Food

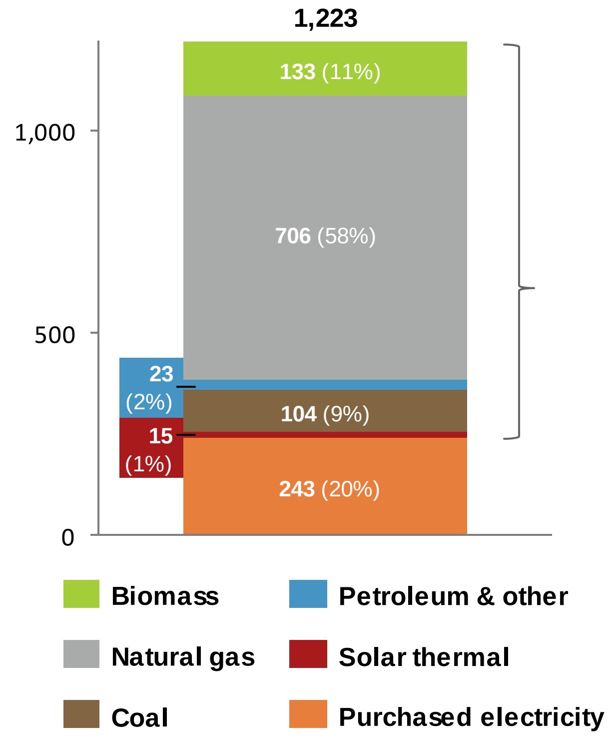
Sector Perspectives

RENEWABLE THERMAL COLLABORATIVE

58% of energy consumption is fueled by high temperature natural gas combustion to serve low temperature needs

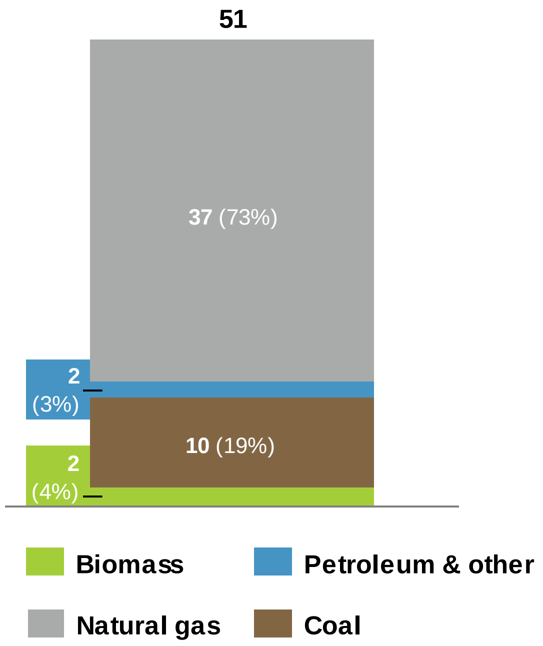
Total energy consumption (2018)[1]

Trillion Btu



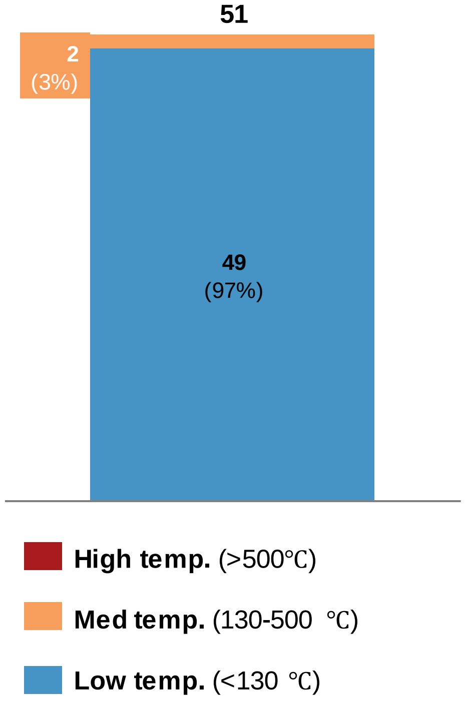
Thermal emissions (2018)[2]

Million Tonnes of CO2e



Estimated thermal emissions by process temperature (2018)[3]

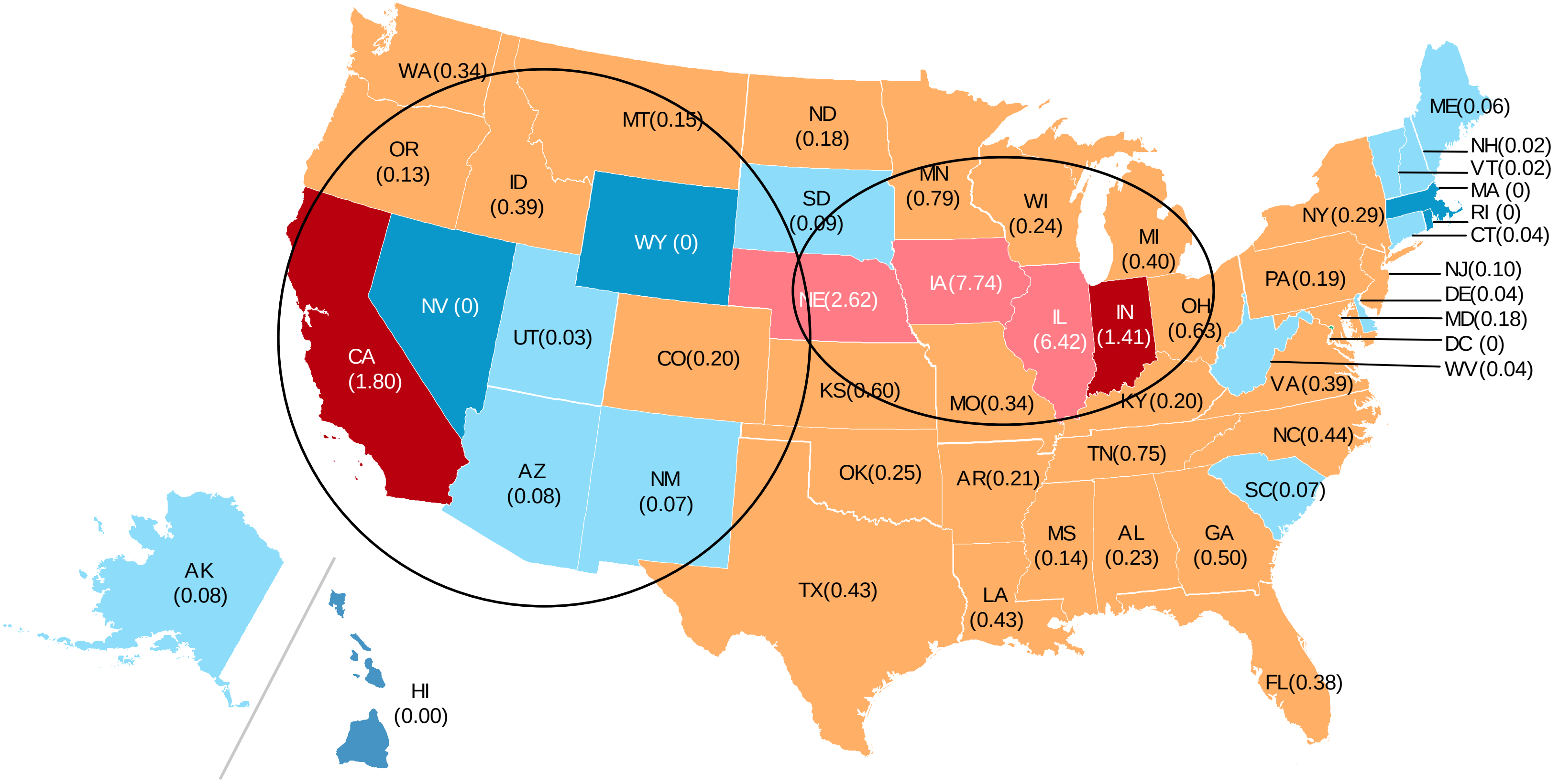
Million Tonnes of CO2e



1. EIA Annual Energy Outlook 2019 2. Based on AEO 2019 Outlook for 2018 energy consumption by combustible fuel (excludes purchased electricity) and EPA emissions intensity of individual fuels; RNG and green hydrogen are considered net zero, biomass is estimated at 15 kg CO2e/mmBtu 3. Calculated using the NREL MECS survey data for thermal energy use (2014) Source: EIA; EPA; NREL; BCG analysis

Thermal emissions are concentrated in the Midwest and California

Food thermal emissions by state (Million Tonnes of CO2e)[1]



Food emissions concentrate in the agricultural regions of the US

- Near zero
- <0.1 Million Tonnes CO2e
- 0.1-1 Million Tonnes CO2e
- 1-2 Million Tonnes CO2e
- >2 Million Tonnes CO2e

1. EPA GHGRP Inventory FLIGHT Database (2018); captures actual onsite reported emissions for large emitters emitting >25K tonnes of CO2e/year

Key heat applications occur in the low and medium temperature ranges

Drying | 30-90 ºC

The drying process reduces moisture in food in order to mitigate unwanted microbial proliferation and biochemical reactions, as well as reduce costs of transportation, packaging, and storage. Large dryers, usually powered by natural gas, circulate air at varying degrees of heat to achieve the appropriate moisture reduction.

Washing | 60-90 ºC

Agricultural produce is cleaned post-harvest by being **washed** with a sanitizer in heated water and subsequently hydrocooled. Larger scale farms use mechanical washing machines to wash large quantities of produce either in batches or continuously.

Pasteurizing | 60-140 ºC

Pasteurizing is a heat treatment of liquid foods (milk, juices, etc.) which extends their shelf lives by destroying organisms or enzymes that can cause spoilage. Foods are typically pasteurized using metal plates and hot water for no less than 15 seconds before being rapidly cooled.

Sterilizing | 110-120 ºC

Sterilization is a process used to eliminate microbial life on raw foods such as meat, poultry, eggs, and fish. Steam, dry heat, or chemicals are commonly used for sterilizing. In the sterilization process, foods are first heated, then equilibrated and held for a certain period, and finally cooled.

Cooking | 95-200 ºC

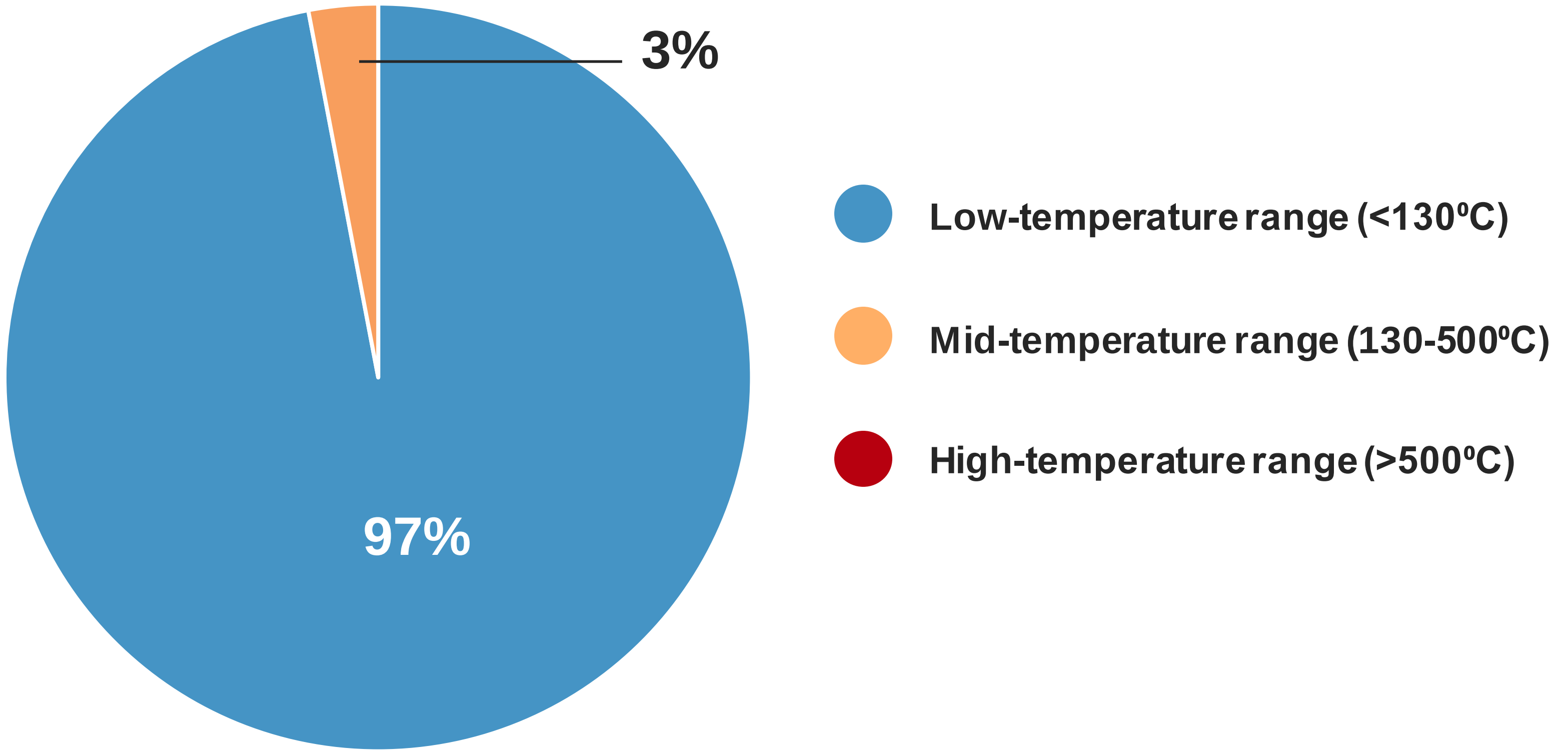
The **cooking** process alters the texture, color, and moisture content of foodstuffs to prepare ready-to-eat products. Examples of equipment used for cooking include various types of ovens, kettles, and boilers.

Low temperature heat processes are well suited for electrification in the immediate, mid, and long term

Source: DOE (2022), industry reports and papers, BCG analysis

97% of industrial heat needs are for applications in the low temperature range (<130ºC)

Thermal energy consumption (TBtu) by heat temperature range (ºC)[1]

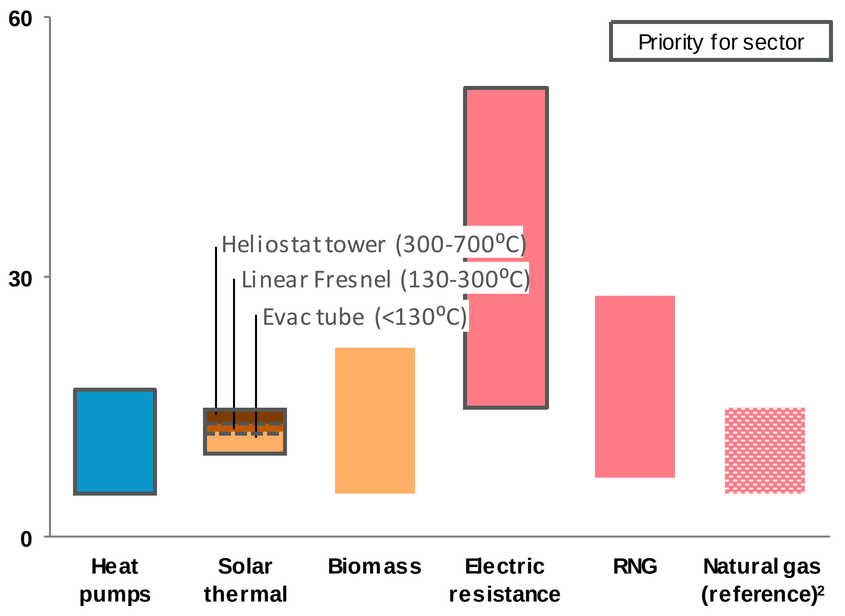


1. NREL Manufacturing Thermal Energy Use in 2014

Electrification and solar thermal offer attractive alternatives to natural gas for low heat applications

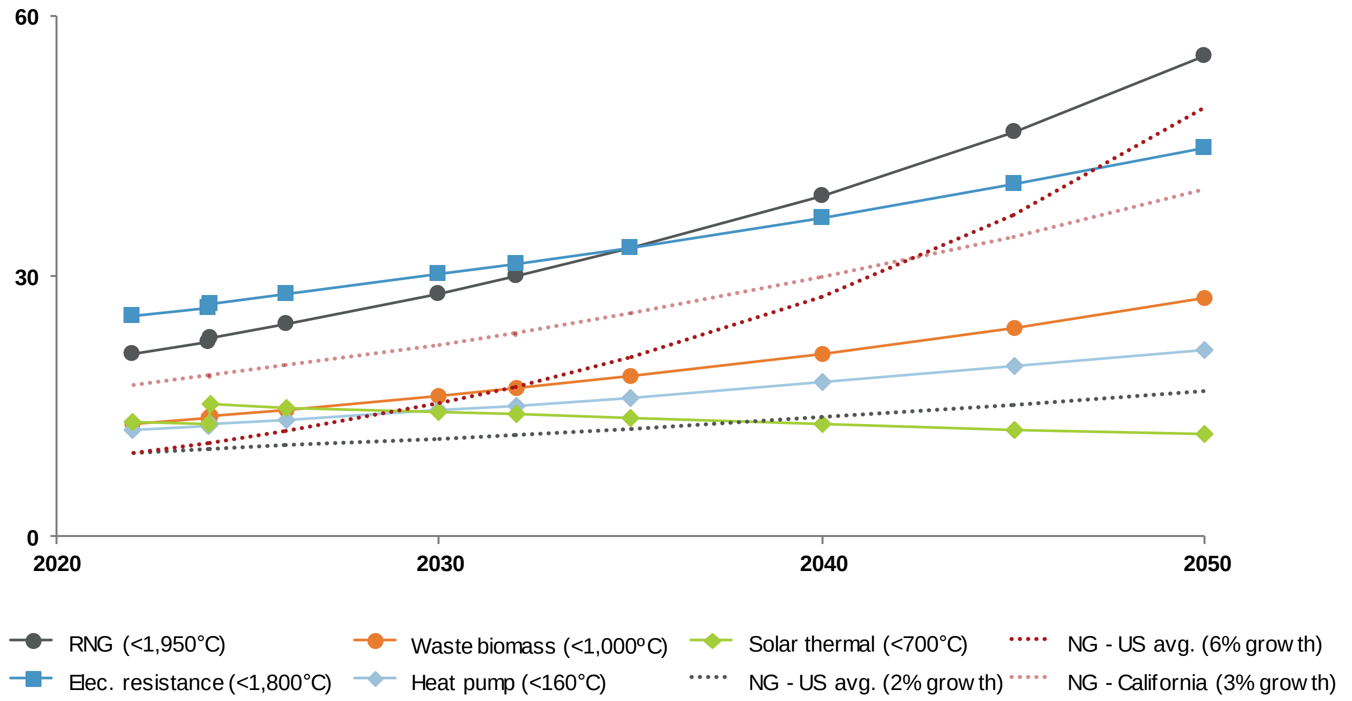
2022 LCOH for relevant technologies[1]

($/MMBtu)



Projected LCOH for relevant technologies[1]

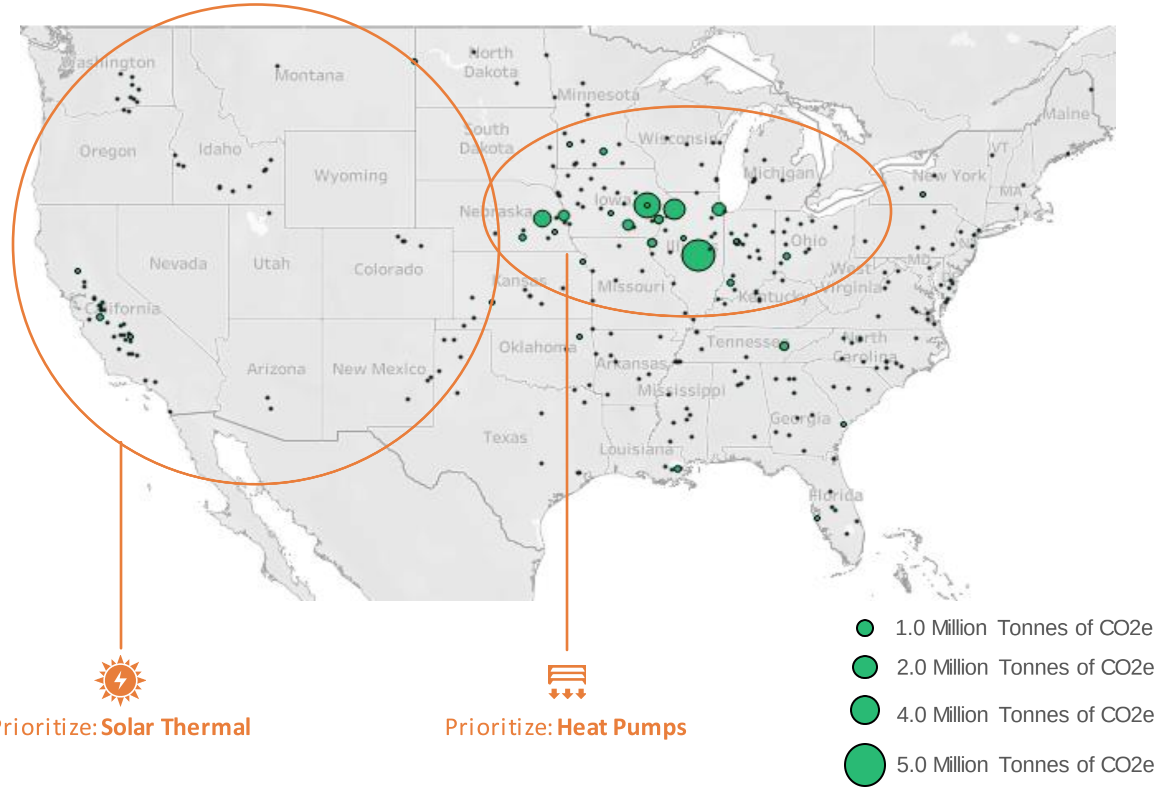
Average US LCOH ($/MMBtu)

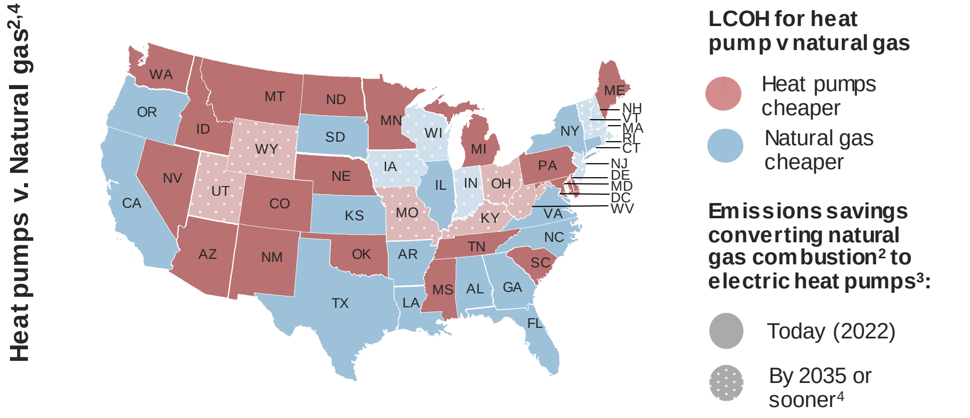


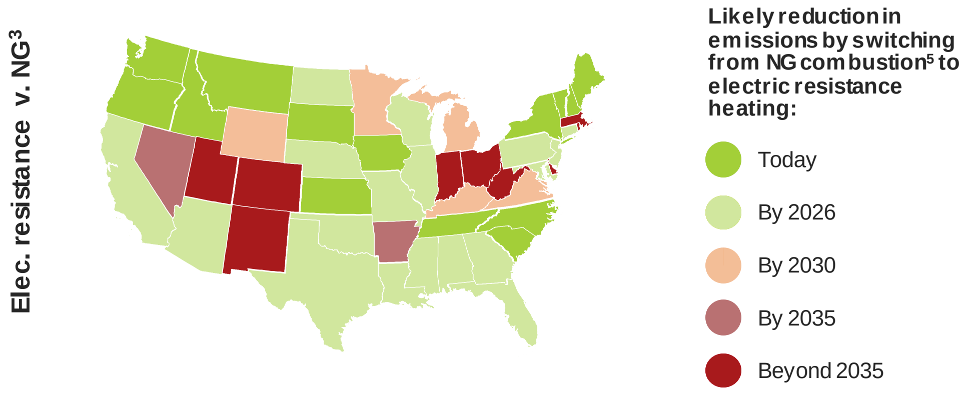
1. LCOH compares project lifetime costs against lifetime energy produced; costs include capital expense of equipment, fuel costs, and maintenance expense assumptions over the usable life of the energy asset. Electricity and natural gas pricing is based on national weighted average wholesale industrial end user electricity and natural gas prices for the past 1 year as of June 2022 industrial electricity modeled to grow at 2% per year. Electric heat pumps, electric resistive, and natural gas heating efficiencies modeled at 300%, 99%, 75%, respectively. Includes Inflation Reduction Act incentives 2. Uses weighted average US natural gas price for the past twelve months as of June 2022 (excludes Hawaii); assumes 75% combustion efficiency Source: EIA; EPA; Inflation Reduction Act; BCG analysis

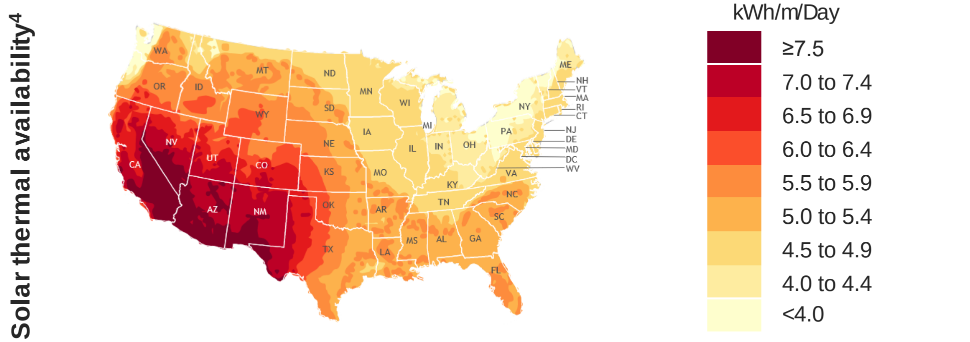
Heat pumps and solar thermal can be deployed in most heavy-emissions areas

US Food thermal emissions by zip code[1]









1. EPA GHGRP Inventory FLIGHT Database (2018); captures actual onsite reported emissions for large emitters emitting >25k tons of CO2e per year 2. US EIA Industrial Electricity Prices (May 2022), US EIA Industrial Natural Gas Prices (May 2022), Industrial Heat Pumps: Electrifying Industry's Process Heat Supply – ACEEE; 3. US EPA GHGRP (2019); US EIA; State Renewable Portfolio Standards; IEA ETSAP Industrial Combustion Boilers Fact Sheet; BCG analysis; 4. NREL 5. Calculated using 85% efficiency for natural gas boiler; 6. Calculated using a conservative COP of 3

Decarbonization pathways

Natural Gas
Displace with renewable fuels

Electrification
Deploy **heat pumps** <130ºC; expand to ~200ºC by 2030+
Deploy **electric resistance** heating for higher temp. and precise control requirements, and in regions with relatively inexpensive electricity

Solar Thermal
Evaluate solar thermal with thermal storage, particularly in advantaged areas for solar power

Electric Resistance + Thermal Storage
Deploy as/where inexpensive intermittent renewable electricity is available

2022 → 2050

Lower temperature heating technologies can serve nearly all thermal processes in the Food sector, where **97% of heat processes occur <130ºC**

Food manufacturers should explore **heat pumps and other electrification options** to displace natural gas and other fossil fuel combustion, which can likely be completed on an **accelerated timeline**

Considerations

- Ability to reach desired temperatures, cost of equipment and facility reconfiguration, grid or PPA supports emissions savings
- Thermal storage lowers costs and expands usability of solar energy
- Grid or PPA supports emissions savings, viable economics

Target First Movers

- Regions with relatively inexpensive and clean electricity
- CA and Southwest states; access to land for solar
- Ability to procure inexpensive intermittent electricity (e.g. states / electricity grids with high renewables)

Thermal decarbonization pathways

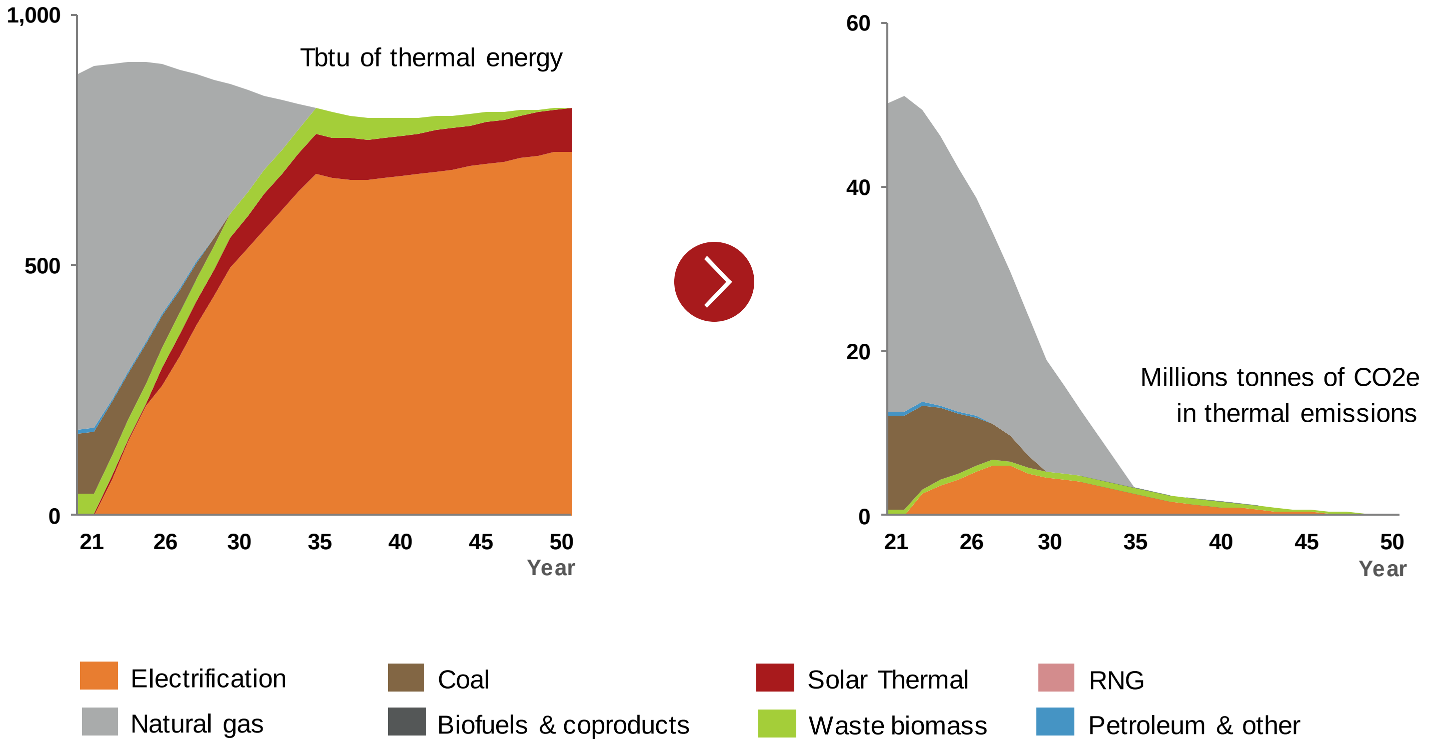
97% of industrial heat needs are for applications is in the low temperature range (<130ºC), which can be **decarbonized on an accelerated timeline** with electrification and heat pumps. Natural gas, which combusts at ~1,850ºC is not required for most heat needs in the sector.

Use of fossil coal and petroleum is **phased out by 2030**, and natural gas **phased out by 2035** – replaced with electrification.

Solar thermal energy with battery storage should also be considered, particularly in the US Southwest, and/or when electric heat pumps have a higher cost to generate heat than fossil natural gas (e.g. California).

Thermal energy consumption[1]

Thermal emissions[2]



1. Total thermal energy consumption based on EIA 2022 Outlook; forecasted energy mix per BCG analysis 2. Thermal emissions calculated based on emissions intensity of individual fuels; RNG and clean hydrogen assumed to be net zero fuels, biomass assumed to have an emissions intensity of 15 kg CO2e per mmBtu, electricity modeled based on US electric grid emissions intensity assuming 80% and 100% renewables by 2030 and 2050 Source: EIA outlook; EIA emissions intensity; BCG analysis

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