Appendix A: Supplemental Information

A1. Energy consumption and CO_2 Emission in U.S.

This section provides additional background information on energy-related CO_2 emissions and energy consumption characteristics in the U.S. Table A1 provides a breakdown of energy-related CO_2 emissions in the U.S. in 2019 by source and by sector. Burning of coal, natural gas and petroleum in the residential, commercial and industrial sectors are mostly for direct heating (and cooling) in these sectors. The associated emissions are significant: 1,618 million metric tons of CO_2 or about 31% of total energy-related CO_2 emissions. Also, a fraction of the electricity-related CO_2 emissions in these sectors are attributed to heating and cooling applications. For example, in the residential sector, Figure A1 reveals that about 30% of U.S. households have an electric heat source as main heating equipment.

Table A1: Energy related CO_2 emissions by source and sector in the United States, 2019 (million metric tons). Table provided by EIA[186].

	Residential	Commercial	Industrial	Transportation	Electric power	Source total
Coal	0	2	104	0	973	1,076
Natural gas	275	194	550	52	619	1,689
Petroleum	69	59	365	1,856	16	2,365
Other[1]					11	11
Electricity[2]	620	585	411	3		
Sector total	963	839	1,428	1,912	1,619	5,142

[1]Emissions from combustion of waste materials derived from petroleum and emissions from some types of geothermal power plants.
[2]Electricity-related CO_2 emissions are based on electric power sector electricity sales to the other sectors and the emissions associated with the generation of that electricity.

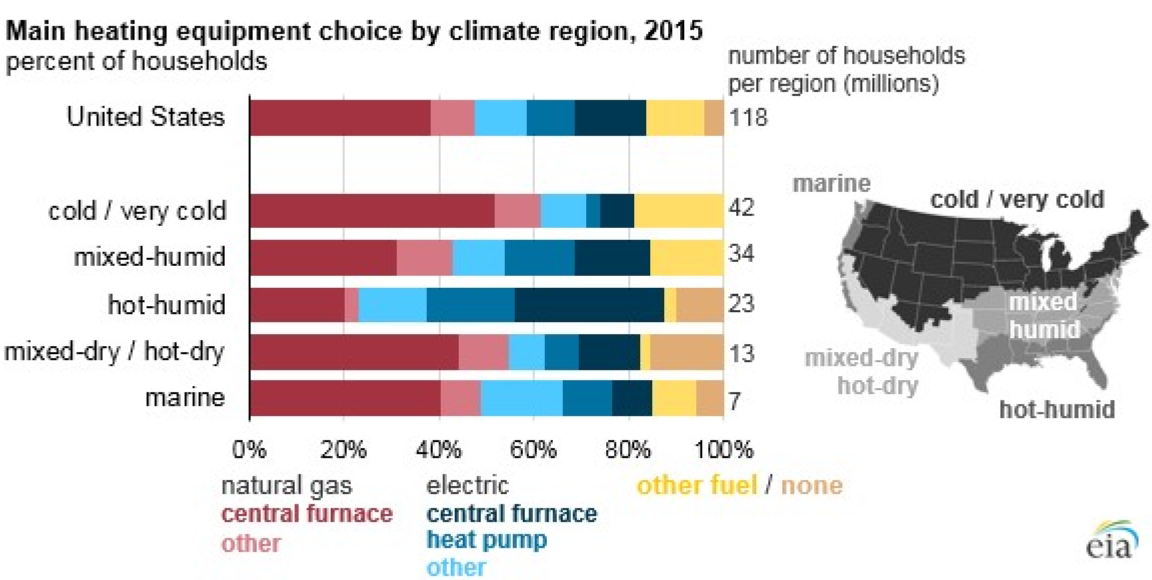

Figure A1: Primary heating equipment choice by climate region, 2015. Figure from EIA[187].

Figure 1 in the paper illustrated the large fraction of heat consumption in the Northern Tier states expressed as a percentage of heat and electricity demand in the residential and commercial sector in each state. Alternative figures are provided below. Figure A2 shows the electricity consumption (left figure) and low-temperature heat consumption (right figure) in 2018 as a percentage of the total energy consumption in each state. Electricity consumption includes the electricity used for heating and cooling. Heat consumption includes low-temperature (<150°C) thermal demand in the residential, commercial, manufacturing and agricultural sector. Cold climate states (northern tier and especially northeastern states) have relatively high thermal demand while southern and western states have relatively high electricity demand. The same trends are visible when plotting the ratio of electricity demand over thermal demand for each state (Figure A3). Two apparent anomalies are North Dakota and Wyoming, which have high electricity demand in the industrial sector.

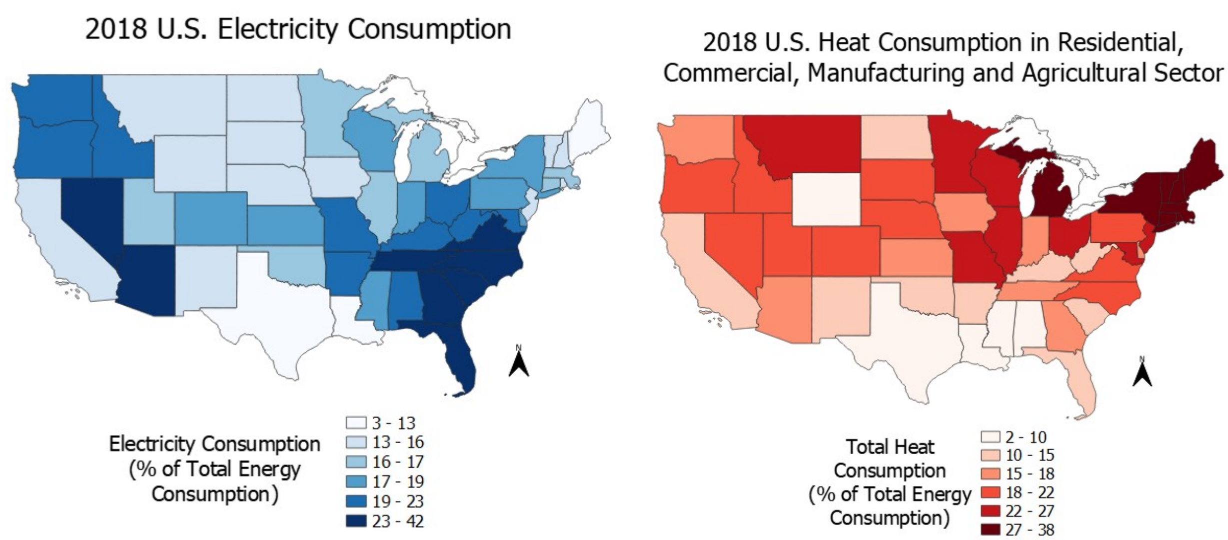

Figure A2: 2018 U.S. electricity (left) and heat demand (right) as percentage of total energy demand by state. Heat demand includes low-temperature (<150°C) heat demand in residential, commercial, manufacturing and agricultural sector. Data from EIA[1,7–9] and McCabe et al.[10] The electricity consumption includes the electricity used for heating and cooling.

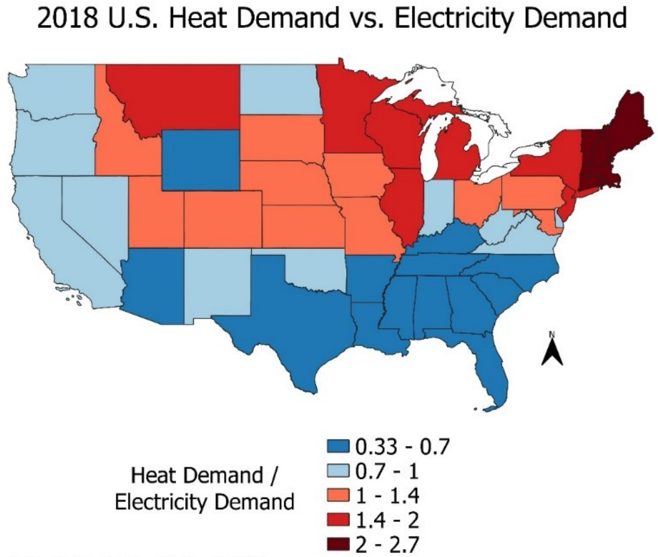

Figure A3:2018 U.S. heat demand vs. electricity demand by state. Heat demand includes low-temperature (<150°C) heat demand in residential, commercial, manufacturing and agricultural sector. Data from EIA[1,7–9] and McCabe et al.[10] The electricity consumption includes the electricity used for heating and cooling.

A2. U.S. Geothermal Resource Assessment

This section provides supporting information for the geothermal resource assessment presented in Section 5 of the paper. As discussed, the subsurface temperature is a key metric of the geothermal resource assessment. Bottom hole temperature temperatures (Figure 7) are combined with rock thermal conductivity estimates, rock heat generation figures, and the local surface temperature (Figure A4) to estimate the rock temperature at different depths. SMU has used this procedure to generate several temperature-at-depths maps. Examples are Figure 8 at 4.5 km, Figure A5 at 3.5 km and Figure A6 at 5.5 km.

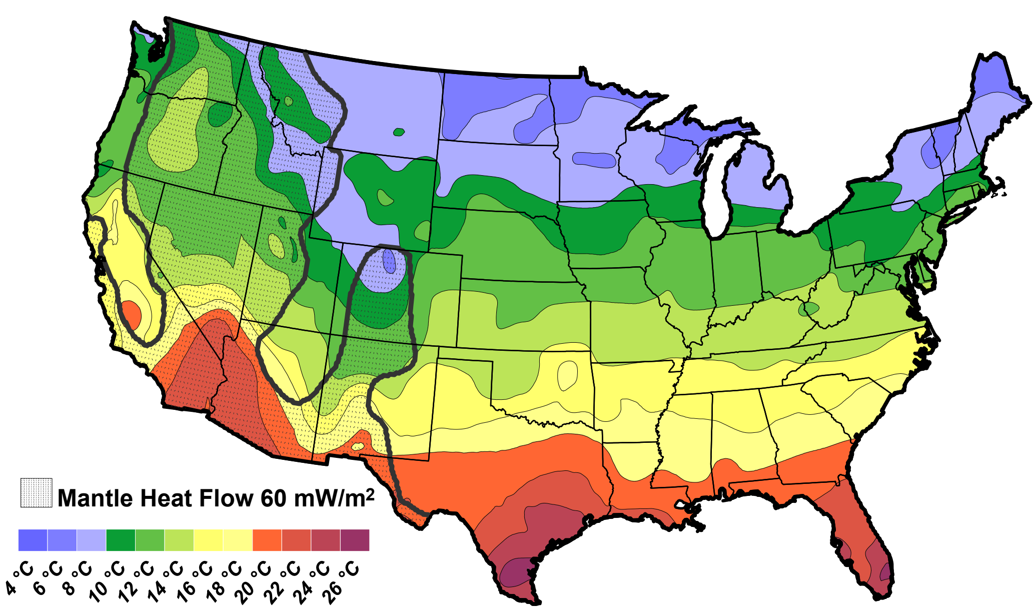

Figure A4: Map of surface temperature[188] and mantle heat flow for the conterminous U.S.

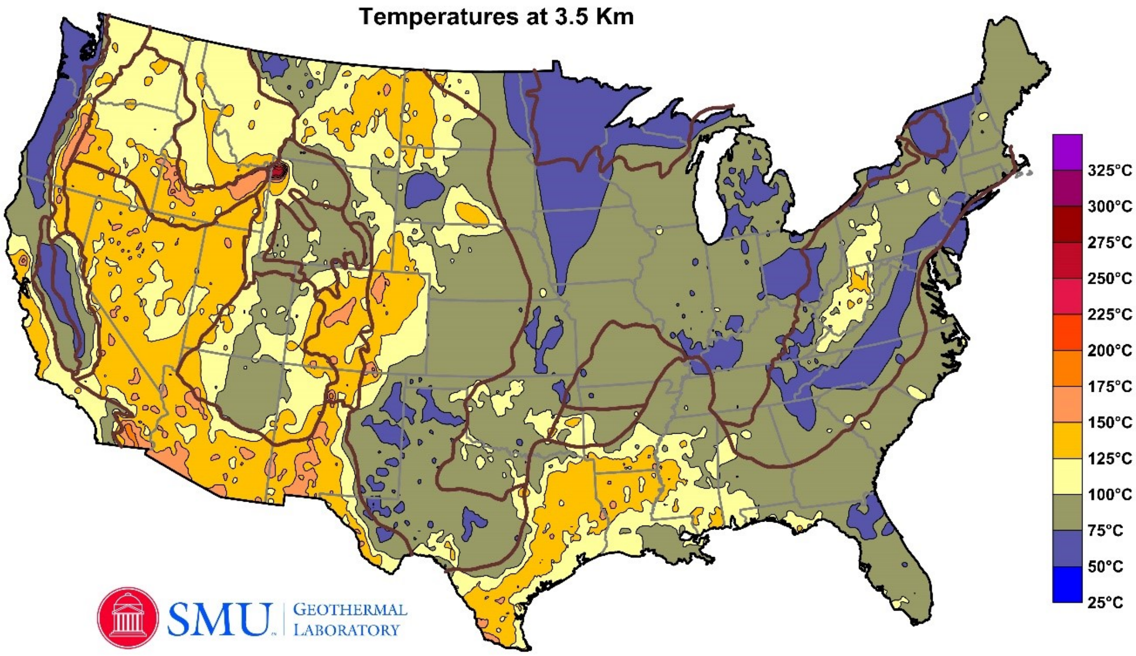

Figure A5: Subsurface temperature at 3.5 km depth estimated by SMU Geothermal Laboratory[20] based on well bottom hole temperatures and rock thermo-physical properties.

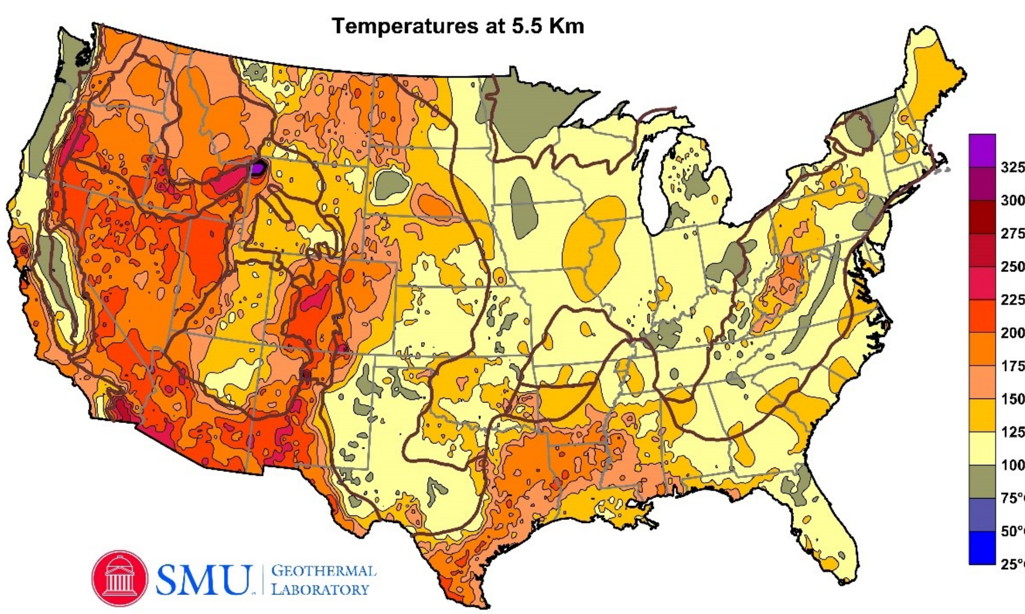

Figure A6: Subsurface temperature at 5.5 km depth estimated by SMU Geothermal Laboratory[20] based on well bottom hole temperatures and rock thermo-physical properties.

A summary of the non-hydrothermal geothermal resources assessment for the U.S. as presented in the Future of Geothermal Energy Report[31] is provided in Table A2. Resources considered include geopressured systems, co-produced fluid, sedimentary basin EGS, conduction-dominatedEGS basement rock and volcanic EGS. All protected and highly populated areas including national parks and large cities have been excluded from the resource base estimates.

Table A2: Summary of non-hydrothermal U.S. geothermal resource-base estimates in Future of Geothermal Energy Report.[31]

Source & Category		Thermal Energy, in 10^{18}J = EJ	SCF* of Methane x 10^{12}	Total Gas + Thermal Energy, in 10^{18}J = EJ
Geopressured (Papadopulos et al.[189])		46,000	23,700	71,000
Geopressured (Wallace et al.[190])		110,000	59,000	170,000
Co- produced Resources		0.0944 – 0.451 (depends on water temperature)		
Sedimentary Basin EGS (lower 48 states)		100,000		
Conduction-Dominated EGS basement rock (lower 48 states)		13,900,000		
Volcanic EGS	(Excl. Yellowstone, + AK)	65,000 (high)		
	Alaska only-26 systems	9,000 (low)		
	Hawaii -1 system	100		
Alaska – all EGS		3,295,000		
Hawaii		N/A		

* SCF = standard cubic feet of methane (ideal gas conditions) at 1 atm, 60˚F.

A3 - Alphabetical listing of references cited by first author last name

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