Geospatial Characterization of Low-Temperature Heating and Cooling Demand in the United States

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Introduction

- The U.S. low-temperature geothermal resource contains approximately 30,000 EJ and 6 million EJ in the relatively shallow subsurface for hydrothermal systems and enhanced geothermal systems, respectively (Mullane et al. 2016).
- Nevertheless, fossil fuels were major sources for U.S. primary energy consumption, and **only 0.24% of consumed energy** was supplied by geothermal energy in 2021 (EIA 2022).
- Total U.S. thermal demand is known to be very large (Fox, Sutter, and Tester 2011; Tester et al. 2021).
- To understand where heating and cooling demand occur and where this demand may co-locate with geothermal resources, this study geospatially quantifies U.S. low-temperature heating and cooling demand at the county level in residential, commercial, manufacturing, and agricultural sectors and data centers.

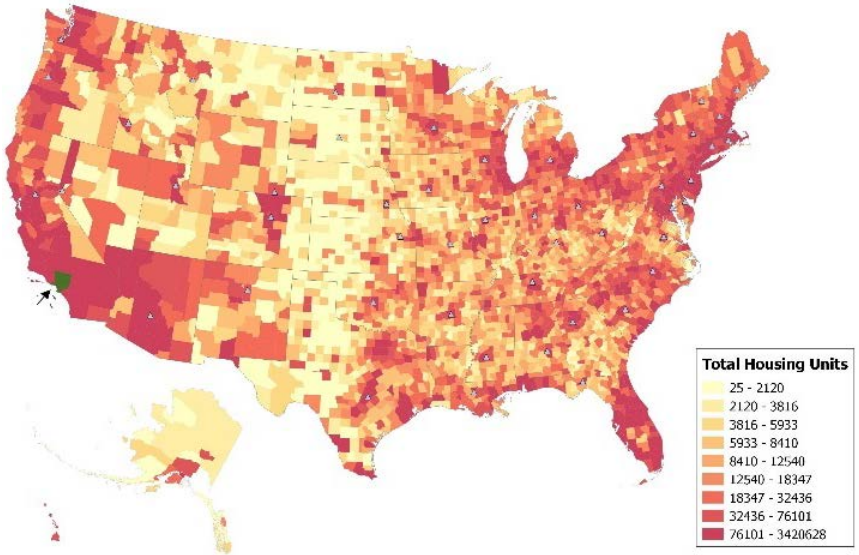
Methodology

- The U.S. Energy Information Administration (EIA) end-use energy consumption and expenditure (C&E) survey data:
  - Residential Energy Consumption Survey (RECS)
  - Commercial Building Energy Consumption Survey (CBECS)
  - Manufacturing Energy Consumption Survey (MECS)
- Fuel expenditures in the USDA Farm Production data
- Commissioned power for data centers
- Coefficient of performance (COP) incorporated for heat pump or refrigeration cycle.

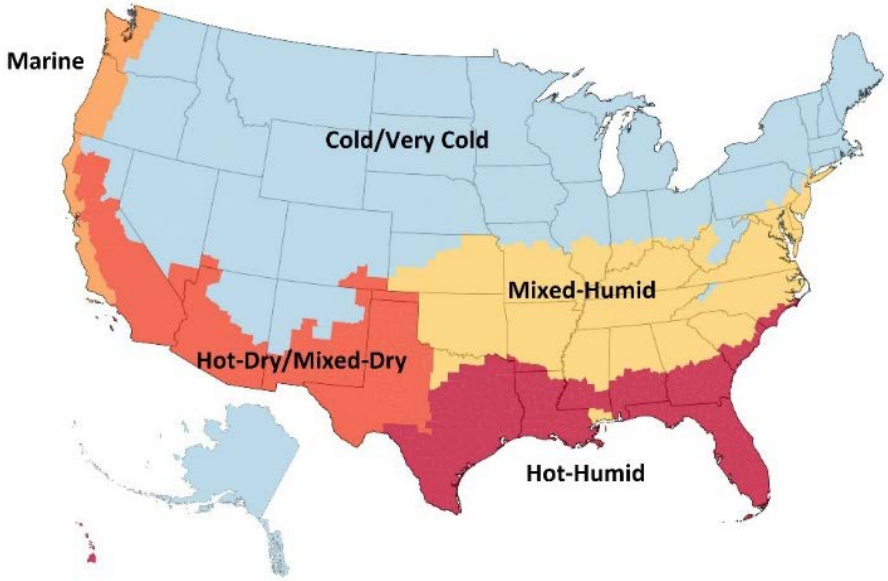
Residential Sector

- Space heating, water heating, cooking, microwave, clothes dryer, hot tub heater, and swimming pool heater end-use categories were selected in 2015 RECS for heating demand analysis (EIA 2018).
- Air conditioning, all refrigerators, and freezer end uses were used for cooling demand analysis.
- The end-use energy consumption database was incorporated with COP.
- The census division-level database was disaggregated to county-level resolution using the number of housing units in the 2020 decennial census and then weighted relative to climate zone designations.

Residential Sector

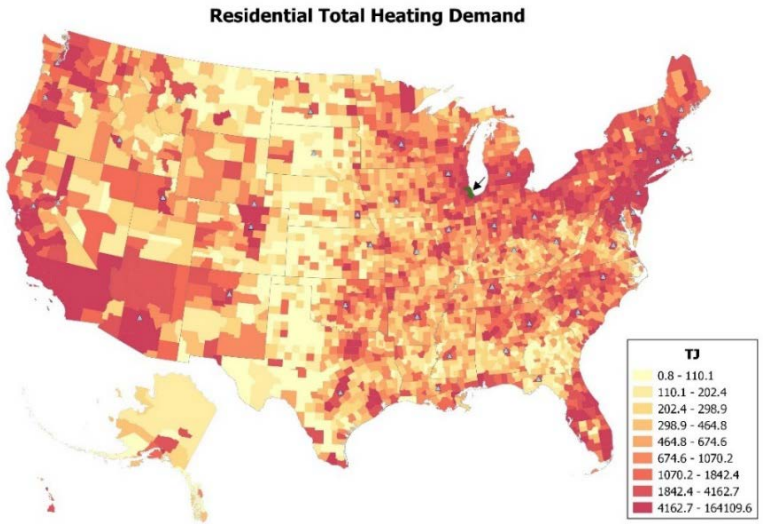


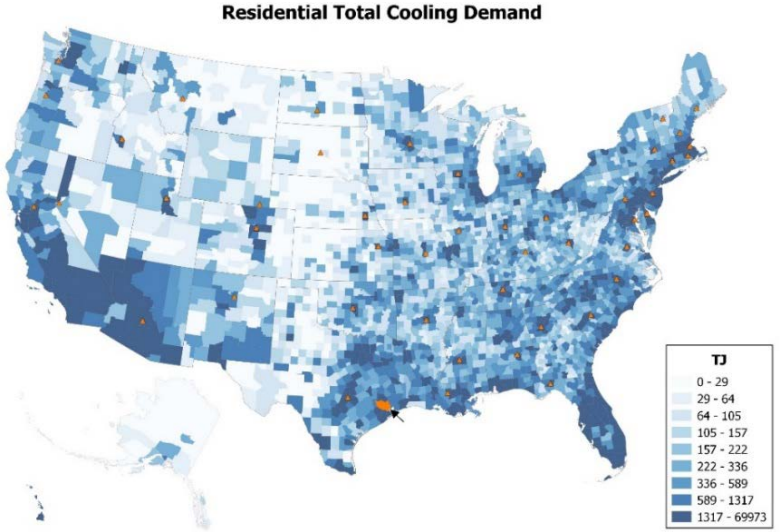
Number of housing units



Climate zone designations

Residential Sector – Results



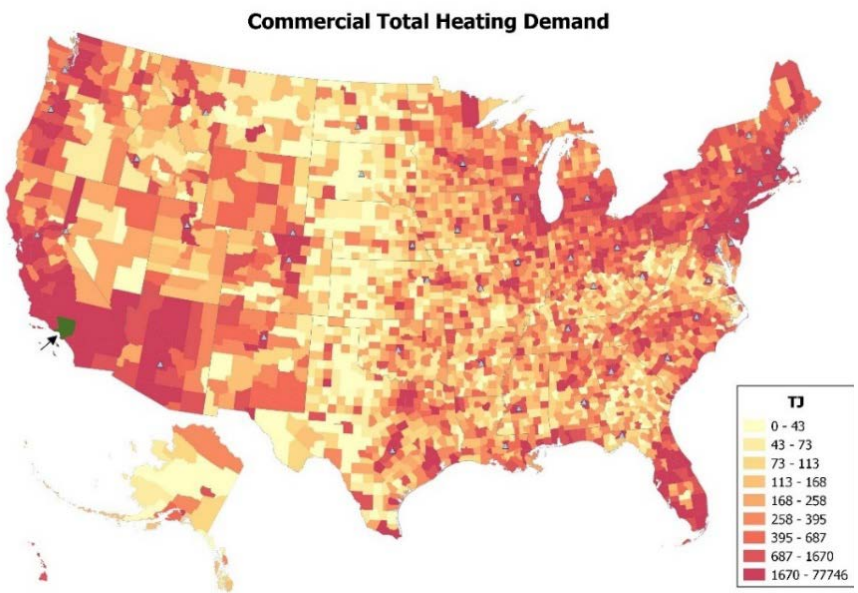


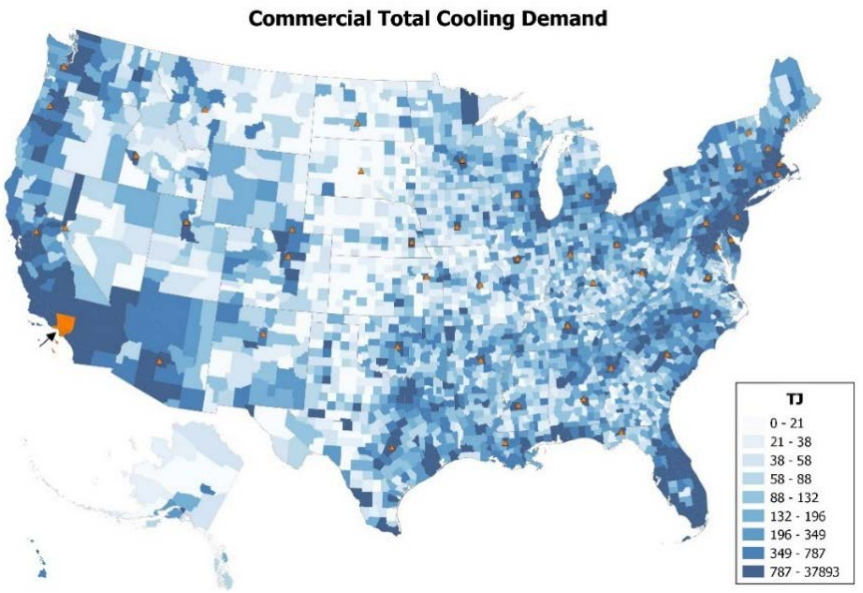
- The heating and cooling demand were significantly affected by both the number of housing units and climate zone designations.
- Los Angeles County, classified as hot-dry climate, had the highest energy consumption for six heating end-use categories (except space heating end use).

Commercial Sector

- Space heating, water heating, and cooking end uses and cooling and refrigeration end uses were selected in 2012 CBECS for commercial heating and cooling demand analyses, respectively (EIA 2016).
- To disaggregate the EIA's regional data to county-level resolution, the energy intensity specified by the 53 principal building activities was reconciled with 18 building types in each county obtained from the Federal Emergency Management Agency's 2013 Hazus Comprehensive Data Management System database (FEMA 2013).

Commercial Sector – Results



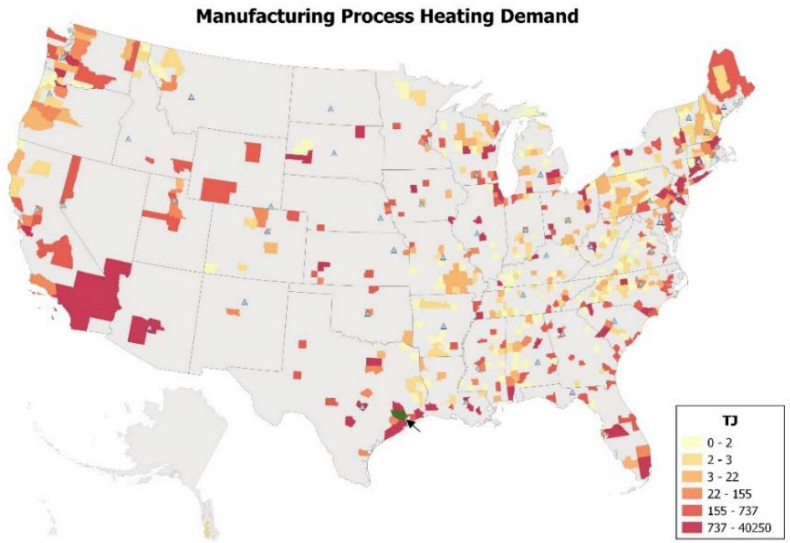


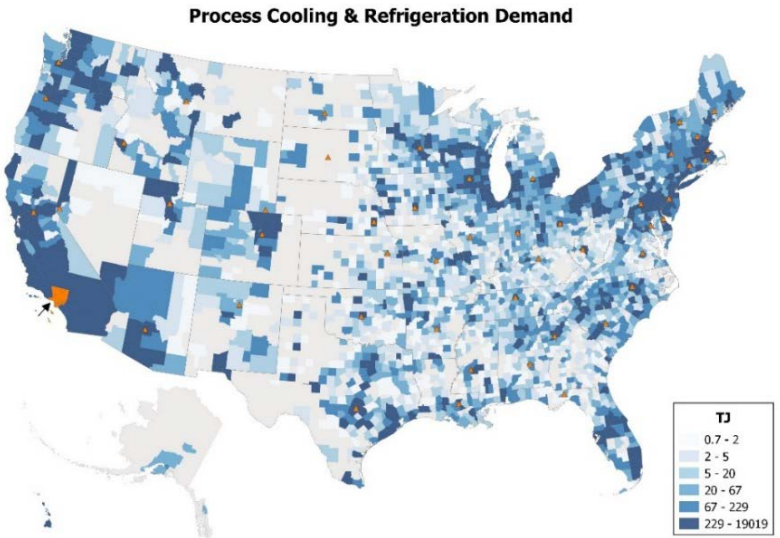
- Los Angeles County also had the highest demand for water heating, cooking, total heating, refrigerator, and total cooling in the commercial sector.

Manufacturing Sector

- 14 manufacturing categories where the process temperature is less than 150°C and 66 categories were selected in 2018 MECS for manufacturing heating and cooling demand analyses, respectively (EIA 2021).
- End-use energy consumption data in process heating and process cooling and refrigeration were analyzed.
- The U.S. Census Bureau's County Business Patterns were incorporated using North America Industry Classification System (NAICS) codes to disaggregate the data to the county level.

Manufacturing Sector – Results





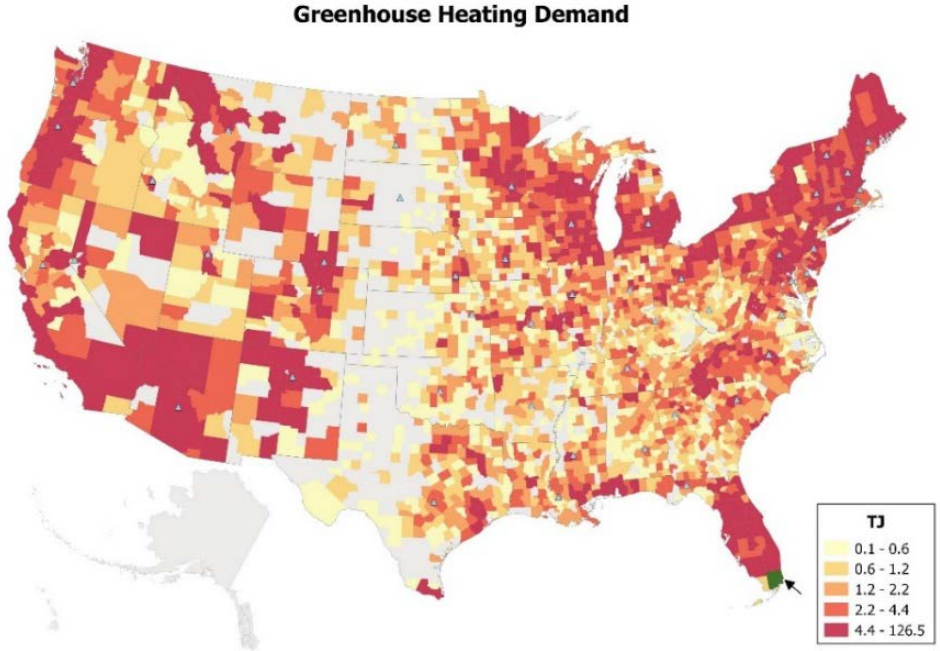
- The low-temperature heating and cooling demand in the manufacturing sector was mainly dependent on the number of facilities and their locations.
- The highest process cooling and refrigeration demand occurred in Los Angeles County, which includes a wide range of manufacturing industries.

Agricultural Sector

Fuel Expenditure ($) / Fuel Price ($/volume) × Energy Content (Btu/volume) = Energy Consumption (Btu)

- The regional energy consumption was disaggregated using the USDA Census of Agriculture to county-level resolution.
- The county-level energy consumption was weighted relative to the average farm size in each county.
- 70% of the total greenhouse energy consumption was allocated for heating demand.

Agricultural Sector – Results



- Miami-Dade County, Florida, had the highest heating demand in the agricultural sector for the greenhouse category.

Data Centers

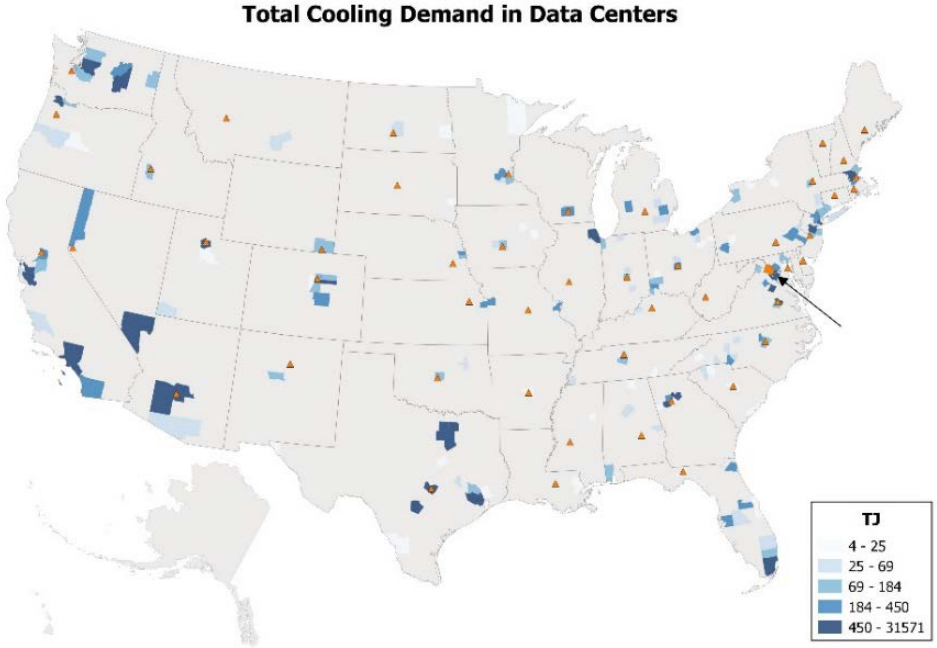
- This study assumes operating Information and Computer Technology (ICT) equipment generates heat that needs to be removed:

  Electricity Used for ICT Equipment = Heat Generated from Equipment Operation = Cooling Demand

- Commissioned power for data centers in the United States was collected using a commercial platform (datacenterHawk, LLC); it incorporated power usage effectiveness (PUE) of 1.5 and 80% power factor to estimate the data center cooling demand.

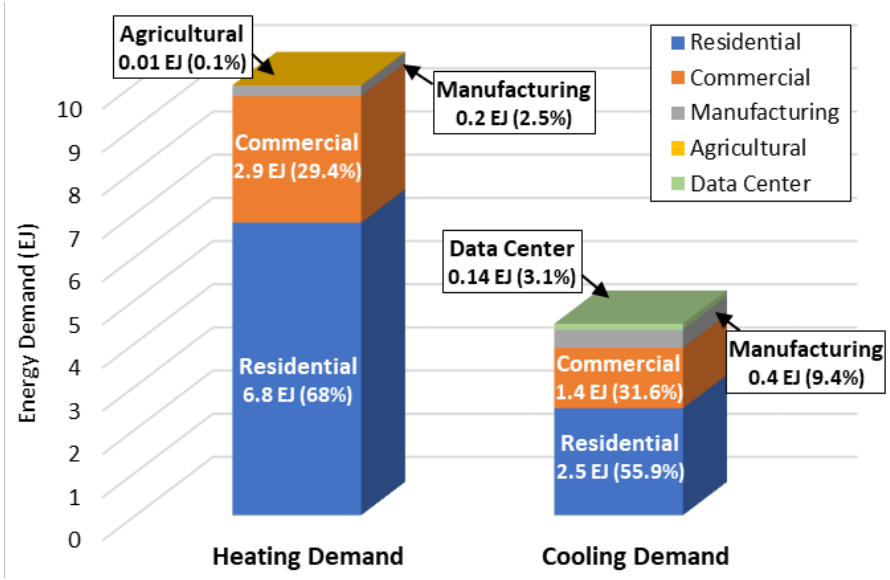
- Co-location (private companies for leasing) and enterprise (for own use) data centers were analyzed in this study, excluding hyperscale data centers built by a hyperscale company or designed specifically to meet the needs of a hyperscale company, such as Amazon.

Data Centers - Results



- Numerous data centers were in northern Virginia (near Washington, D.C.), and the highest data center cooling demand was observed in Loudoun County, Virginia.

Total Heating and Cooling Demand



- Total low-temperature heating and cooling demand in the sectors were 9.96 EJ and 4.43 EJ, respectively.
- Residential: space heating = 64.9%, air conditioning = 77.7%; Commercial: space heating = 63.2%, refrigeration = 50.6%.

Conclusion

- Total low-temperature thermal energy demand analyzed in this study was about 15 EJ, with the residential sector having the highest heating and cooling demand and requiring about 14.6 % of the U.S. total primary energy consumption.
- Thermal demand in the residential and commercial sectors was present in each county, whereas thermal demand in the manufacturing and agricultural sectors and data centers was more geospatially concentrated in certain counties.
- All data are available in the Geothermal Data Repository (https://gdr.openei.org), and this study continues with dGeo work, which will leverage the results from these maps.

Thank You

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