Michigan Renewable Natural Gas Study

Stakeholder Meeting #2

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ICF Contributions to 2nd Stakeholder Meeting for MI RNG Study

- Review of Inputs, Assumptions, and Methodology
- Competing uses of feedstocks
- Alternatives to RNG

ICF: Review of Inputs, Assumptions, and Methodology

Inputs, Assumptions, Methodology

- Feedstocks for RNG production
- Supply considerations for RNG production
- Cost considerations for RNG production
- GHG emissions and cost-effectiveness considerations for RNG production

Inputs, Assumptions, Methodology: Feedstocks for RNG production

Feedstocks for RNG production

- Resource base
  - Publicly available information
- Energy content of feedstock
  - Publicly available information
- Geographic allocation
  - Ten regions of Michigan (vs 80+ counties)

Inputs, Assumptions, Methodology: Supply considerations

Supply considerations for RNG production

- Resource base
  - See previous slide
- Three supply scenarios in scope of work
  - Technical: Effectively represents energy content of all the resources characterized previously.
  - Achievable: A low level of feedstock utilization, with utilization levels depending on feedstock, with a range from 20% to 50% for feedstocks using AD technologies and 30% for TG at lower biomass prices. *Overall, the Achievable scenario captures 18% of the RNG feedstock resource in Michigan.*
  - Feasible: Balanced assumptions regarding feedstock utilization, with a range from 60% to 85% for AD technologies and 40% to 50% at moderate biomass prices. *Overall, the Feasible scenario captures 47% of the RNG feedstock resource available in Michigan.*

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Inputs, Assumptions, Methodology: Cost considerations

Cost considerations for RNG production

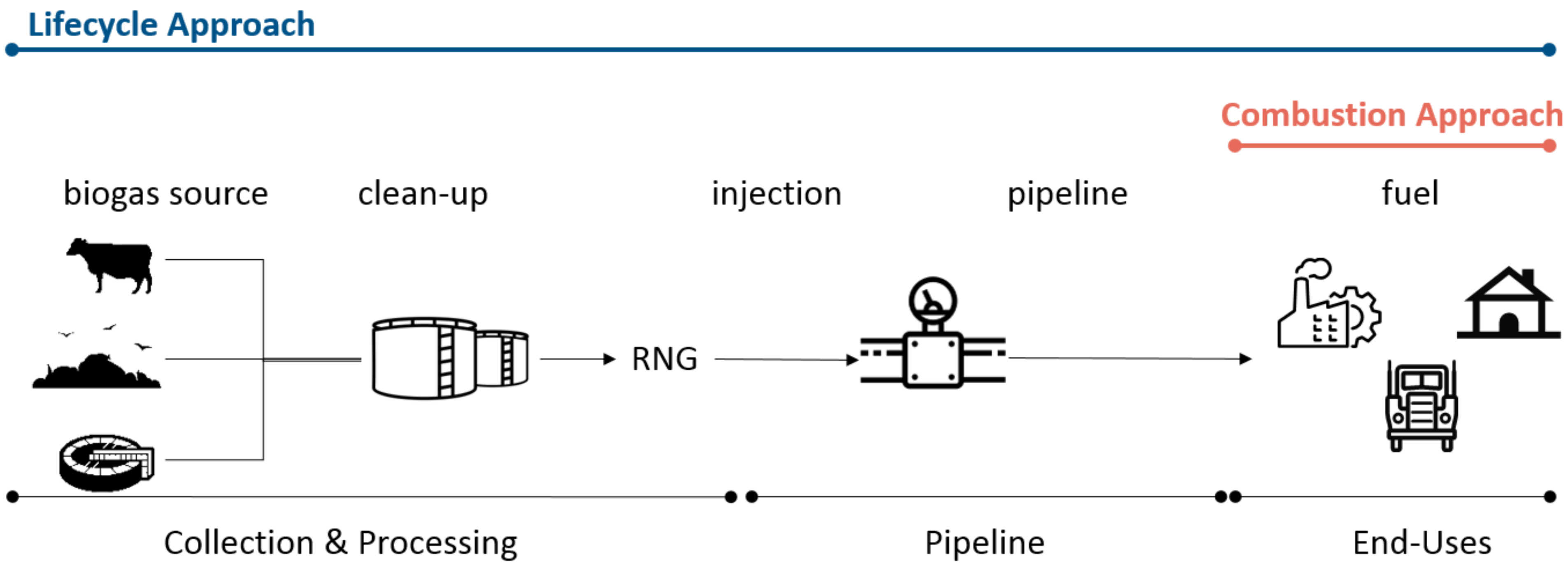
- Costs presented as Levelized Cost of Energy (LCOE)
  - LCOE is a measure of the average net present cost of RNG production for a facility over its anticipated lifetime. The LCOE enables us to compare across RNG feedstocks and other energy types on a consistent per unit energy basis. The LCOE can also be considered the average revenue per unit of RNG (or energy) produced that would be required to recover the costs of constructing and operating the facility during an assumed lifetime.
  - ICF notes that our cost estimates are not intended to replicate a developer's estimate when deploying a project. For instance, ICF recognizes that the cost category "gas conditioning and upgrading" actually represents an array of decisions that a project developer would have to make with respect to CO_2 removal, H_2S removal, siloxane removal, N_2/O_2 rejection, deployment of a thermal oxidizer, among other elements.

- Capital Costs + O&M Costs (or Revenues) + Financing

Inputs, Assumptions, Methodology: GHG emissions and cost-effectiveness

GHG emissions and cost-effectiveness considerations for RNG production

- GHG Accounting Framework

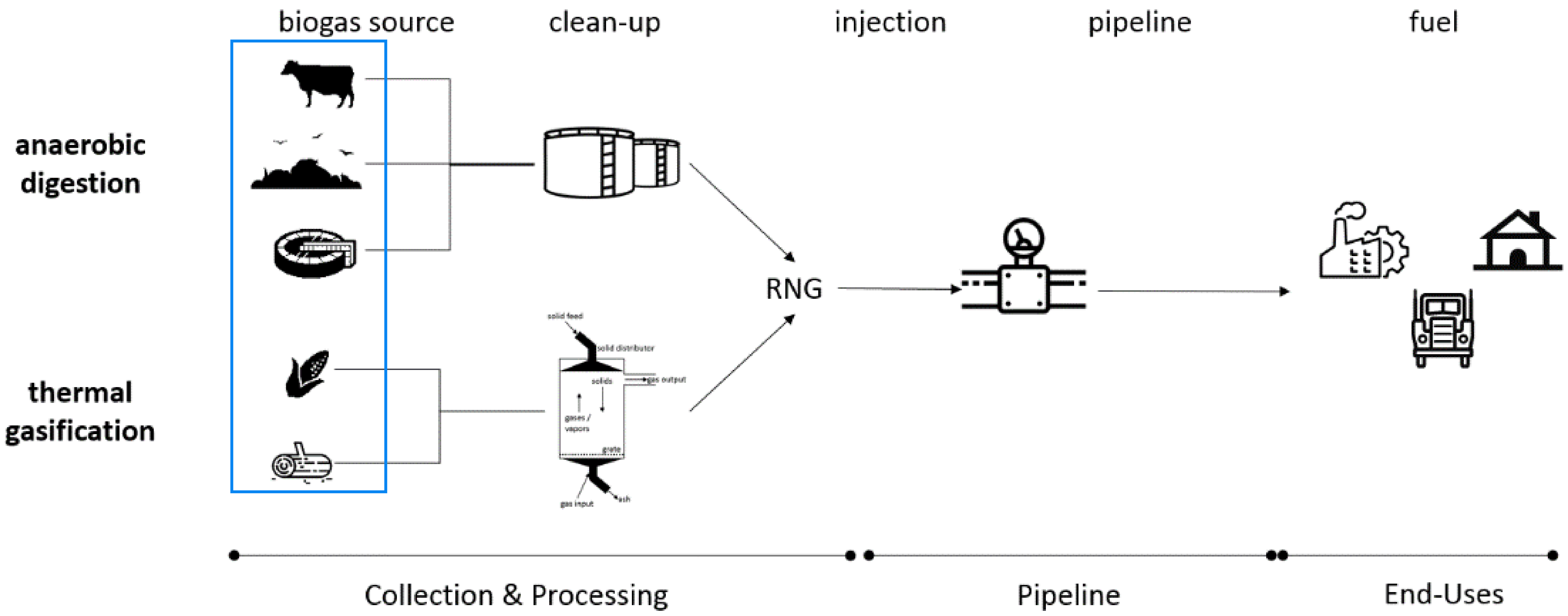


- Cost-Effectiveness

$$\Delta(RNG_{cost}, Fossil\ NG_{cost}) / 0.05306\ MT\ CO_{2e}$$

Analysis of Alternatives
Competing use of feedstocks

Overview of RNG Production



This study is not intended to analyze the economics of different end uses of biomass in general, but instead assess the potential of applicable biomass for RNG (or biogas-to-electricity) production in Michigan.

Competing use of feedstocks

	Feedstock for RNG	Description	Competing uses of feedstock
Anaerobic Digestion	Animal manure	Manure produced by livestock, including dairy cows, beef cattle, swine, sheep, goats, poultry, and horses.	RNG, biogas-to-electricity; fertilizers and compost materials; and manure being diverted for existing anaerobic digestion systems.
Anaerobic Digestion	Food waste	Commercial, industrial and institutional food waste, including from food processors, grocery stores, cafeterias, and restaurants.	Animal feed; compost; liquid fuel production.
Anaerobic Digestion	LFG	The anaerobic digestion of organic waste in landfills produces a mix of gases, including methane (40–60%).	Industrial process heat; existing LFG contracts for biogas-to-electricity.
Anaerobic Digestion	WRRF	Wastewater consists of waste liquids and solids from household, commercial, and industrial water use; in the processing of wastewater, a sludge is produced, which serves as the feedstock for RNG.	Industrial process heat; existing biogas-to-electricity production.
Thermal Gasification	Agricultural residue	The material left in the field, orchard, vineyard, or other agricultural setting after a crop has been harvested. Inclusive of unusable portion of crop, stalks, stems, leaves, branches, and seed pods.	Animal feed; livestock bedding (e.g., straw from grains); liquid biofuels (e.g., POET-DSM); carbon sequestration, and; benefits to agricultural land such as reduced soil erosion, soil nutrient recycling, and maintenance of soil organic matter and fertility.
Thermal Gasification	Energy crops	Inclusive of perennial grasses, trees, and annual crops that can be grown to supply large volumes of uniform and consistent feedstocks for energy production.	Electricity production and liquid fuel production.
Thermal Gasification	Forestry and forest product residue	Biomass generated from logging, forest and fire management activities, and milling. Inclusive of logging residues, forest thinnings, and mill residues. Also materials from public forestlands, but not specially designated forests (e.g., roadless areas, national parks, wilderness areas).	Fuel for boilers, kilns, dryers; pulp-and-paper; pellet and briquette manufacturing; landscaping (e.g., bark chips); fertilizer for forest land; particleboard manufacturing, and; animal bedding (e.g., shavings and sawdust).
Thermal Gasification	Municipal solid waste (MSW)	Refers to the non-biogenic fraction of waste that would be landfilled after diversion of other waste products (e.g., food waste or other organics), including construction and demolition debris, plastics, etc.	Electricity production and liquid fuel production.

Biomass in the context of deep decarbonization

Deep Decarbonization & the Role of Biomass/Bioenergy

- Across the U.S. and globally there is a heightened focus on aggressive long-term GHG emission reductions, referred to as 'deep decarbonization'.
  - Deep decarbonization typically reflects emission reduction targets of between 80–100% by 2050 (e.g., Net-Zero).
- Deep decarbonization requires aggressive deployment of emission reduction measures across the economy:
  - GHG-free electricity grids, comprehensive transportation electrification, and deployment of low or zero carbon fuels.
  - Renewed focus on the role that biomass and bioenergy can play to reach these aggressive GHG emission reduction targets.
- Bioenergy is a broad emission reduction measure.
  - Includes liquid biofuels, gaseous biofuels and direct combustion of biomass.
  - RNG is typically classified as a type of bioenergy.

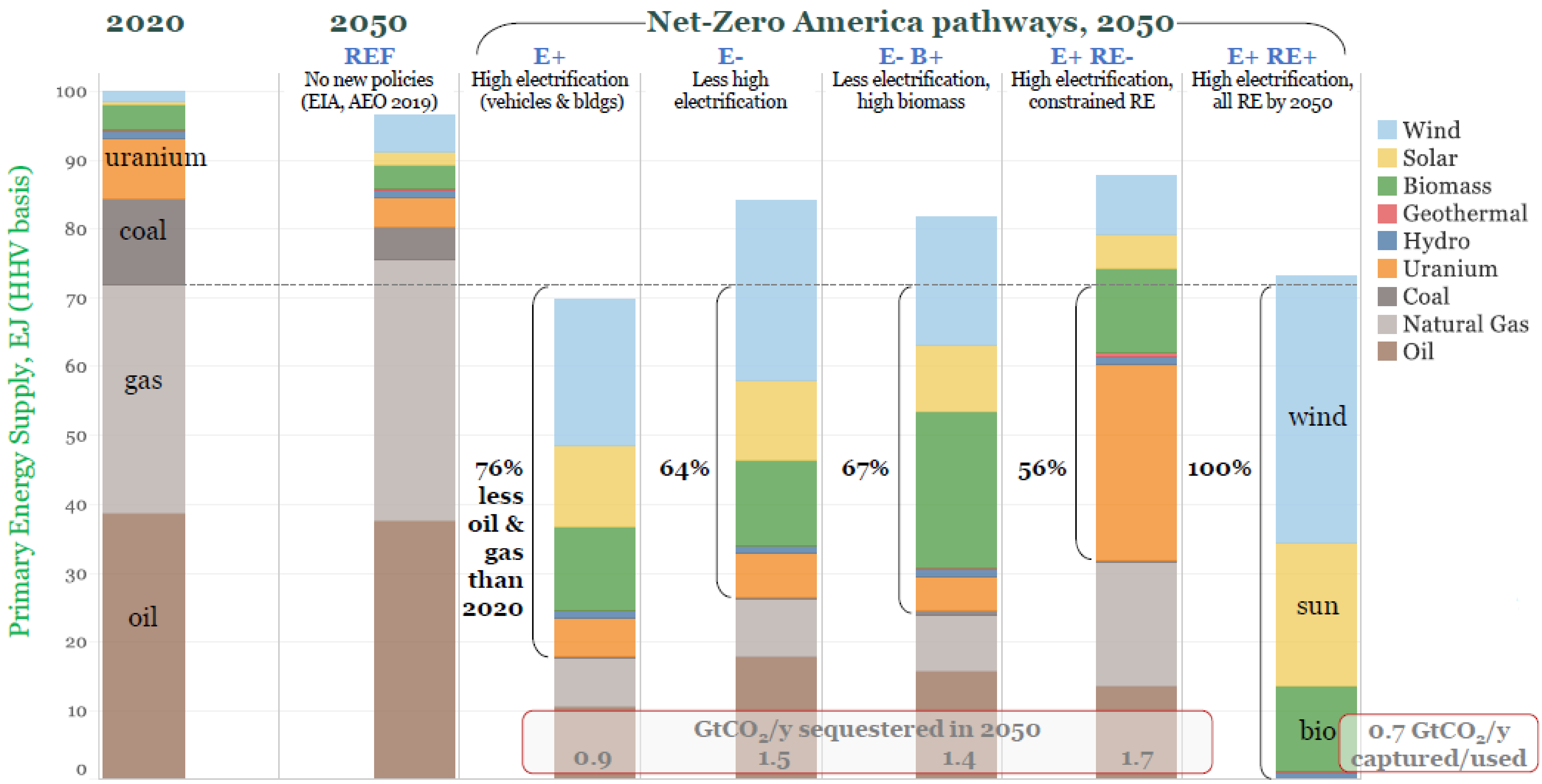
- To achieve deep decarbonization targets over the long-term, various analyses have shown that an 'all hands on deck' approach is needed.
  - This includes the aggressive utilization of biomass and deployment bioenergy, including RNG.

Examples:

- *IEA World Energy Outlook 2021:*
  - US bioenergy demand of 14,000 tBtu in 2050.
- *Princeton Net-Zero America:*
  - Most scenarios utilize 13,000 tBtu of bioenergy in 2050.
  - Sensitivity scenario has 23,000 tBtu of bioenergy in 2050.
- In the *2016 Billion Ton Study*, the U.S. Department of Energy estimated national biomass potential in excess of 1.5 billion dry tons in 2040.
  - ICF estimates that the equivalent of roughly 18,000 tBtu of biomass feedstocks could be used for RNG production.

Alternative Uses of RNG Feedstocks

Princeton Net-Zero Primary Energy Supply by Scenario



Analysis of Alternatives
Alternatives to RNG

Alternatives to RNG

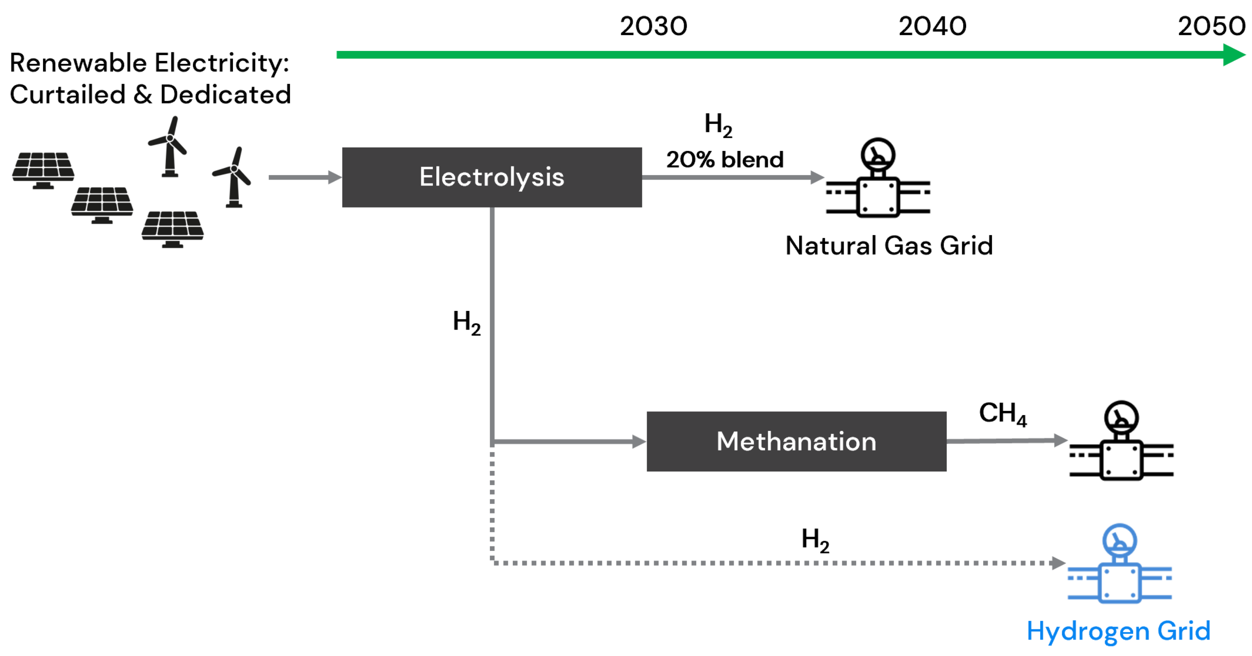
Scope of work requires that we compare RNG to other measures, including:

- Renewable hydrogen blending;
- Electricity generation
  - Focused on renewable electricity generation, and electricity via nuclear energy
- Building electrification;
- Transportation electrification; and
- Other technologies and options as identified by ICF and MPSC Staff.

Alternatives to RNG: Renewable hydrogen blending

<u>Renewable hydrogen blending</u>

- Renewable hydrogen refers to hydrogen generated from electrolysis using renewable electricity, also referred to as power to gas (P2G). Electrolyzers split water into hydrogen and oxygen, and the hydrogen can be further processed to produce methane. The electricity is typically sourced from renewable resources, such as wind and solar.
- Renewable hydrogen can then be blended into the existing gas pipeline system (with constraints on volume).



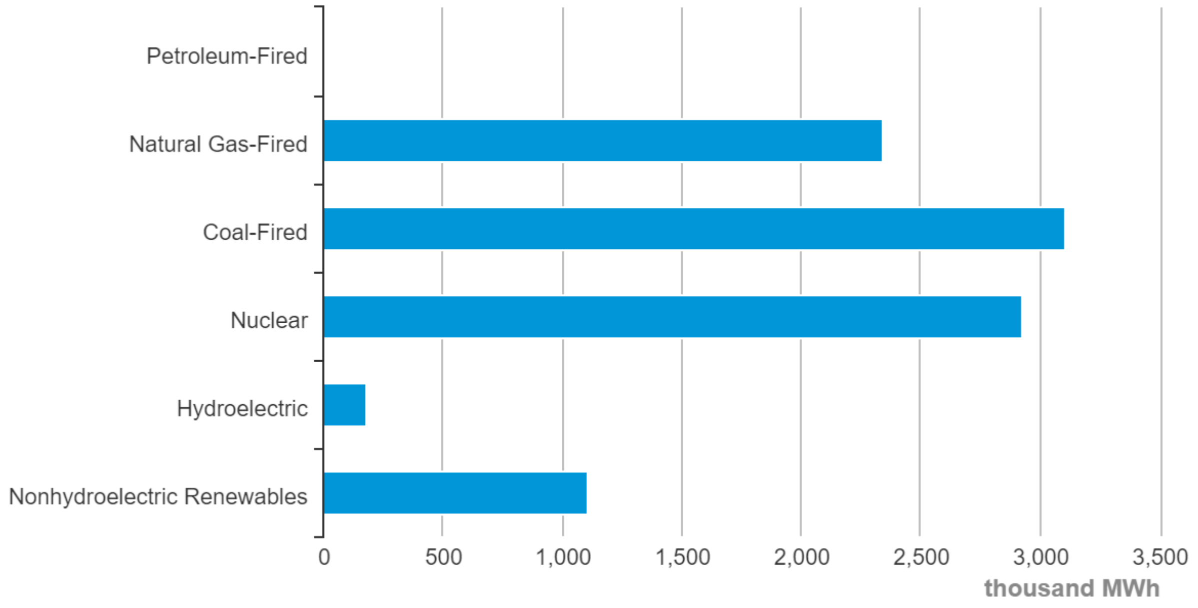
- <u>Key Studies / Analysis</u>
  - Previous ICF analysis of hydrogen production economics
  - Parkinson et al (EES 2019)

Alternatives to RNG: Electricity generation

<u>Electricity generation: Renewables + Nuclear</u>

- Michigan generates electricity using a mix of natural gas-fired plants, coal-fired plants, nuclear facilities, hydroelectric facilities, and renewable electricity
- For the purposes of this study, ICF will be considering the abatement costs of RNG in the context of abatement costs for renewable electricity production and nuclear electricity production.
- This can also be referred to as grid decarbonization.

- <u>Key Studies / Analysis</u>
  - Previous ICF analysis using IPM Framework
  - NREL Advanced Technology Baseline Reports
  - MI-focused literature review



Source: Energy Information Administration, Electric Power Monthly

Alternatives to RNG: Building electrification

Building electrification

- Describes the strategy of shifting to use electricity for building energy uses like space heating and cooking.
  - The biggest focus tends to be on heat pumps. In residential and commercial buildings, appliances powered by natural gas, propane, or heating oil powered appliances (e.g., furnaces and boilers) are assumed to be ground- or air-source heat pumps.
  - Similarly, gas-powered heaters can be replaced with heat pump water heaters.
  - Kitchen appliances running on natural gas can be replaced with electric ranges and induction stove tops.
- To be clear: Building electrification is NOT the same as grid decarbonization. The underlying principle of building electrification assumes that the electric-powered equipment used for space heating and cooking is powered by renewable electricity.
- Determining the impact of building electrification (e.g., via costs and GHG emissions) relies on assumptions and sophisticated analysis regarding how renewable electrons are delivered on an as-needed basis (i.e., dispatched) to align electricity demand with renewable electricity generation.

- Key Studies / Analysis
  - Work in comparable climates: Pennsylvania (ICF), Multiple locations (RMI), Nebraska (GTI)
  - To be clear: ICF is NOT conducting original building electrification analysis for the Michigan RNG Study

Alternatives to RNG: Transportation electrification

Transportation electrification

- Refers to the use of electric vehicles in the light-, medium-, and heavy-duty segments, rather than internal combustion engines.
- Transportation electrification and RNG are unlikely to be "competitors" in Michigan in the mid- to long-term future.
  - RNG is not a substitute for gasoline.
  - Most RNG is used in CNG vehicles in the medium- and heavy-duty market segments (e.g., transit buses, refuse haulers, regional haul trucks, etc.)
- For the sake of reference:
  - Fewer than 25 CNG stations in all of Michigan.
  - Estimated annual consumption of CNG is ~3-5 million diesel gallon equivalents (DGE).
  - Comparatively, there are about 1 billion gallons of diesel and 4.5 billion gallons of gasoline consumed in Michigan.

- Key Studies / Analysis
  - ICF analysis from previous work (e.g., MD/HD Vehicle Technologies 2019)
  - North American Council on Freight Efficiency

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