NREL Transforming ENERGY

Quantifying the Technical, Economic, and Market Potential of Geothermal District Heating Systems in the United States

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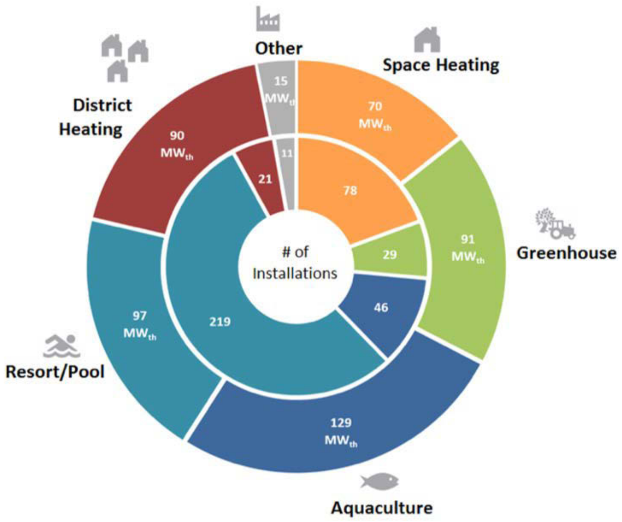
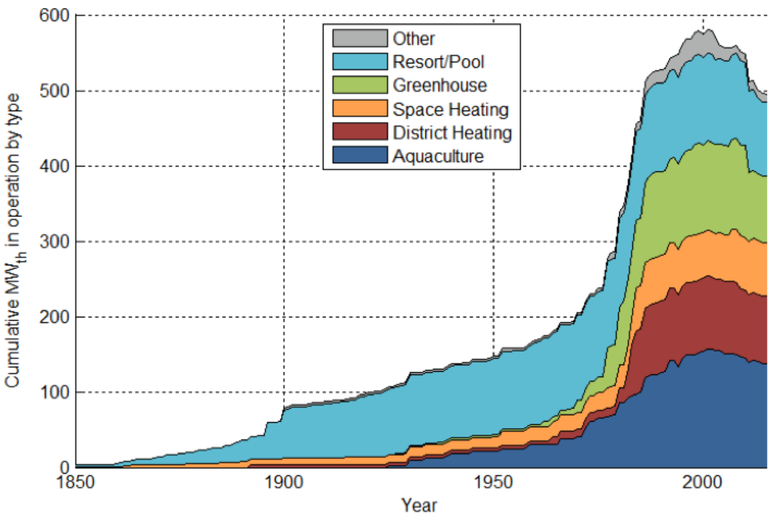
Current Market for Direct Use Systems

Recent review of geothermal direct use (GDU) installations in the United States found 407 systems in operation, including **21 geothermal district heating (GDH) systems**.

Significant increase in GDU installations in 1970s and 1980s correlate with **increase in fossil fuel prices** in the same period.





Source: Snyder et al. (2017)

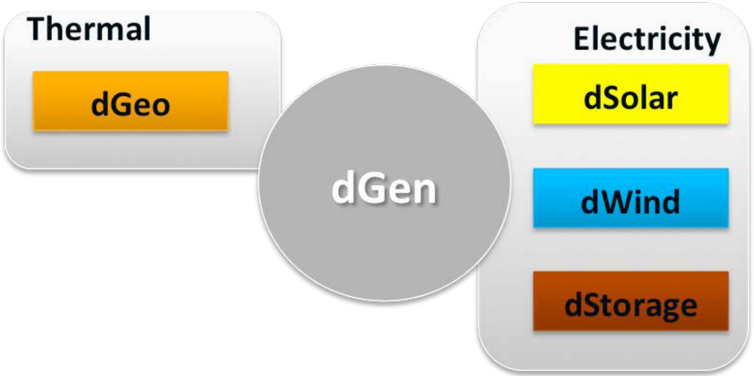
The Distributed Geothermal Market Demand Model (dGeo)

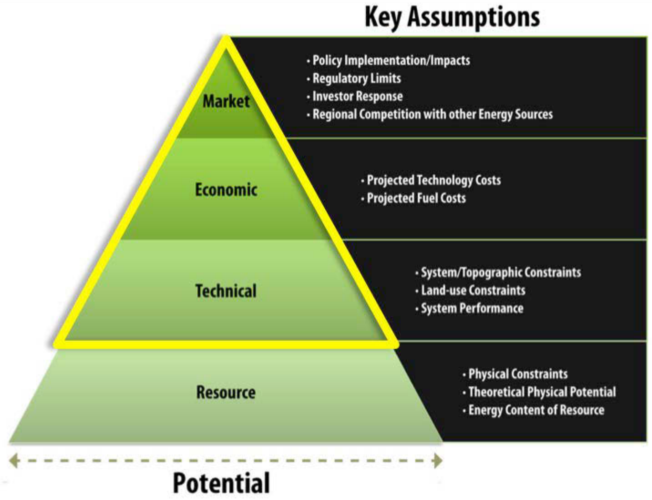
Description: dGeo is a tool for projecting customer adoption of distributed geothermal technologies in the United States through 2050.

Motivation and Scope: dGeo was developed to support DOE's GeoVision Study, with a focus on two technologies:

- Geothermal heat pumps (GHP)
- Direct use district heating systems (GDH)

Core capabilities: Quantify/project the potential opportunity (**technical**, **economic**, and **market**) for distributed geothermal under various modeling scenarios





dGeo Model Assumptions and Limitations

Time: 2014 – 2050, two year time-steps

Geography: Continental U.S. with sub-county resolution

Market Sectors: Commercial and Residential

Technology:

- **DU:** Shallow (<3km), low-temperature (30-150°C) district heating systems for space and water heating
  - Considers both hydrothermal and enhanced geothermal system (EGS) resources
  - EGS resource **not available until 2030** to align with ReEDS assumptions

Interaction with the Power Sector (i.e., ReEDS):

- DU model not linked to ReEDS – anticipate gas sector impacts primarily

Interaction between technologies:

- GDH modeled independent of other technologies, including GHPs and other thermal/electric DERs

dGeo Model Inputs

Categories of input include:

- Current and future **technology costs**
  - e.g., drilling cost reductions, GHX capital cost reductions
- Current and future **technology performance**
  - e.g., improved recovery factors, improved GHP efficiency
- Current and future **financing terms**
  - e.g., DU plant construction timeline, interest rates; GHP interest rates, down payment percent
- Current and future **incentive policies**:
  - Federal and state incentive policies
- Current and future **macroeconomics**:
  - Current and future fuel/electricity prices, projections of new construction

Input parameters developed by Thermal Applications Task Force

- **GHP** – Oak Ridge National Laboratory (X. Liu)
- **DU** – National Renewable Energy Laboratory (K. Young & K. Beckers)

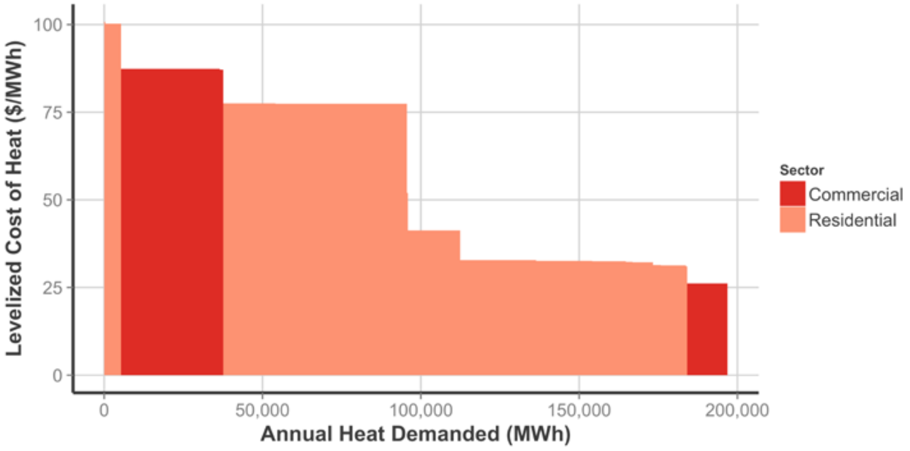
Input parameters reflect competition of GHP and DU with baseline (HVAC) systems

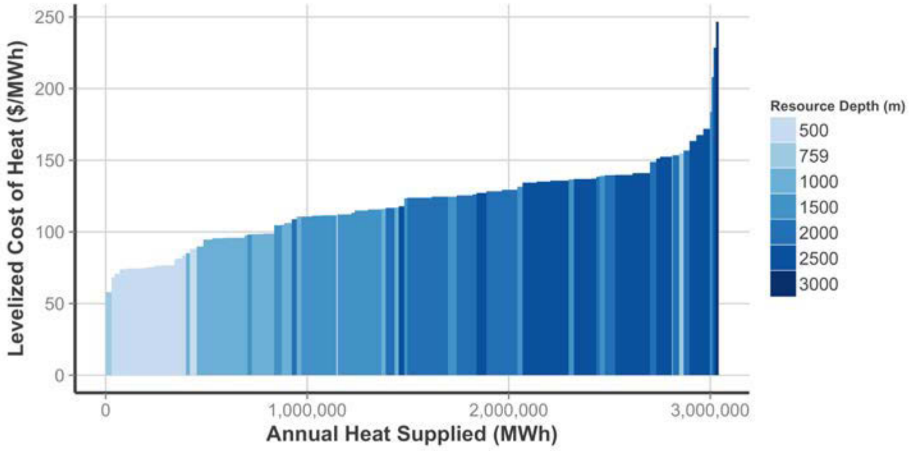
- Baseline systems represent typical configurations of residential and commercial buildings
- **Systems modeled** – boilers, furnaces, individual heaters and A/C units, steam and hot water systems, etc.
- **Fuels modeled** – electricity, natural gas, propane, fuel oil, and district-supplied fuels

Assessment of Economic Potential

Economic potential is broadly defined as the portion of technical potential that is "economically viable" – those projects for which revenues exceed costs, producing a positive return on investment.

dGeo estimates economic potential by simulating local **demand and supply** for each county, then determining the portion of supply with sufficiently low price to meet demand.





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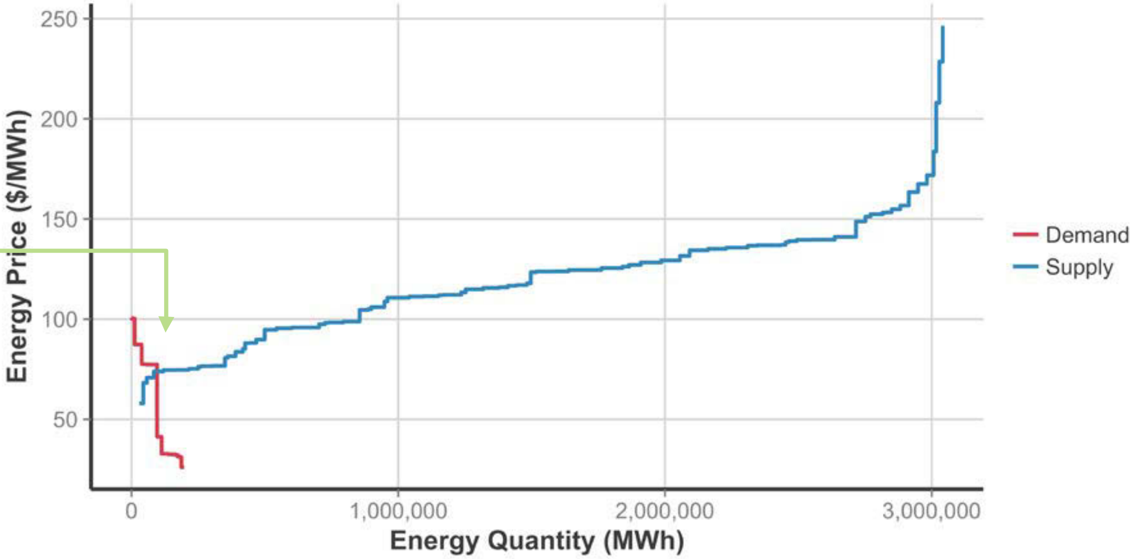
Equilibrium point

Lowest price supply side willing to sell product (geothermal heat) and highest price demand side would be willing to purchase product



Sensitivity Analysis Informs dGeo Scenarios

Literature review conducted to identify parameters that have biggest impact on GDH levelized cost of heat (LCOH). Categories of high-impact parameter improvements include:

- **Geothermal reservoir system** – drilling costs, well flow rate, geothermal gradient
- **User application** – surface equipment capital costs, reinjection temperature
- **Financing** – discount rate

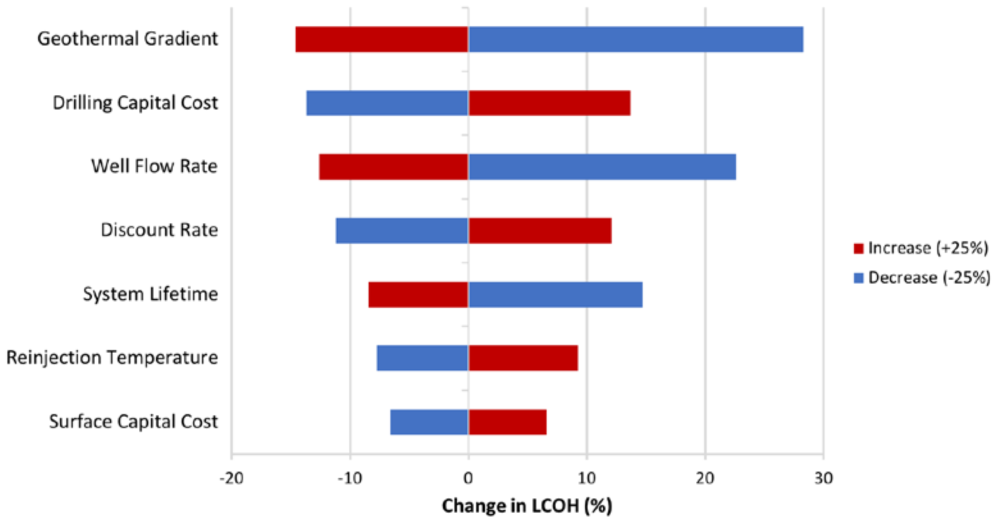
Potential technological improvements informed the creation of two distinct scenarios:

Business-as-Usual (BAU):

- Assumes no technology or financing improvements

Technology Improvement (TI):

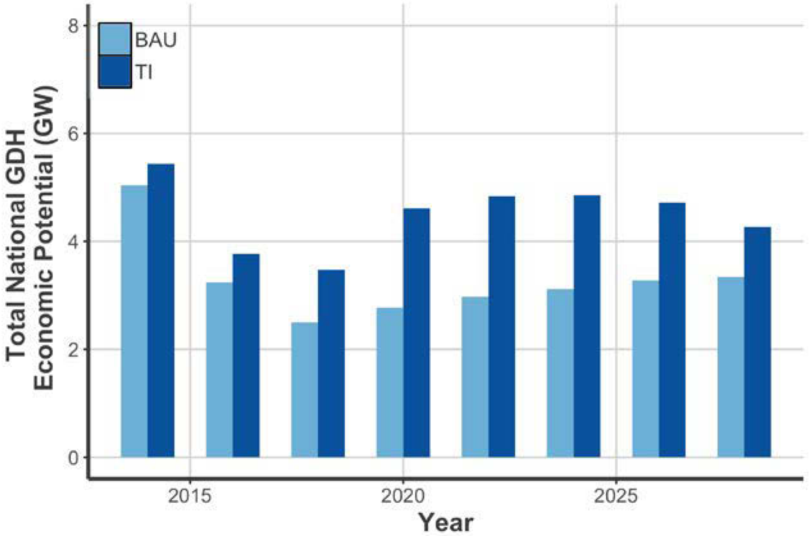
- 50% reduction in drilling costs
- Increase in EGS flow rate from 40 to 110 L/s
- Approximate 15% decrease in discount rate
- Average 15% decrease in exploration costs

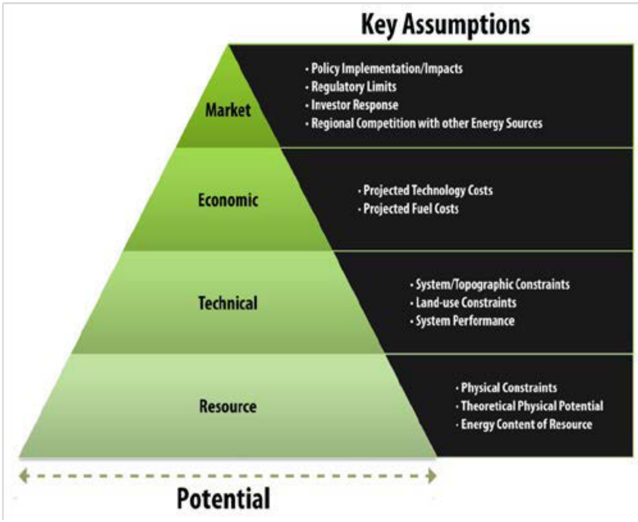


Results – Economic Potential

Prior to 2030, only **hydrothermal resources** are considered for development, and the economic potential estimate is moderate. dGeo projects **4.6 GW$_{th}$** of economically viable GDH capacity in 2020 (TI scenario).

The economic potential results exhibit the influence of time-variant factors such as thermal load growth, incentive availability, cost and technology inputs, and fuel prices.



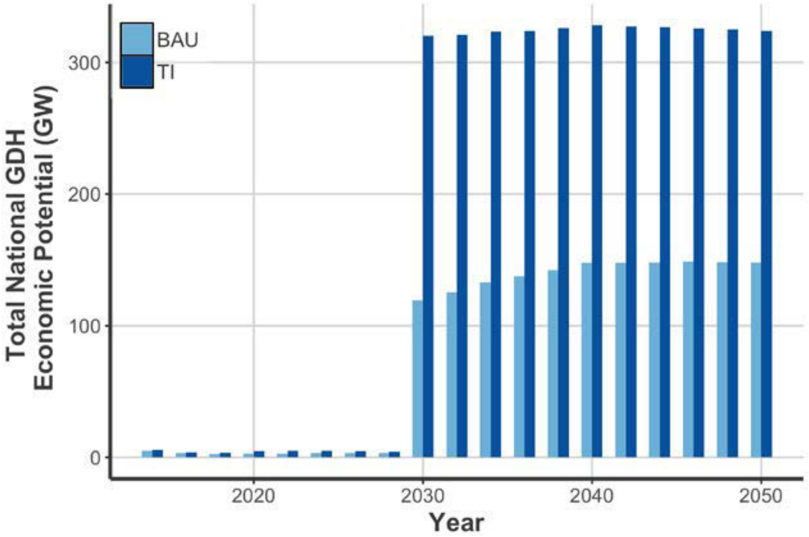


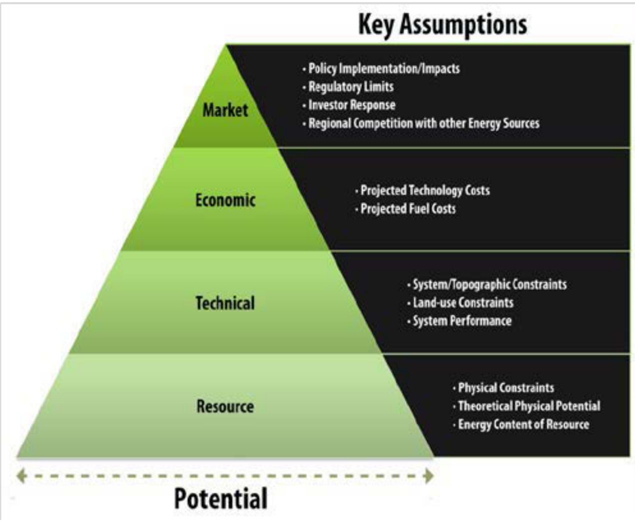
Hydrothermal (GWth)	EGS (GWth)
1.6 GW$_{th}$ TI (2020)	172 GW$_{th}$ TI (2030)
4.6 GW$_{th}$ TI (2020)	315 GW$_{th}$ TI (2030)
27 GW$_{th}$ TI	1,186 GW$_{th}$ TI (2030)
46.5 GW$_{th}$ (Mullane et al. 2016)	46,500 GW$_{th}$ (Mullane et al. 2016)

Results – Economic Potential

After 2030, the two scenarios assume that EGS is commercially viable, and its massive resource base increases the estimates of the potential values relative to the values for hydrothermal resources only.

In the TI scenario, with improved cost, technology, and financing parameters, the economic potential is approximately **315 GW_{th}**. dGeo estimates that nearly **17,500** unique district heating systems nationwide could contribute to this total.





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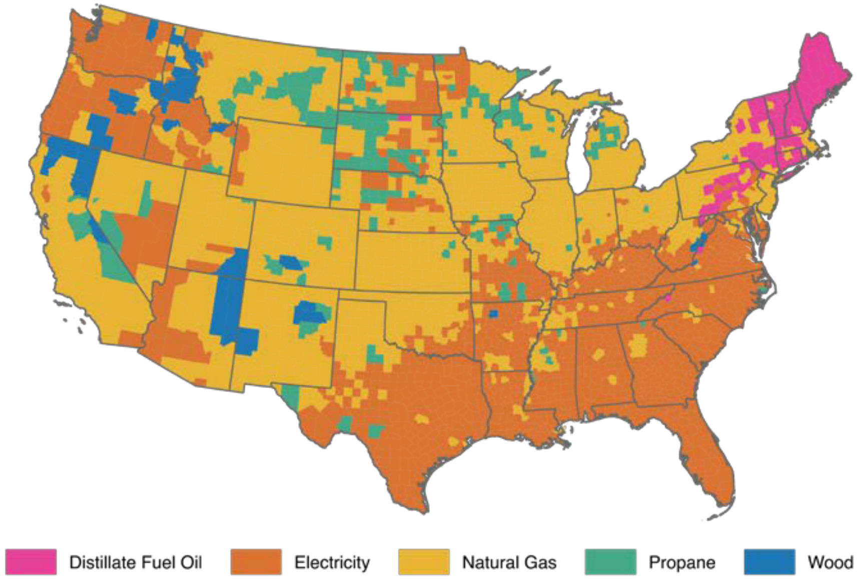
Spatial Trends in GDH System Viability

The outputs from dGeo are all functions of underlying spatial trends in the data. Thermal load growth, heat demand profiles, and DER incentive availability are all examples of distinct geospatial layers that inform regional trends.

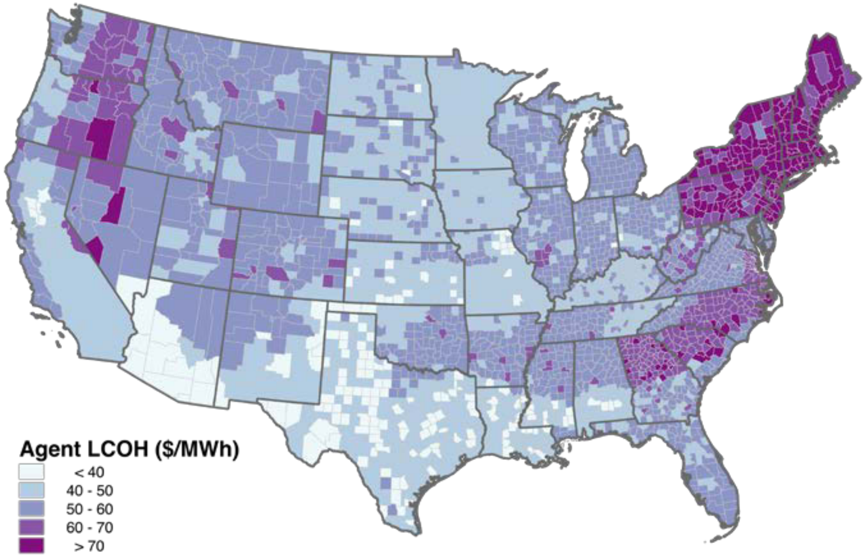
In particular, the **predominant heating fuel type** demonstrates regional trends that reflect the viability for GDH systems. **Fuel oil and electric heating** represent expensive fuel types with which GDH can compete, whereas the relatively inexpensive natural gas fuel type is more challenging to displace.

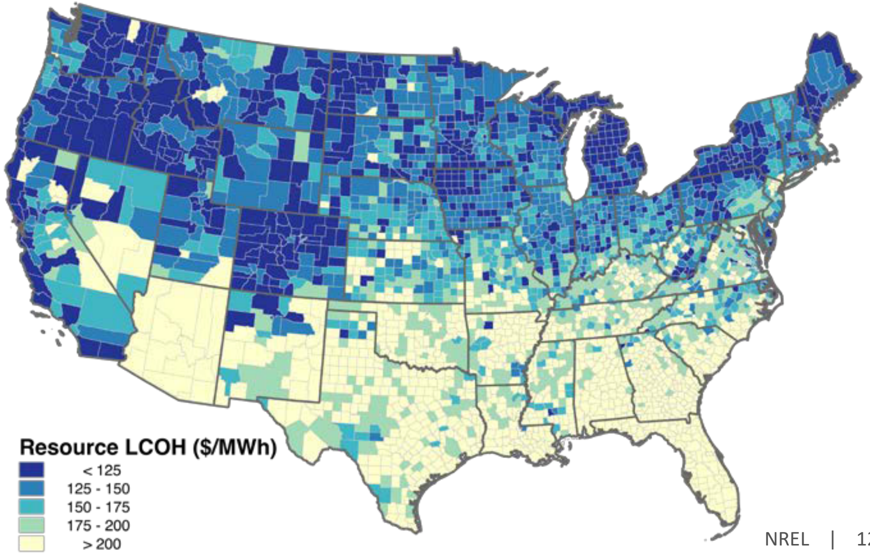


Spatial Trends in GDH System Viability

dGeo creates and “intersects” spatial layers of **Agent LCOH** (weighted average of heating costs) and **Resource LCOH** (function of cost, technical, financial parameters, and total heat demanded) to inform areas of greater favorability for GDH systems.

The Agent LCOH values by county reflect the **regional trends in predominant heating fuel type**. The Resource LCOH values reflect **areas of greater thermal demand** (northern U.S.) and therefore **greater capacity factors**.



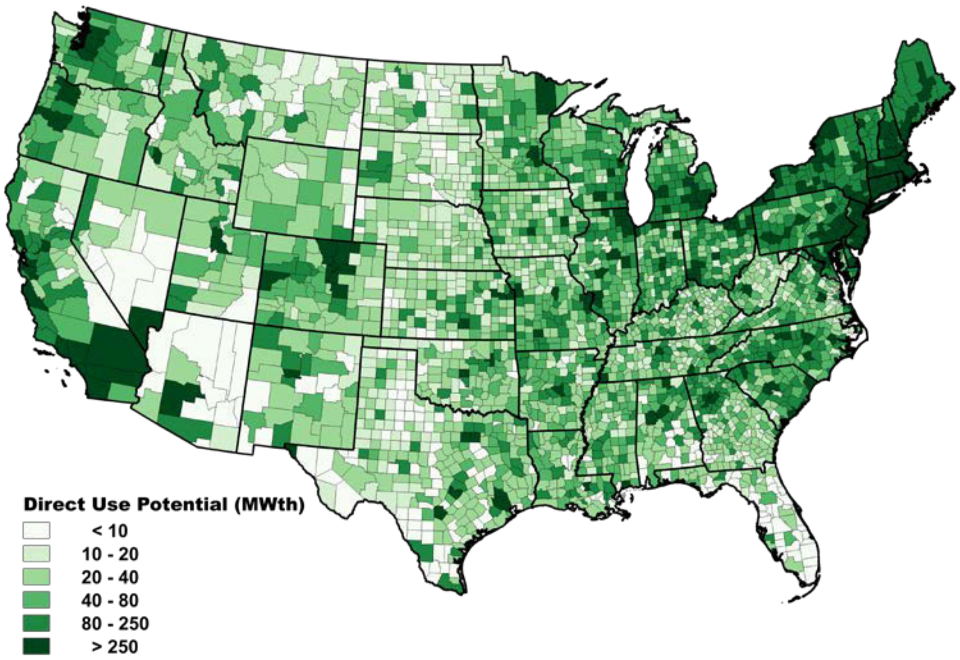


Economic Potential by County

Similar spatial trends emerge in the map of economic potential—notably, the **Northeast and New England regions** tend to use more expensive heating fuels and therefore have higher fuel costs and greater economic potential.

Another key geospatial trend—the **colocation of elevated economic potential and population centers** throughout the United States.

Demonstrates that the viability of GDH systems depends not only on the existence of a feasible geothermal resource, but also on the **proximity of a demand center** which can utilize this supply



Conclusions & Discussion

In support of the Geothermal Vision Study, the **dGeo model** was created to assess the potential for geothermal district heating systems (GDH) to provide heating solutions for residential and commercial buildings in the U.S.

Scenario modeling results show significant potential for GDH through 2050: **1.6 GWth in the TI scenario from hydrothermal resources** alone. This amount of capacity accounts for a market penetration level of approximately 0.16%—equal to a **16-fold increase** from the current level of GDH deployment of 100 MW_{th}.

The development and deployment of EGS technology would increase the economic potential estimate to **315 GW_{th}** and make geothermal a major player across the United States.

Areas in which **expensive heating fuels** are predominant **demonstrate the greatest potential** for GDH replacement—New England and the Northeast U.S. in particular show greater favorability.

Further Reading

The Geothermal Vision (GeoVision) Study

https://www.energy.gov/eere/geothermal/geovision

GeoVision Scenario Viewer

https://openei.org/apps/geovision/

Thermal Applications Task Force Reports

DU: https://www.nrel.gov/docs/fy19osti/71715.pdf

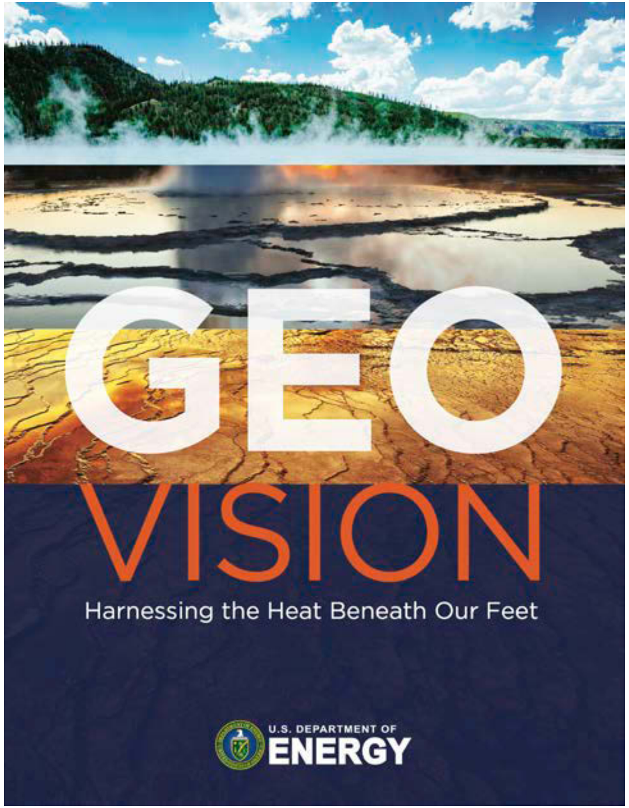
GHP: https://info.ornl.gov/sites/publications/Files/Pub103860.pdf

All other Task Force Reports

https://openei.org/apps/geovision/task-force-reports

dGeo Documentation Report

https://www.nrel.gov/docs/fy18osti/67388.pdf



Questions?

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