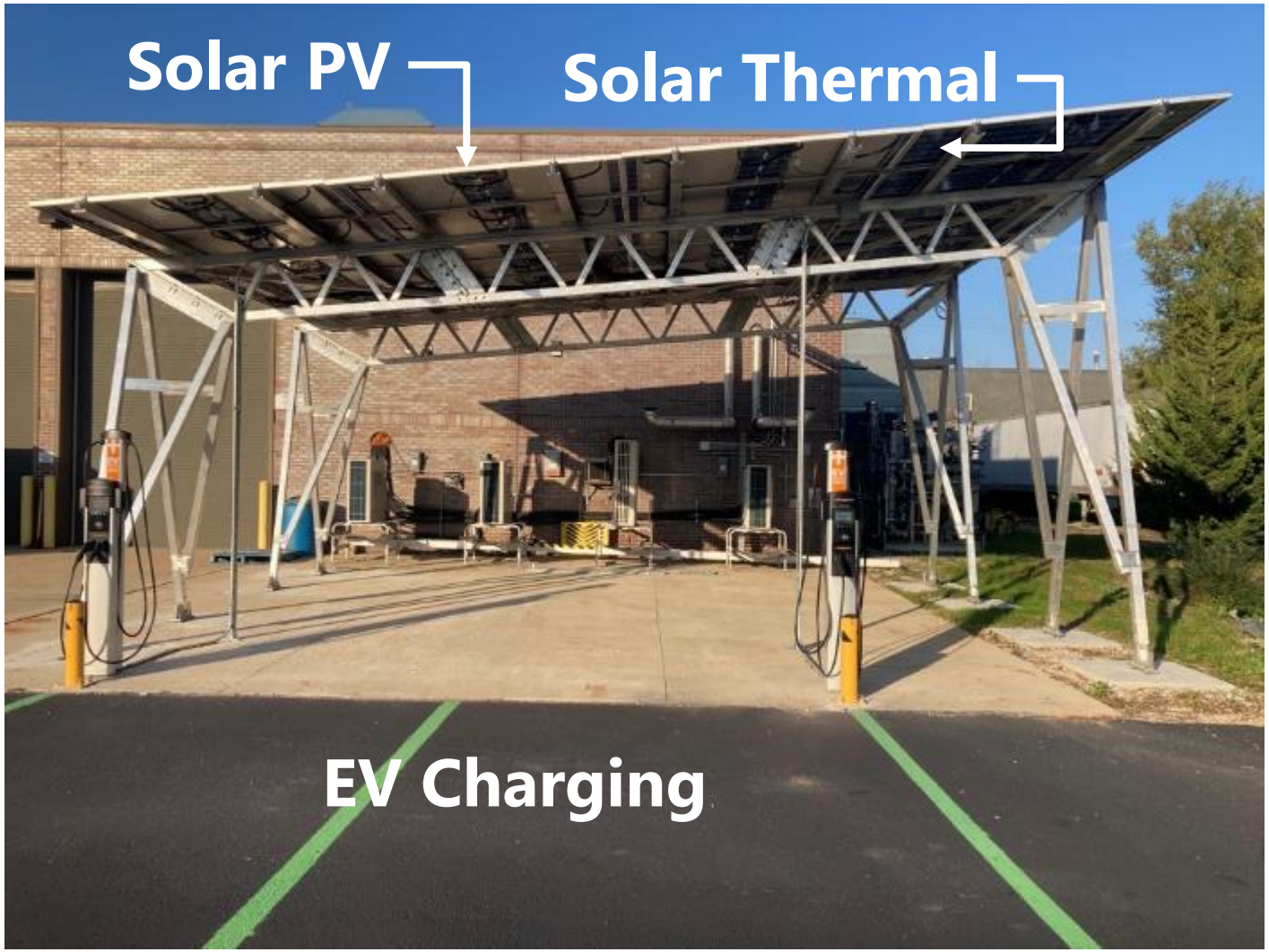


Integrated Envelope+Mech - Hydronic Shell

- Water-based heat/cooling/vent
- Paired with rooftop A2W heat pump
- Non-invasive install w/ R30 wall retrofit

Whole Building Integrated Solutions:
GTI Energy's Microgrid Test Bed





Decarbonizing Pipeline Gas

Using Renewable Gas or Clean Hydrogen

RNG and clean hydrogen can have carbon intensities (CI's) that are low, zero or negative depending on production process and feedstocks

- *Landfill gas (LFG)*
- *Animal manure*
- *Water resource recovery facilities (WRRF)*
- *Food waste*

- *Agricultural residue*
- *Forestry and forest product residue*
- *Energy crops*
- *Municipal solid waste (MSW)*

- *Renewable electricity*

Renewable gases can be used to decarbonize gas space heating or gas power generation and production processes can be coupled with CO2 sequestration to achieve negative CI's

Veritas: Measurement to Reduce Methane Emissions

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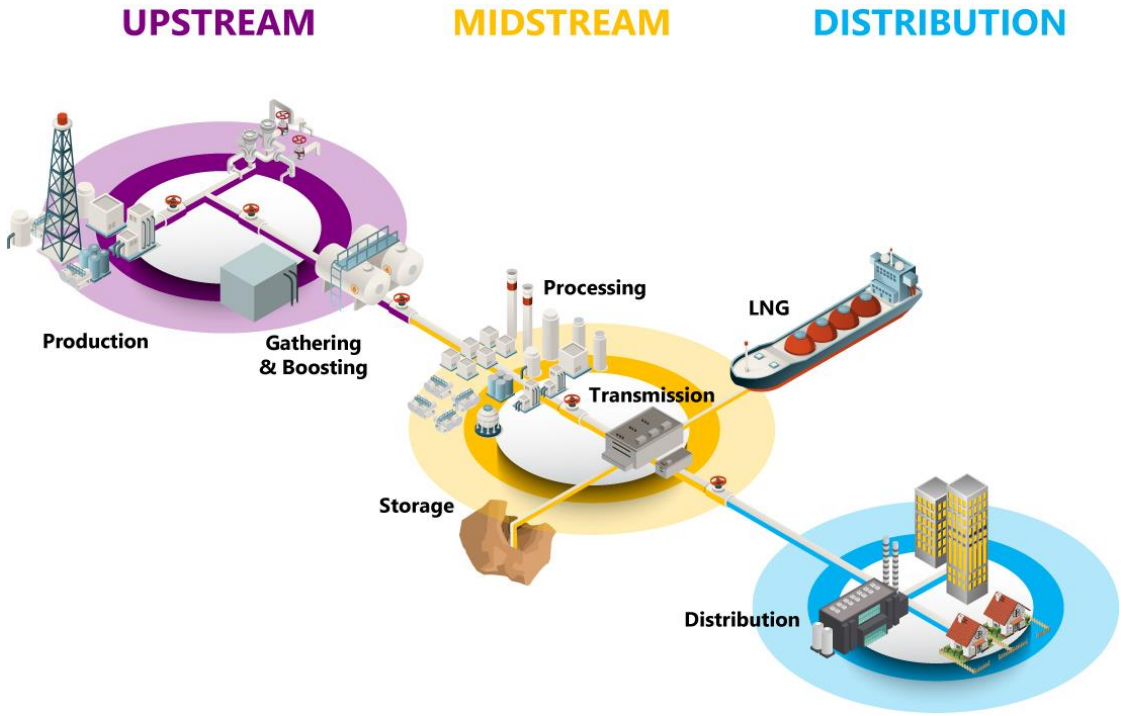
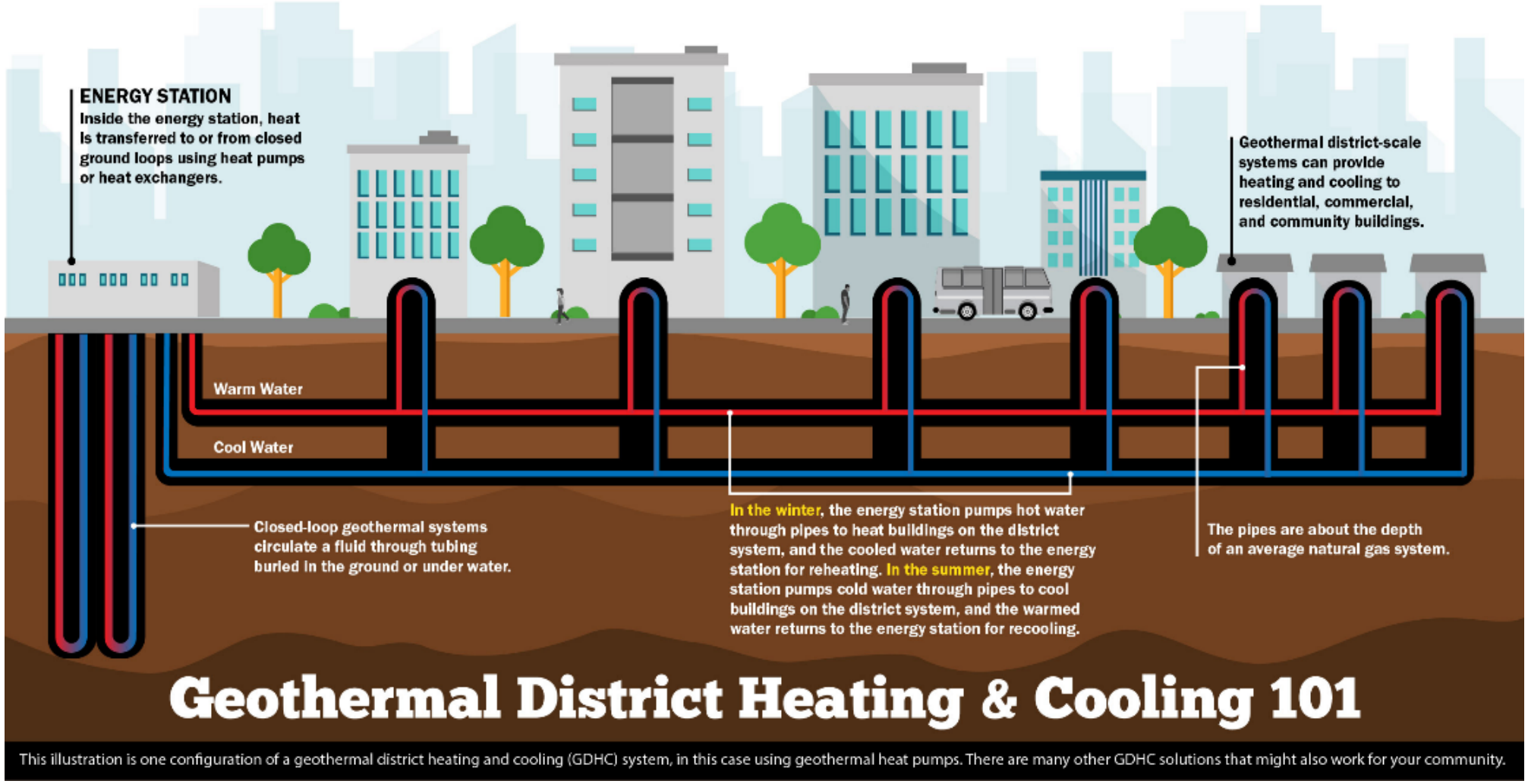
Veritas has four Technical Protocols

- **Measurement & Reconciliation:** Describe how to take measurements and reconcile emission-factor inventories with actual measurements
- **Methane Emissions Intensity:** Define methane intensities
- **Value Chain Summation:** Add multiple segments to reach a total emissions intensity
- **Assurance:** Provide guidance for verifying emissions inventory

Veritas covers **six segments** of the natural gas supply chain:



What is Network Geothermal?



Source: U.S. DOE

Hydrogen Pathways for Gas Decarbonization

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Centralized Hydrogen Production

Blending into Current Grid

How do H_2/NG blends impact existing **customer gas assets and gas-fired equipment?**

Studying the blended hydrogen safety/efficiency/emissions impacts

Convert to Hydrogen Dist.

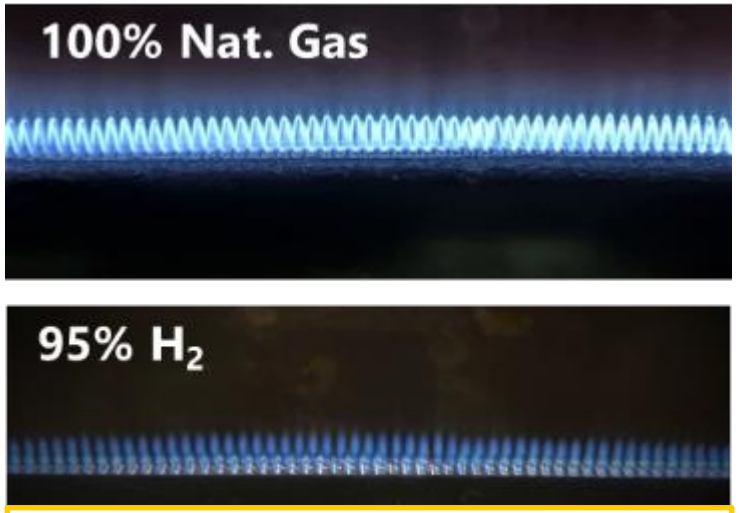
How can we assure that new gas equipment and retrofits are **hydrogen-ready?**

RD&D/Tech Transfer with equipment and sensors for hydrogen end use

Dist. H_2 Generation

Hydrogen Microgrids

How do we design and prepare for **hydrogen fuel-flexible systems?**

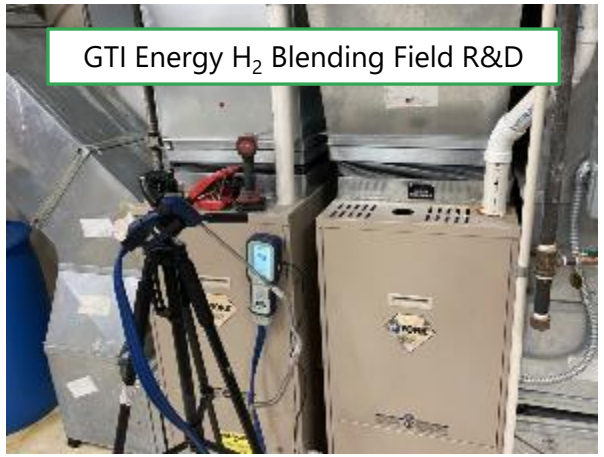


Developing and demonstrating fuel-flexible combustion/CHP systems

Hydrogen Economy – Utility Investments

- RNG/Biomethane, Bio-LPG, available in many markets to reduce GHG emissions
- SNG/E-methane projects underway, H_2 with captured CO_2
- Numerous States/Provinces have one or more H_2/NG blending demo projects in planning/underway
  - Several involving 100s – 1,000s of utility customers
- H_2 distribution projects are ramping up in US/Canada

Many North American natural gas companies have active H2 demo projects



GTI Energy H_2 Blending Field R&D

CenterPoint Energy

Oklahoma Natural Gas. A Division of ONE Gas

Nicor Gas

Dominion Energy

NW Natural

TECO PEOPLES GAS AN EMERA COMPANY

ENBRIDGE Life Takes Energy

SOUTHWEST GAS

nationalgrid

SoCalGas

PG&E

Buildings – Project Portfolio by GHG Savings

Near-Term (25-50+%)

- Expanded use of high-efficiency gas equipment

- Hybrid natural gas furnace/ boilers and electric heat pump systems

- Building envelope improvement

Next-Gen (40-60+%)

- Heat pumps for space & water heating

- Micro CHP systems

- Deep building retrofits

Renewables (Added 10-30%)

- Renewable gas blends (bio-methane, hydrogen)
- Solar thermal/natural gas space & water heating systems

Lower Methane Emissions (5-10%)

- Reducing full-cycle natural gas methane emissions

Summary

- Meta NZ analysis shows gases and fuels will be used in 2050 net zero scenarios
- Natural gas is a very large portion of our nation's energy mix
- All decarbonization solutions have costs
  - Which ones will be most cost effective in short, medium and long term?
  - Continued analysis and R&D needed
- Decarbonization opportunities
  - Hybrid natural gas/electric space heating systems
  - Thermal heat pumps
  - Building envelope & deep EE retrofits
  - Micro CHP – onsite renewables and power
  - Decarbonizing pipeline gas (renewable gas, H_2, CO_2 capture)
  - Network or community geothermal
  - Reduction of upstream methane emissions