Hidden Treasure

Potential Benefits of Residential GSHP Retrofit

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for

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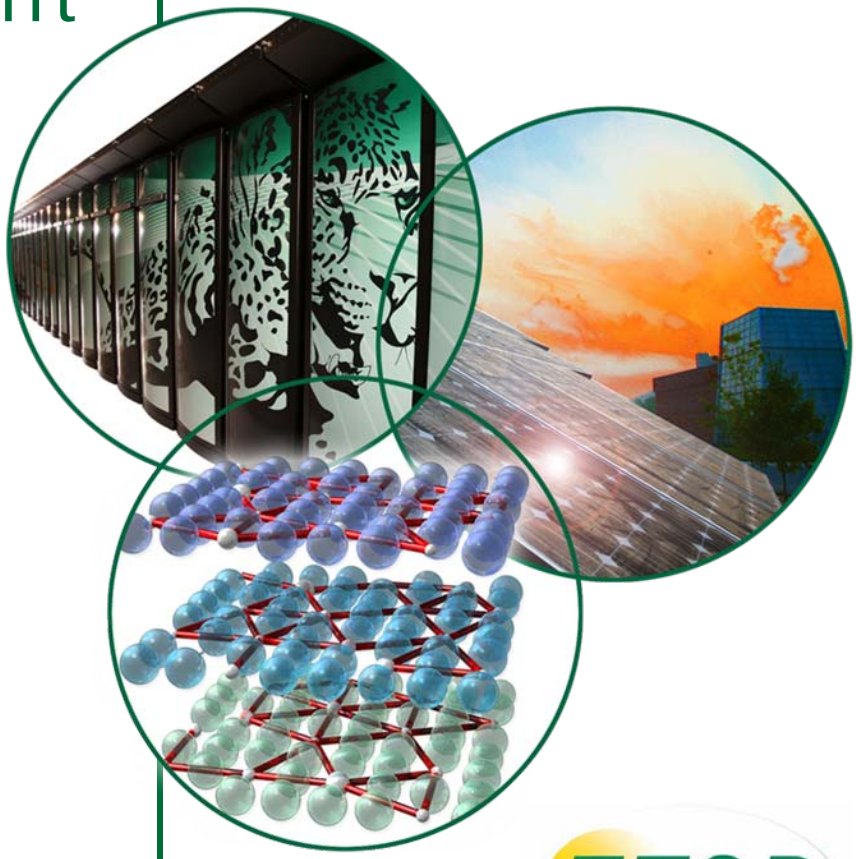

ETSD
Energy & Transportation Science Division

U.S. DEPARTMENT OF ENERGY

OAK RIDGE NATIONAL LABORATORY
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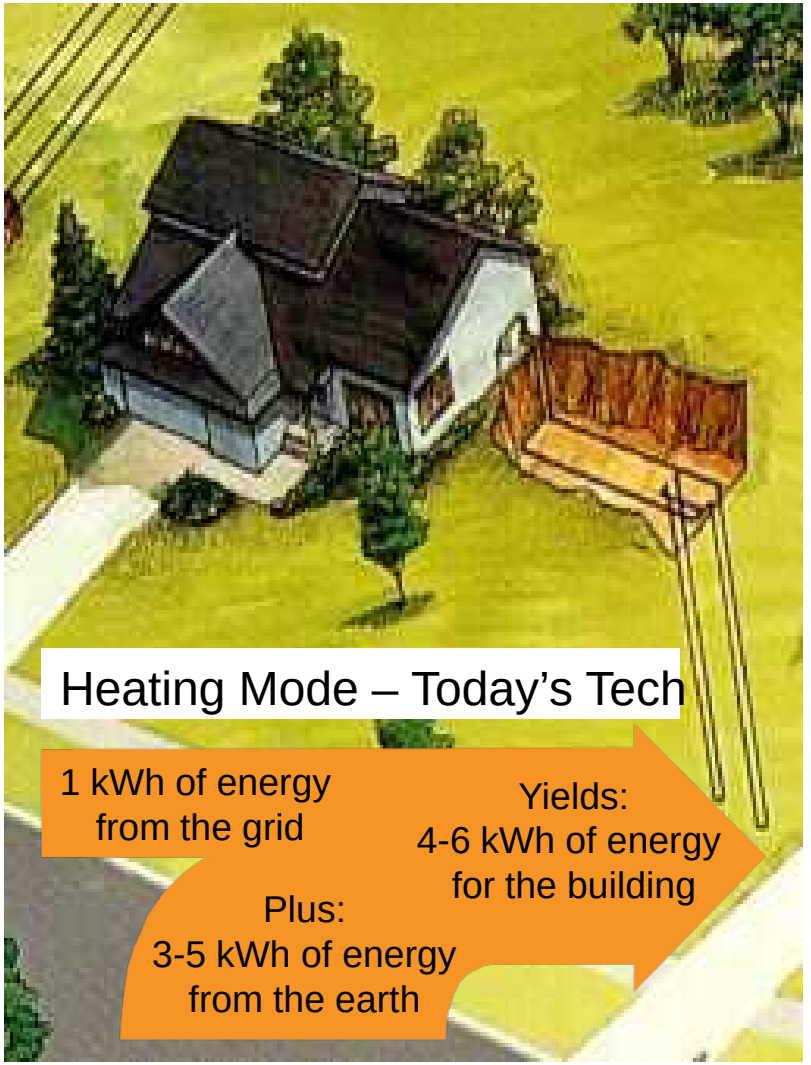
Agenda

- **Background**
- **Assessment methodology**
- **Results**
  - **National assessment**
  - **12 GW goal of CA: a different solution**
- **Actions to Realize the Potential**
- **Conclusions**

Characteristics of GSHP

- Use renewable low-grade energy in
  - Earth, ground water, river, etc.
- Move heat at high energy efficiency
  - With 4-6 COP today
- Reduce summer peak electrical demand and improve load factor
- Labor intensive installation (create jobs)
- Widely applicable
  - New
  - Retrofit
  - Commercial and residential



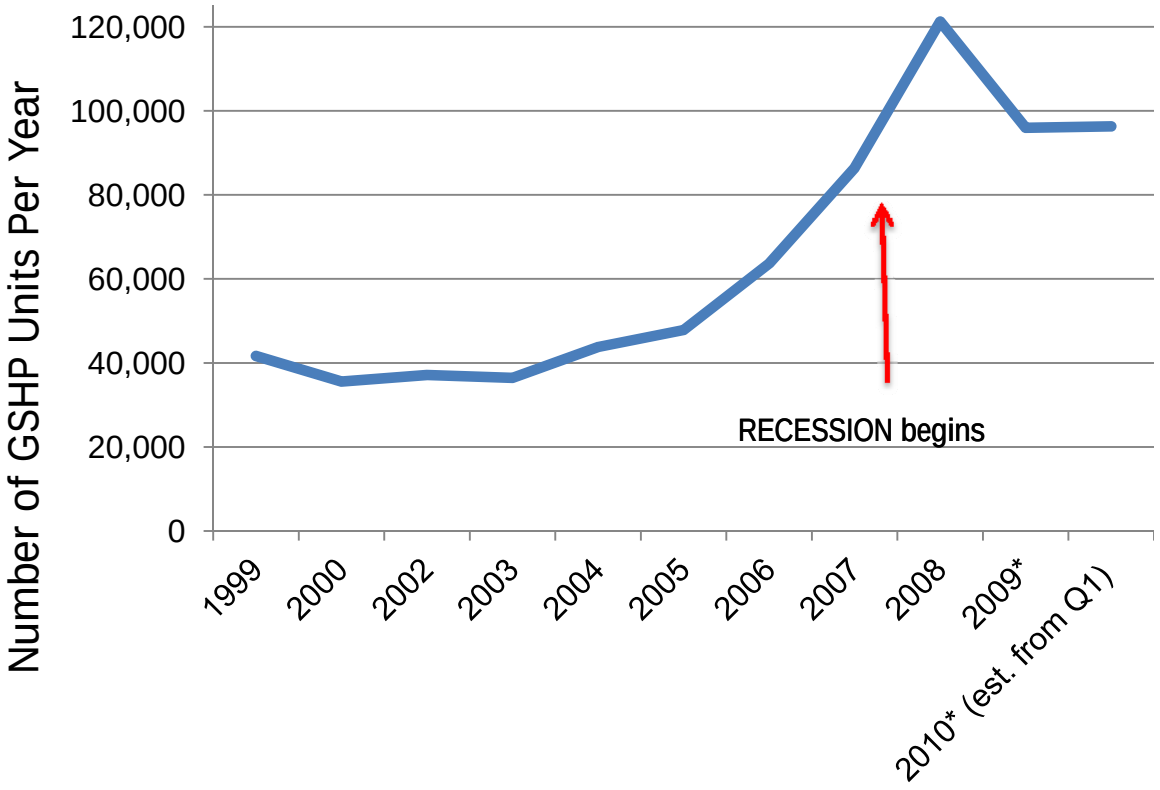
Largest Potential Market for GSHP:
Single-family Homes

86.1 million single-family homes (SFH) in U.S. (Census 2008)

- On average, 73% of the energy consumed in SFH is for space conditioning and WH (DOE 2009)
- Many of existing conventional space conditioning and WH equipments in SFH are approaching the end of their service life and thus need to be replaced
- Many SFHs have adequate space and accessibility for installing ground heat exchanger

Market Status of GSHP in U.S.

- Approximately 1 million GSHP units have been installed in the U.S.
- Less than 1% existing SFHs in the US are using GSHP
- Shipments of GSHP units grew rapidly before the recession and around 100,000 GSHP units were shipped in 2009



(Source: Tina Kaarsberg at DOE)

Rationale for Assessing National Benefits of Residential GSHP Retrofits

- Increase awareness of public, especially the policy makers, about the potential benefits of GSHP retrofit in residential buildings:
  - Savings in primary energy
  - Reduced carbon dioxide (CO_2) emissions
  - Reduced summer electrical peak demand
  - Savings in consumer energy expenditures
- Inform potential investors about the economics of residential GSHP retrofits
- Facilitate the development of roadmap for GSHP industry

Assessment Methodology

- Based on energy consumption data of existing residential space-heating, space-cooling, and water-heating (SH–SC–WH) systems obtained from Residential Energy Consumption Survey (EIA 2005)
- Determine relative differences in energy consumption between existing residential SH–SC–WH systems and a state-of-the-art GSHP system
- Account for various climate and geological conditions, energy prices, as well as source energy factors and emissions factors for electricity and fossil fuels

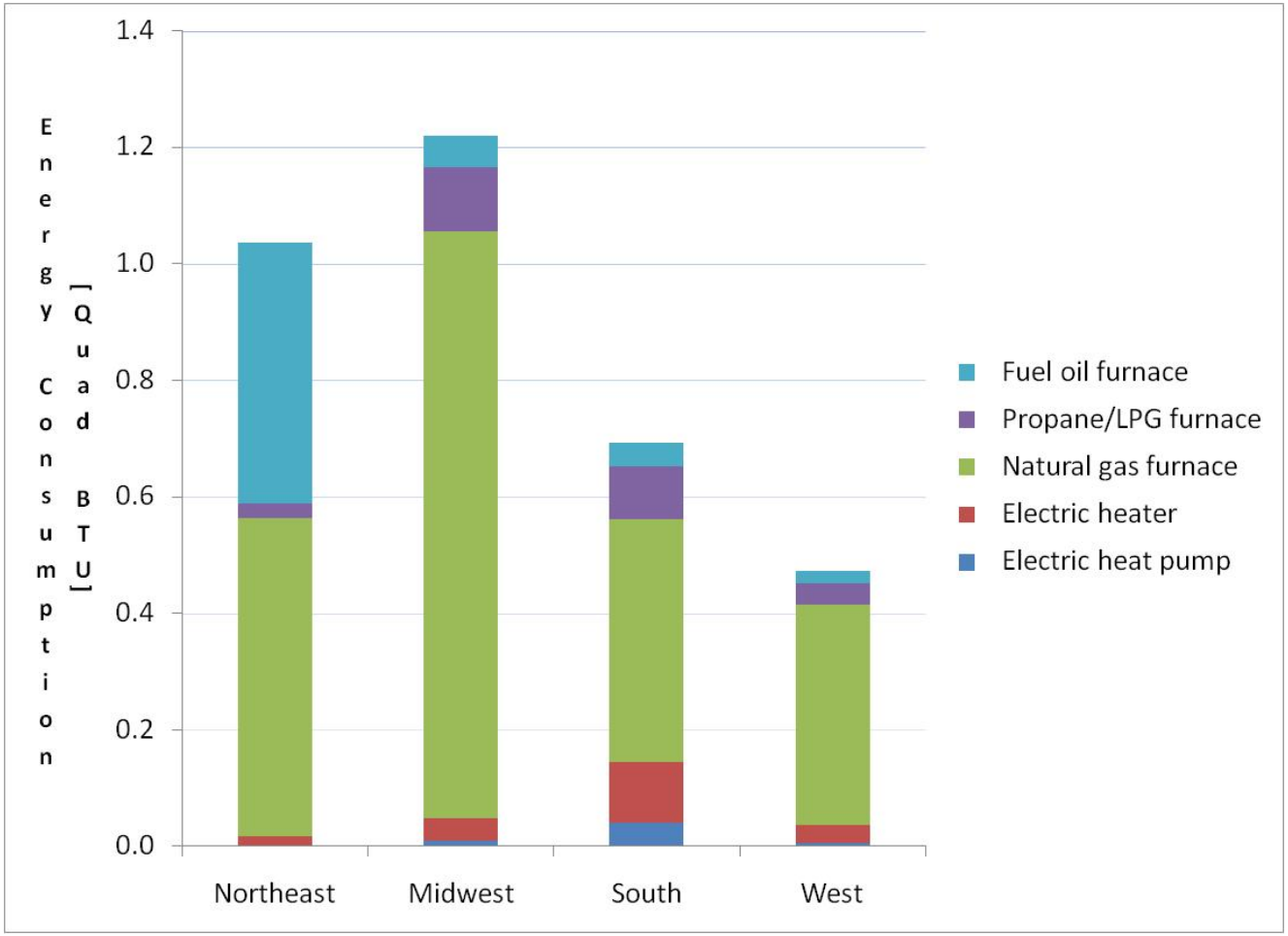
$$\text{Energy saving potential} = \sum_{\text{All existing SH-SC-WH systems}} \text{Total energy consumption of a particular existing SH-SC-WH system} \times \text{Percentage of energy saved by GSHP system}$$

Types and Efficiencies of Existing SH-SC-WH Systems in U.S. SFHs

Energy services	Existing systems and equipment	Rated efficiencies
Space heating	ASHP	3.2 COP
	Electric heater	100 EF
	Natural gas–fired furnace/boiler	80 AFUE
	Propane- or LPG-fired furnace/boiler	80 AFUE
	Heating oil–fired furnace/boiler	80 AFUE
Space cooling	CAC/ASHP	10 SEER
	RAC	7.7 SEER
	Combination of CAC and RAC	7.7–10 SEER
Water heating	Electric heater	88 EF
	Natural gas heater	58 EF
	Propane or LPG heater	58 EF
	Heating oil heater	58 EF

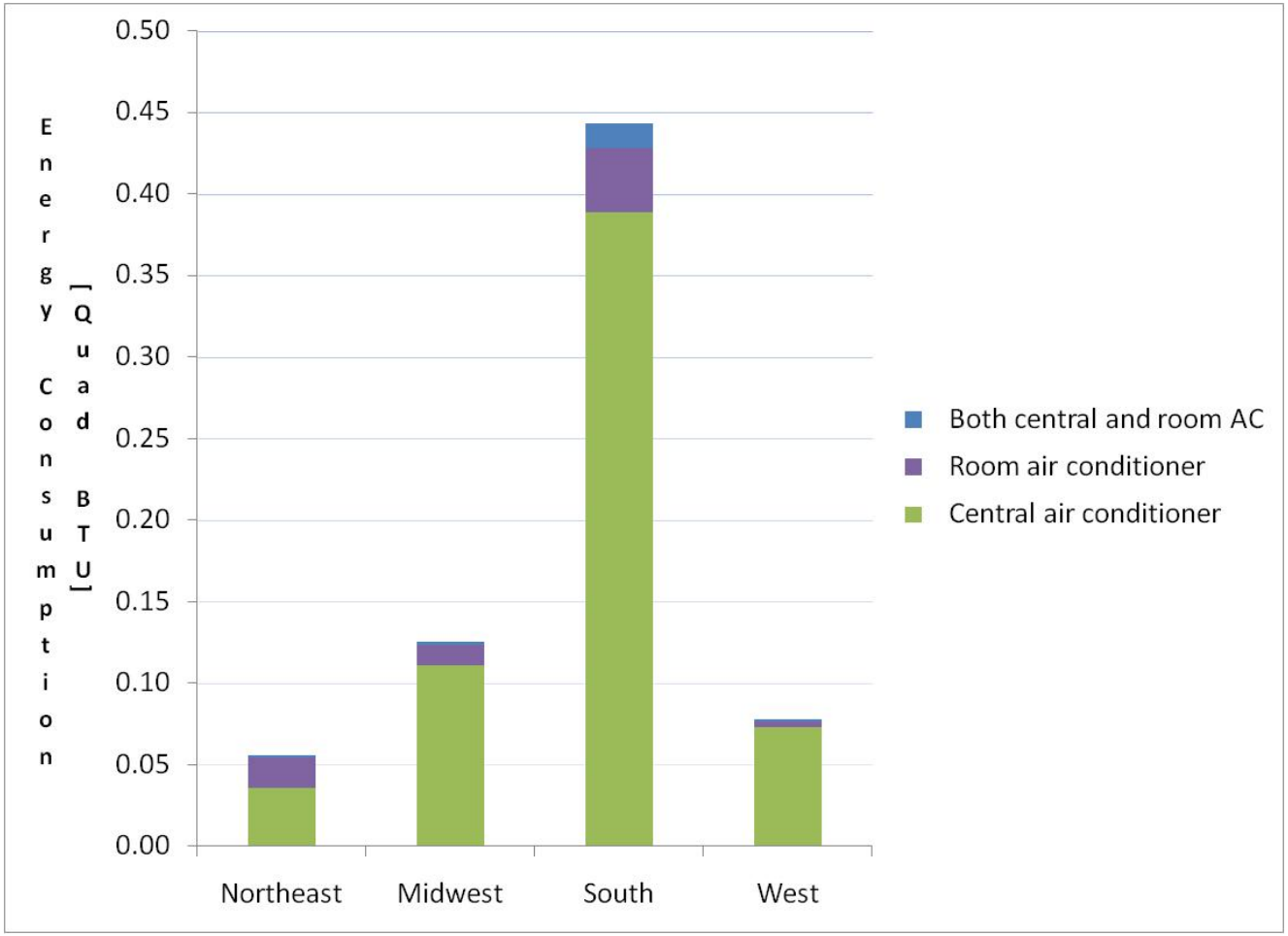
(EIA 2000; DOE 2005)

Energy Consumption of Existing Space Heating Systems by Census Region



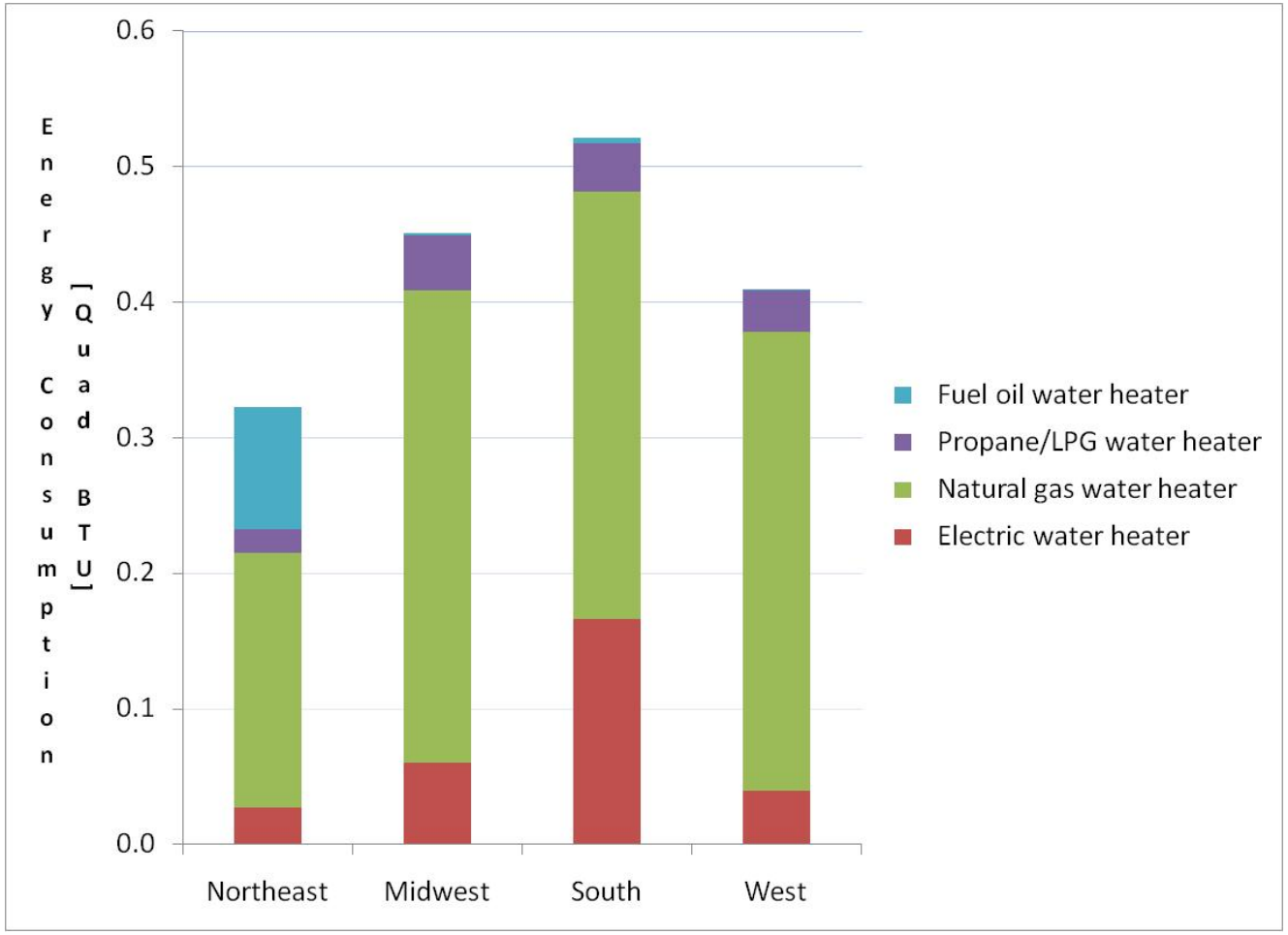
Obtained from 2005 RECS Public Use Microdata Files

Energy Consumption of Existing Space Cooling Systems by Census Region



Obtained from 2005 RECS Public Use Microdata Files

Energy Consumption of Existing Water Heating Systems by Census Region

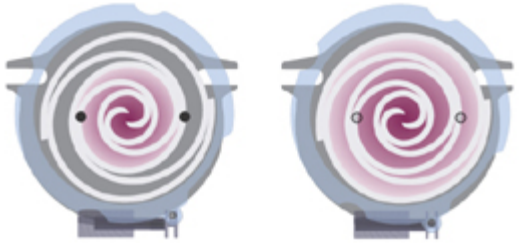


Obtained from 2005 RECS Public Use Microdata Files

State-of-the-Art GSHP System

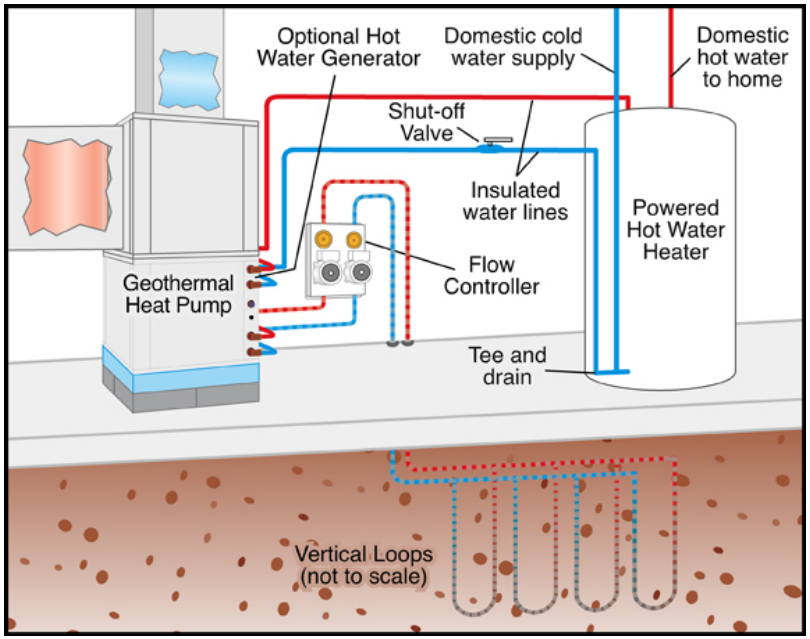
- Packaged water-to-air GSHP unit with two-stage scroll compressor and ECM fan
  - Cooling: 18.2 EER (full load) & 27 EER (part load)
  - Heating: 4.0 COP (full load) & 4.5 COP (part load)
- Vertical closed-loop ground heat exchanger (maintaining 30°F–95°F EFT to GSHP unit)
- Storage-type electric water heater assisted with the desuperheater of GSHP unit
- Highly energy-efficient circulation pump

Two-stage scroll compressor

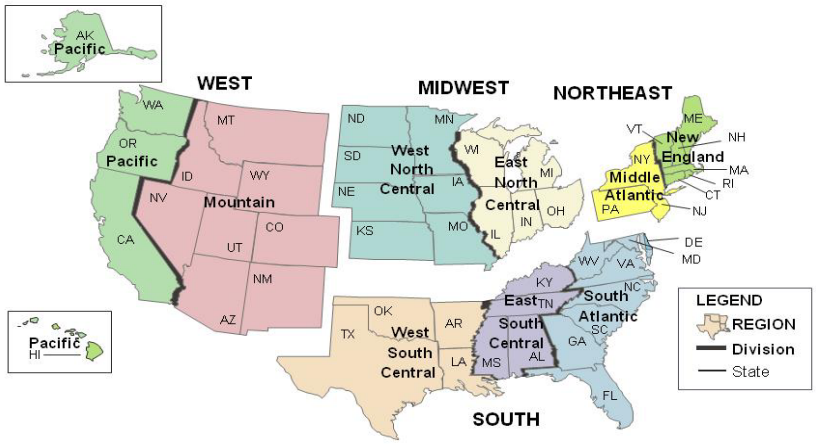


67% Capacity @ part load

100% Capacity @ full load

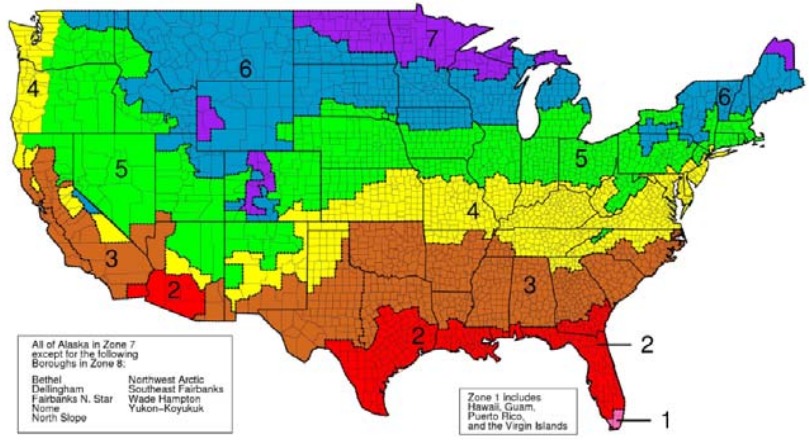


Various Climate and Geology Conditions

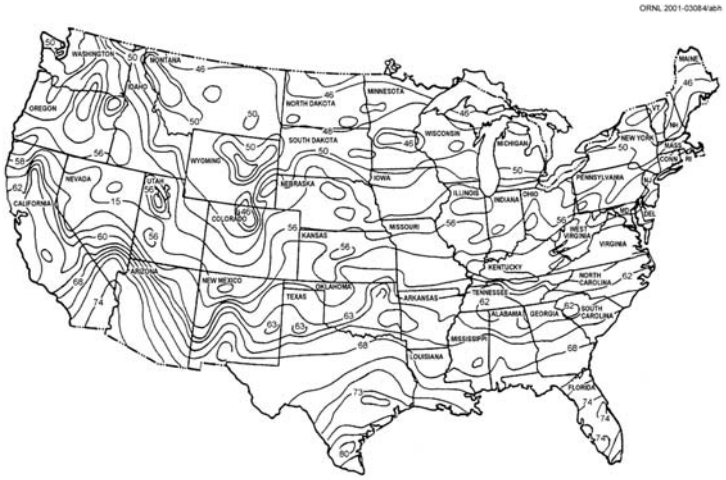


U.S. census regions and divisions

- Select 14 cities to represent various major climate zones within each census region
- Use weather data and undisturbed ground temperature of each representative city
- Assume typical ground thermal conductivity for all cities



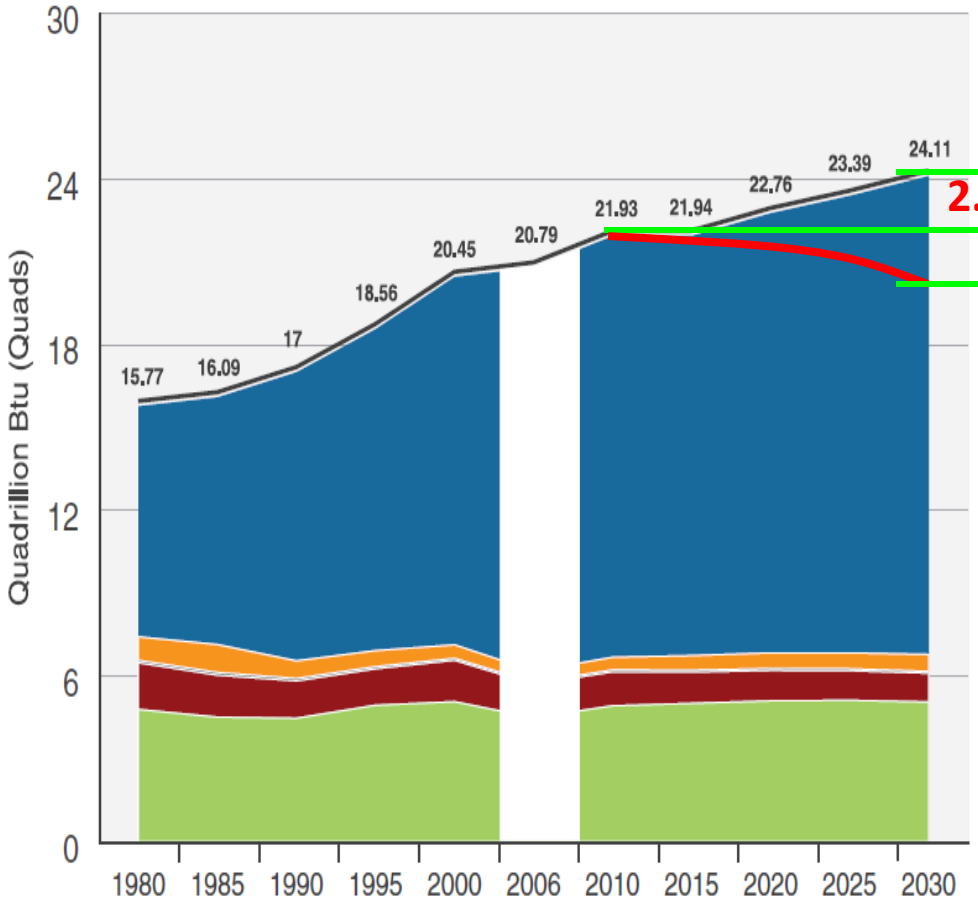
2004 IECC climate zones of the U.S.



Ground or groundwater temperatures in the U.S.

Potential Energy Savings from Ground Source Heat Pump (GSHP) Systems

U.S. Residential primary energy consumption by year and fuel type (DOE 2009)



Predicted increase of primary energy consumption if "business as usual"

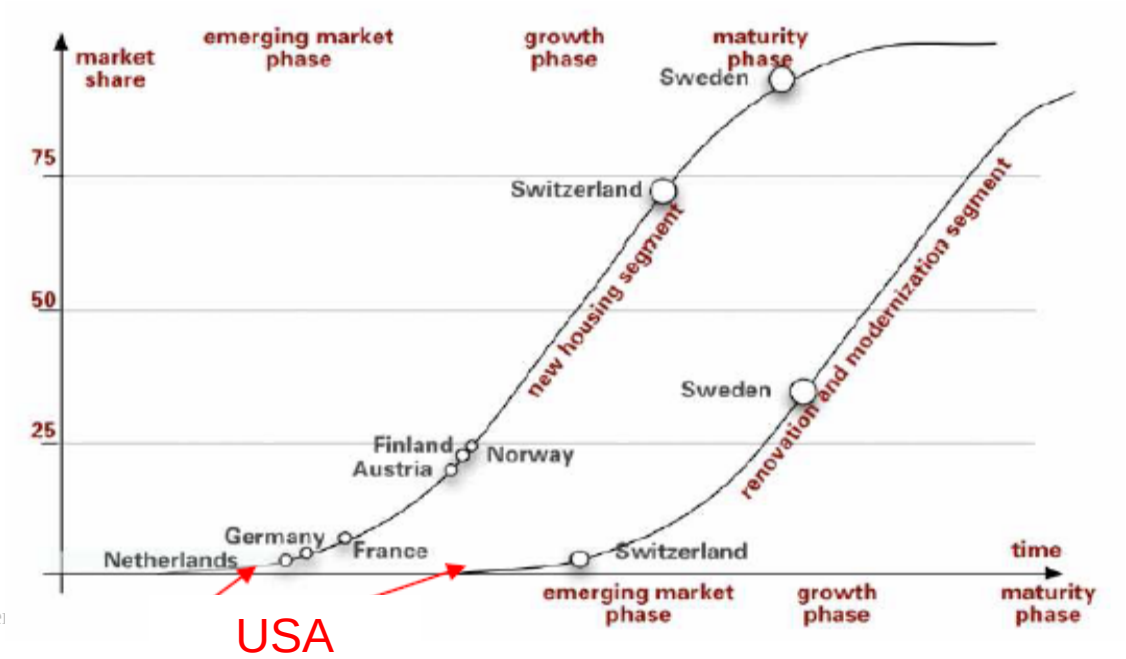
2.2 quad Btu

4.2 quad Btu

Maximum technical potential of the primary energy savings achievable from retrofitting existing homes with state-of-the-art GSHP systems

Annual National Benefits:
at Various Market Penetration Rates

Estimated national benefits	Market penetration rate of GHP retrofit				
	20%	40%	60%	80%	100%
Primary energy savings [quad BTU]	**0.8**	1.7	2.5	3.3	4.2
Percentage savings	**9.0%**	18.0%	27.1%	36.1%	45.1%
CO2 emissions reduction [MM ton]	**54.3**	108.7	163.0	217.3	271.7
Percentage savings	**9.1%**	18.1%	27.2%	36.2%	45.3%
Summer peak electrical demand reduction [GW]	**43.2**	86.4	129.5	172.7	215.9
Percentage savings	**11.2%**	22.4%	33.6%	44.9%	56.1%
Energy expenditures savings [Billion $]	**10.4**	20.9	31.3	41.7	52.2
Percentage savings	**9.6%**	19.3%	28.9%	38.5%	48.1%



12 GW: A Different Solution

How many GSHP-retrofitted homes can avoid the same amount of primary energy consumption as generating 12 GW electricity with solar power?

Assumptions

- A solar energy system output in a day is equivalent to full-load hours: 5 hr/day
- Shading correction factor: 0.8
- Total delivered efficiency: 0.78
- Conversion factor for electricity to source energy: 3.365
- Primary energy savings from GSHP retrofit: 530 Therms per average home per year
- Total number of households in CA: 13 million

Conclusion

- 2.9 million homes (23% market penetration)

Evaluation, Measurement & Verification Report for the Residential Ground Source Heat Pump Program

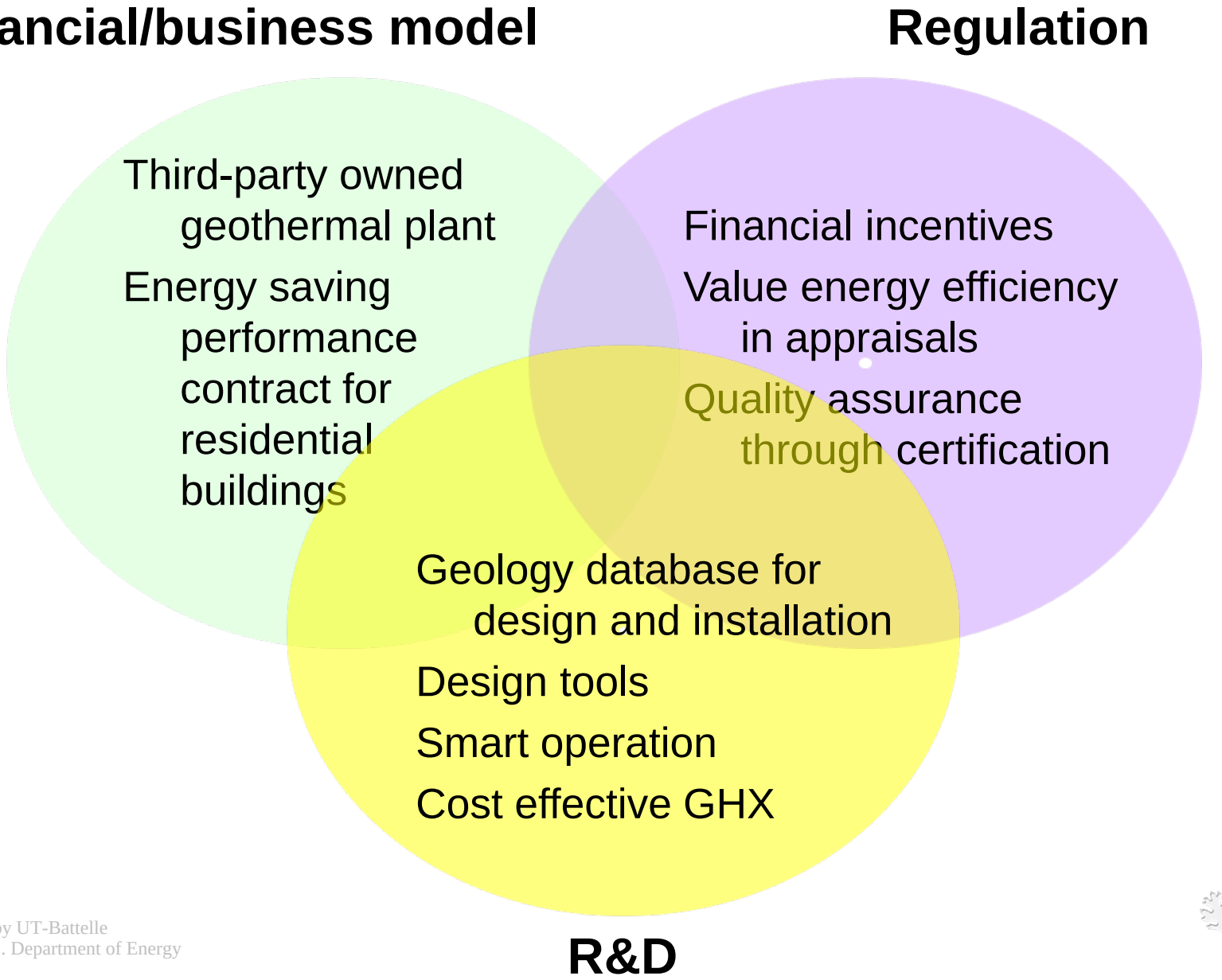
Prepared by Robert Mowris & Associates for Redding Electric

Findings from this study indicate the GSHP units provide advantages for all participants.

- For the utility, the GSHP **reduces peak demand in summer** by an average of 2.1 kW per unit and shifts summer cooling loads to winter increasing annual electricity use by 1,355 kWh per year (roughly 10 percent).
- For the customer, the GSHP **reduces annual energy bills** for space conditioning by **48 percent** saving $639 ± $185 per year.
- For society, the GSHP mitigates global warming by **reducing carbon dioxide emissions for space conditioning by 44 percent**, saving 59 million British thermal units (MMBtu) per year of source energy per GSHP.

Note: Content added by CaliforniaGeo

Actions to Realize the Potential



Conclusions

- **Large scale retrofit of SFHs in U.S. with state-of-the-art GSHP system has tremendous potential in reducing primary energy consumption, CO_2 emissions, and summer peak electrical demand**

Treasures here!

- **Reducing initial cost burden to consumers will make GSHP more competitive**
- **Lots of work needs to be done to fully recognize the value and realize the potential benefits of GSHP**

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