NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Using Geothermal Heat Pumps in Wisconsin

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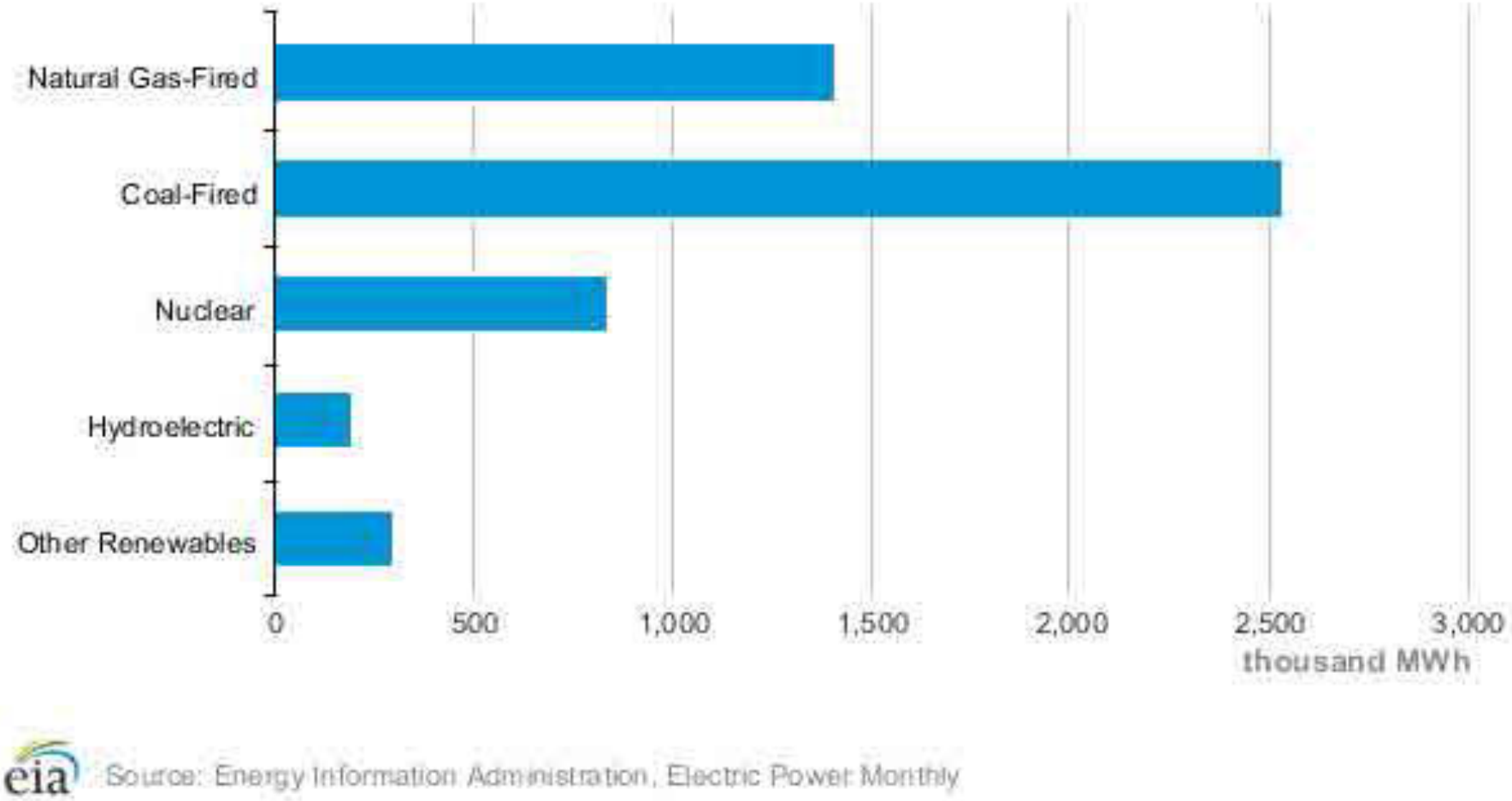
Wisconsin Net Electricity Generation, Feb 2016



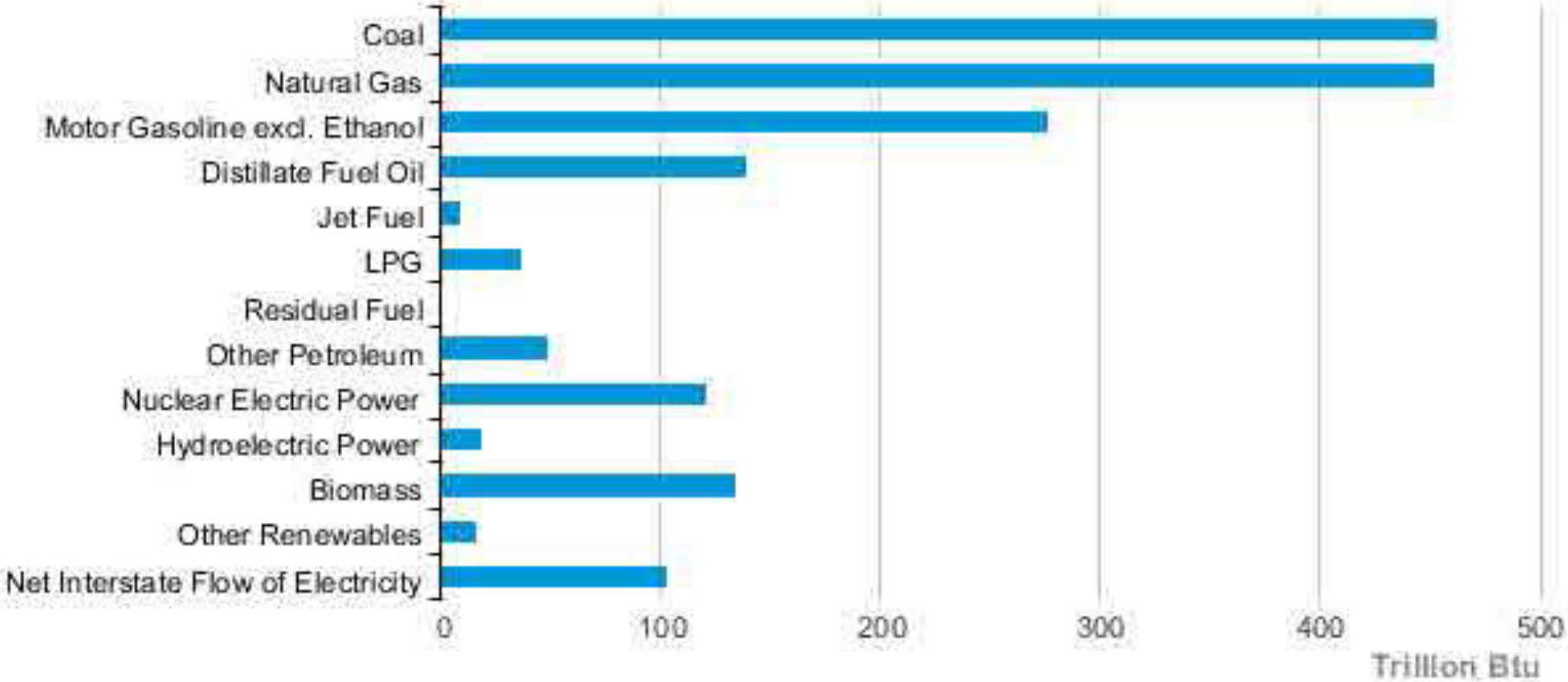
Source: http://www.eia.gov/state/?sid=WI#tabs-4

Wisconsin Net Electricity Generation, Feb 2016

- Biomass Power Plant
- Coal Power Plant
- Geothermal Power Plant
- Hydroelectric Power Plant
- Natural Gas Power Plant
- Nuclear Power Plant
- Other Power Plant
- Petroleum Power Plant
- Pumped Storage Power Plant
- Solar Power Plant
- Wind Power Plant

Source: http://www.eia.gov/state/?sid=WI#tabs-4

Wisconsin Energy Consumption Estimates, 2013

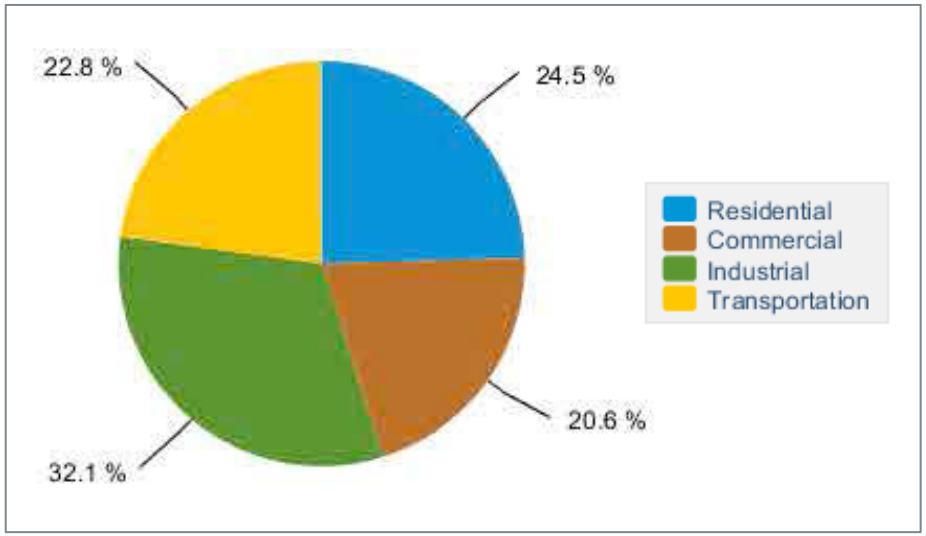


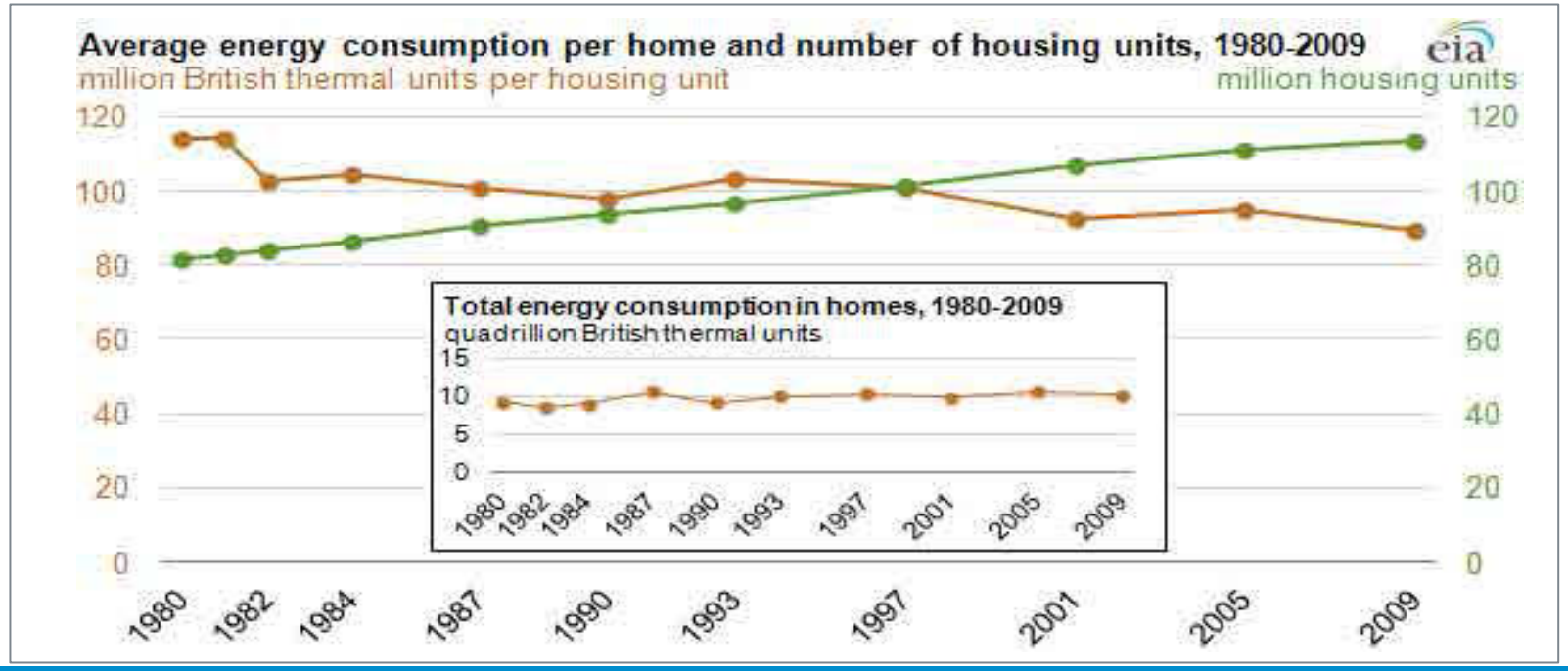
Source: Energy Information Administration, State Energy Data System

Wisconsin Energy Consumption Estimates, 2013

	Consumption	Expenditures
Total	1,804 trillion Btu	$24,716 million
Per Capita	314 million Btu	$4,304

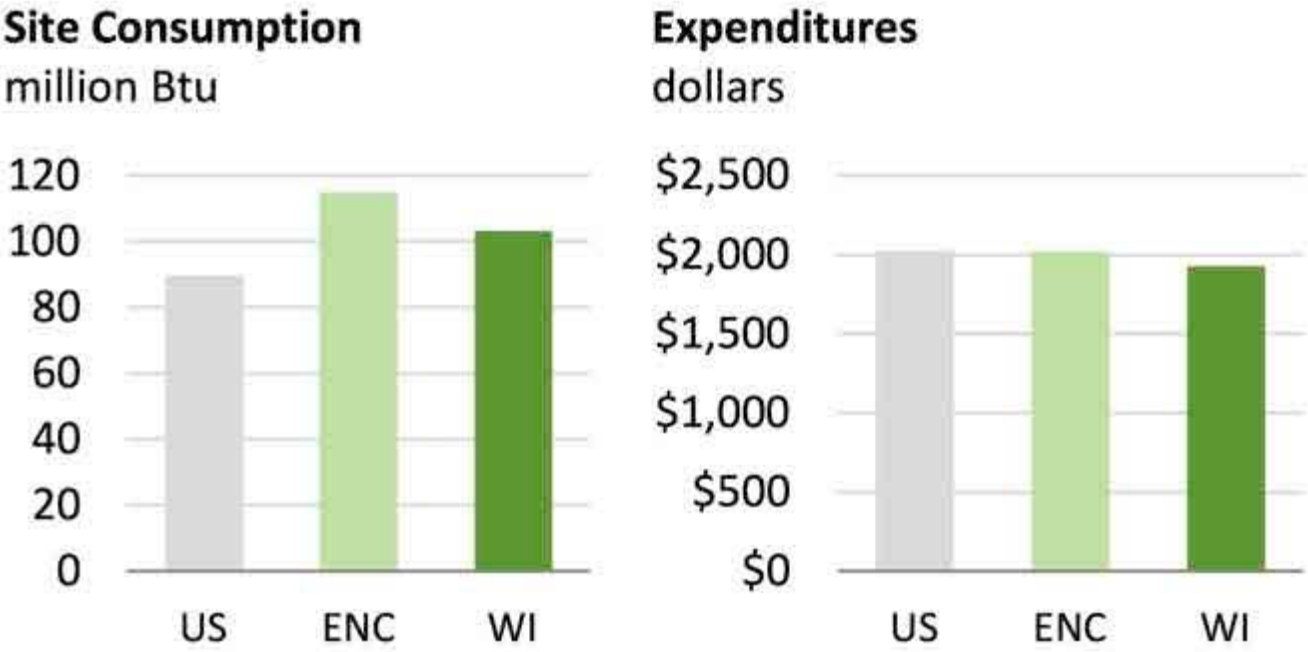
Source: http://www.eia.gov/state/?sid=WI#tabs-2





Wisconsin Energy Consumption

ALL ENERGY *average per household (excl. transportation)*



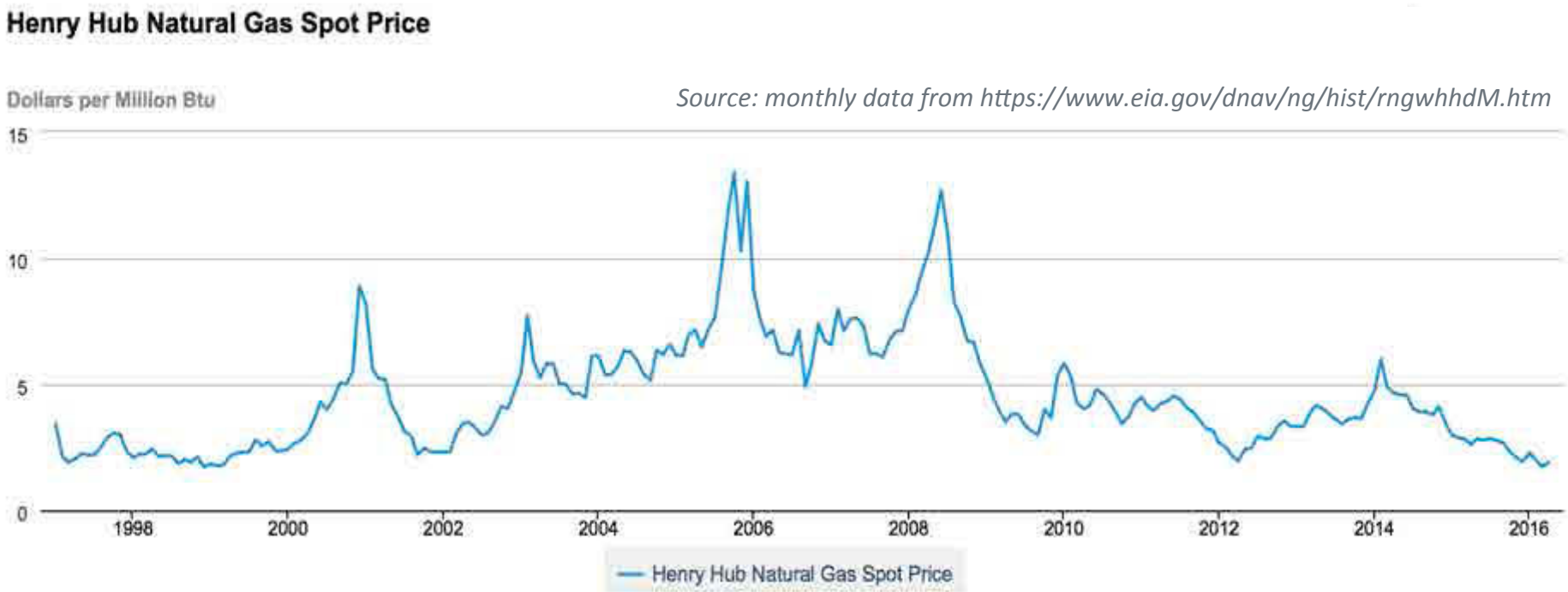
DIVISION: East North Central (ENC)

STATES INCLUDED: Illinois, Indiana, Michigan, Ohio, Wisconsin

- Wisconsin households use 103 million Btu of energy per home, **15% more than the U.S. average**.
- **Lower electricity and natural gas rates** compared to states with a similar climate, such as New York, result in households **spending 5% less for energy** than the U.S. average.
- **Less reliance on electricity** for heating, as well as cool summers, keeps average site electricity consumption in the state low relative to other parts of the U.S.
- Wisconsin **homes** are typically **larger and older** than homes in other states.

http://www.eia.gov/consumption/residential/reports/2009/state_briefs/pdf/WI.pdf

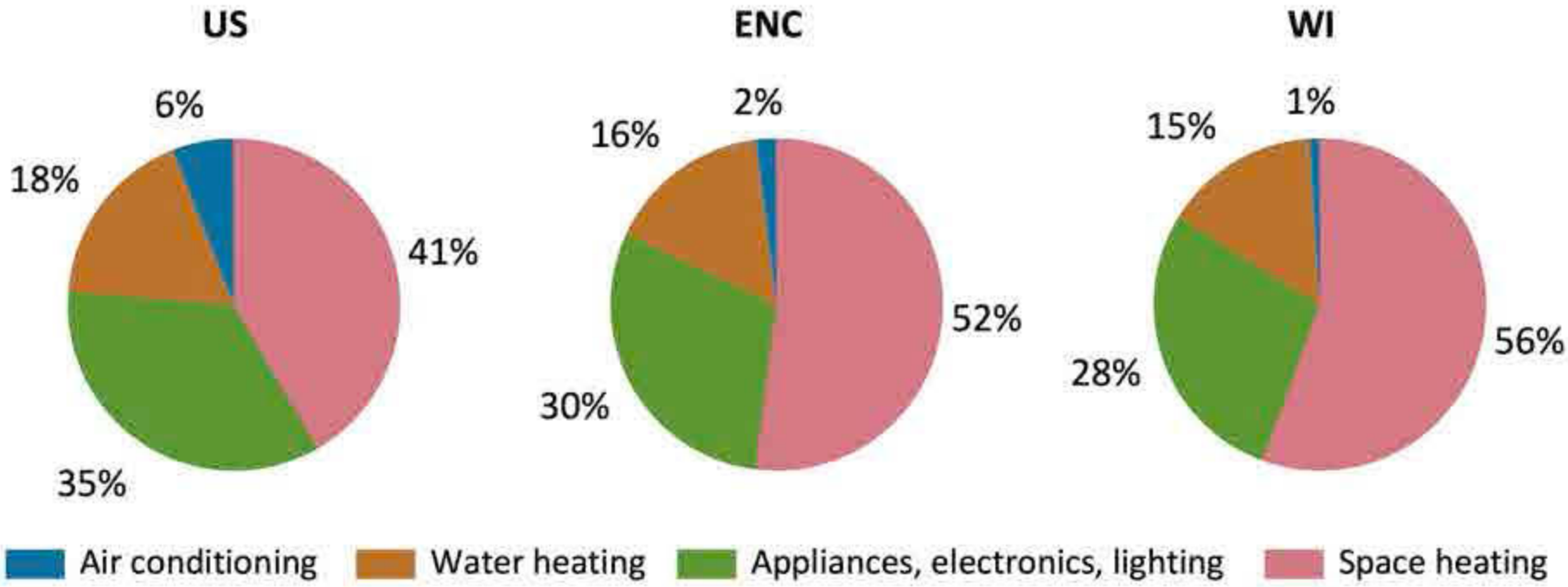
Volatility of Natural Gas Prices



Source: monthly data from https://www.eia.gov/dnav/ng/hist/rngwhhdM.htm

- Natural gas prices fluctuate over time
- Now at a 20-year low
- Payback calculations in this presentation reflect 2013 gas prices data from the U.S. Energy Information Administration (EIA). As gas prices rise, payback times will be even shorter as more money is saved in utility bills each year.

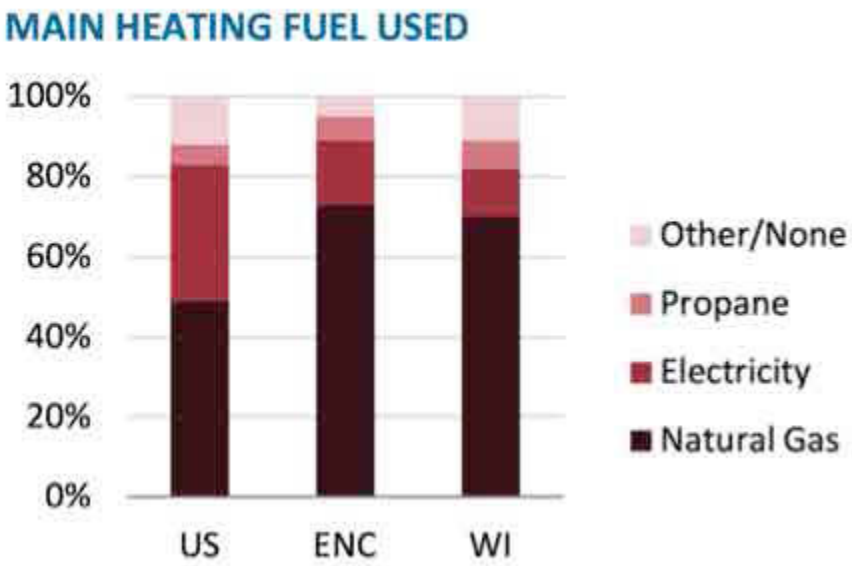
Energy Consumption by End Use

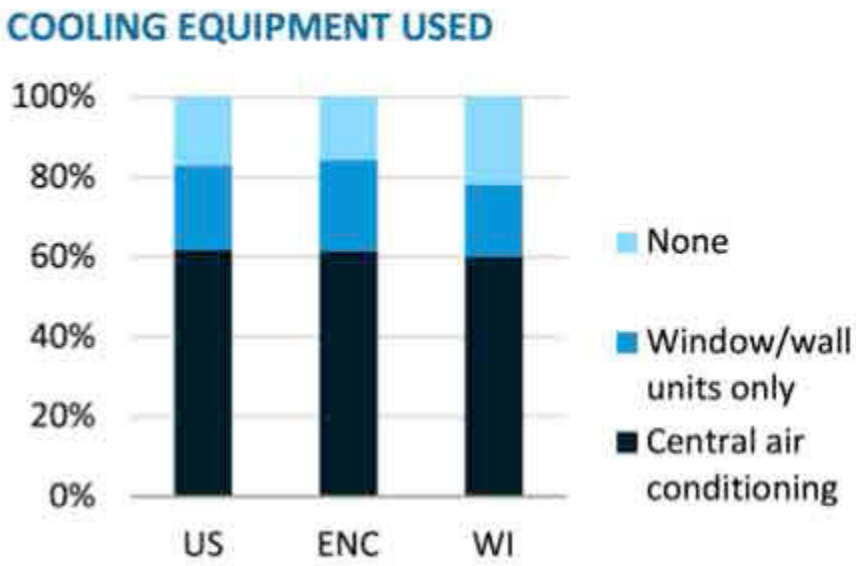


Since the weather in Wisconsin and the Midwest is cooler than other areas of the United States, space heating (56%) makes up a greater portion of energy use in homes compared to the U.S. average and air conditioning makes up only 1% of energy use.

http://www.eia.gov/consumption/residential/reports/2009/state_briefs/pdf/WI.pdf

Wisconsin Heat & Cooling





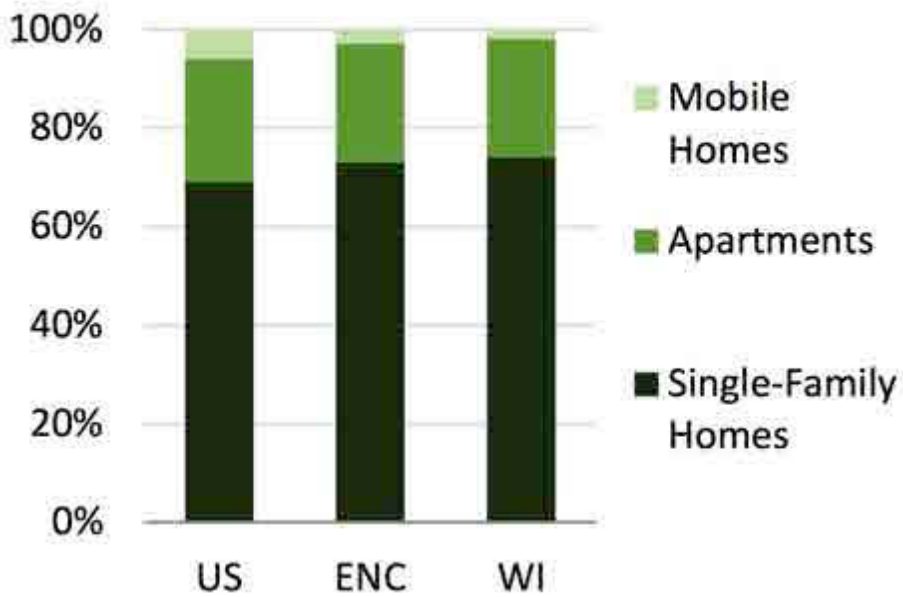
Compared to the U.S. average, **a greater proportion** of Wisconsin residents **use natural gas for heating (70%)** and a much smaller proportion of residents use electricity (12%).

More than **20%** of Wisconsin households **do not use air conditioning**, and those that do still predominantly rely on central air conditioning for cooling.

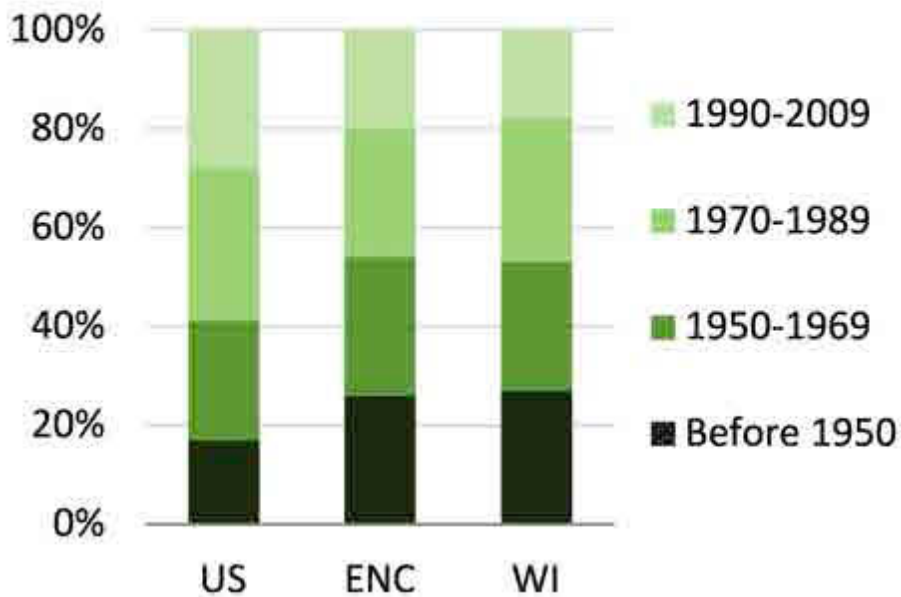
http://www.eia.gov/consumption/residential/reports/2009/state_briefs/pdf/WI.pdf

Wisconsin Housing

HOUSING TYPES



YEAR OF CONSTRUCTION



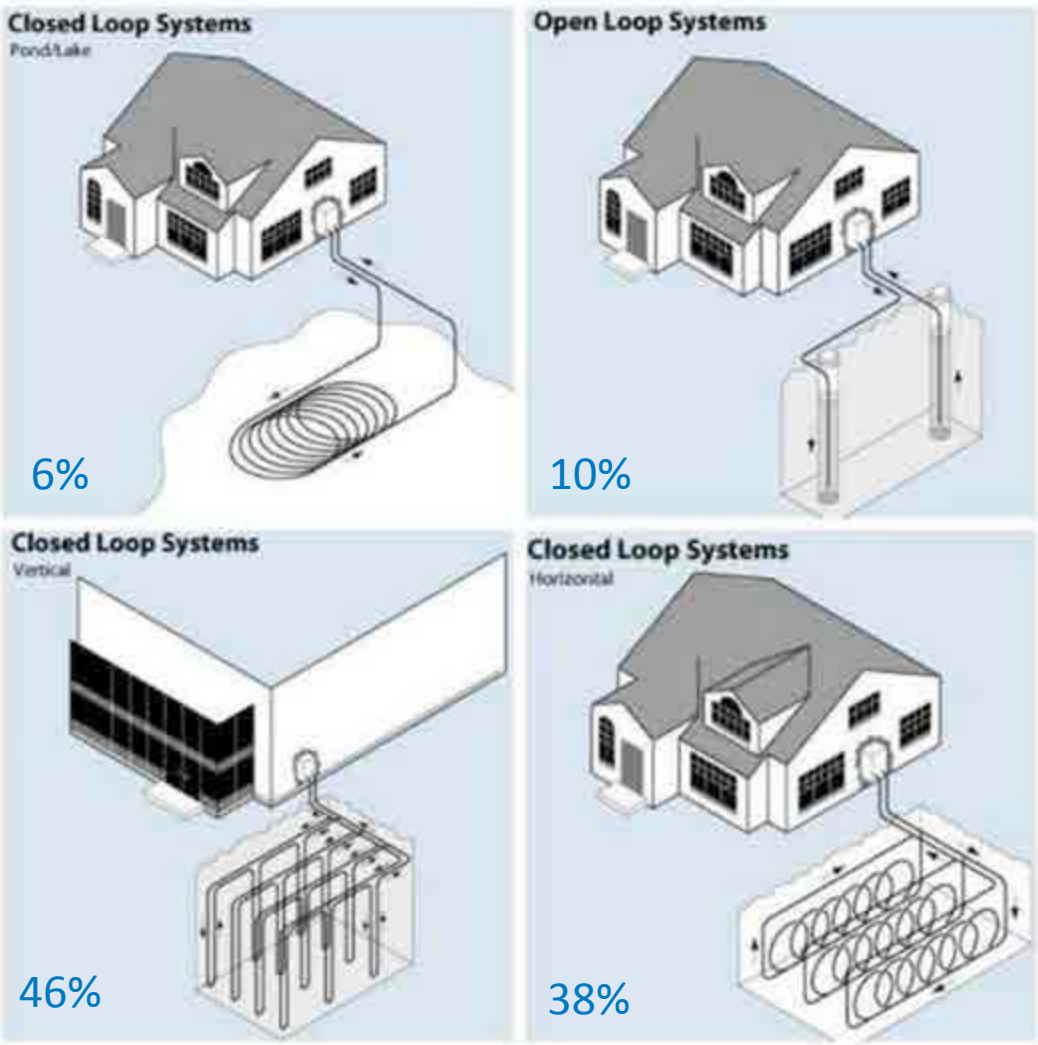
AVERAGE SQUARE FOOTAGE

US	1,971
ENC	2,251
WI	2,605

http://www.eia.gov/consumption/residential/reports/2009/state_briefs/pdf/WI.pdf

What is a Geothermal Heat Pump?

- Uses ground, groundwater, or surface water as heat source and sink
- Used for space heating and cooling, water heating, and snow melt beneath sidewalks and driveways
- No Need for Auxiliary Heating
- No outdoor (above ground) equipment
- Approximately 1.2 million GHP units installed in U.S. by 2015
- Today domestic markets absorb ~100,000 units/yr
  - 70-80% residential (new vs. retrofit: 3 to 1)
  - 20-30% commercial

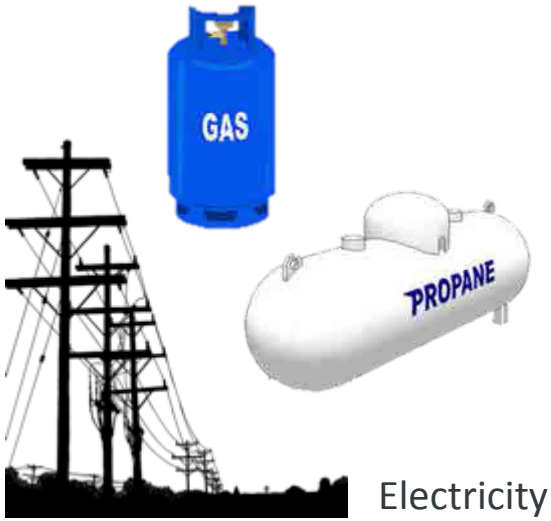


Geothermal heat pumps are sometimes called ground source heat pumps or geo-exchange systems

Data from Oak Ridge National Lab

Use 30%–65% less primary energy than conventional HVAC systems

Energy Source



If building uses gas or propane, transmission is also required.

Conversion

Conversion Efficiency:

- Old, low-end systems: 56-70%
- Mid-range systems: 80-83%
- High-end systems: 90%

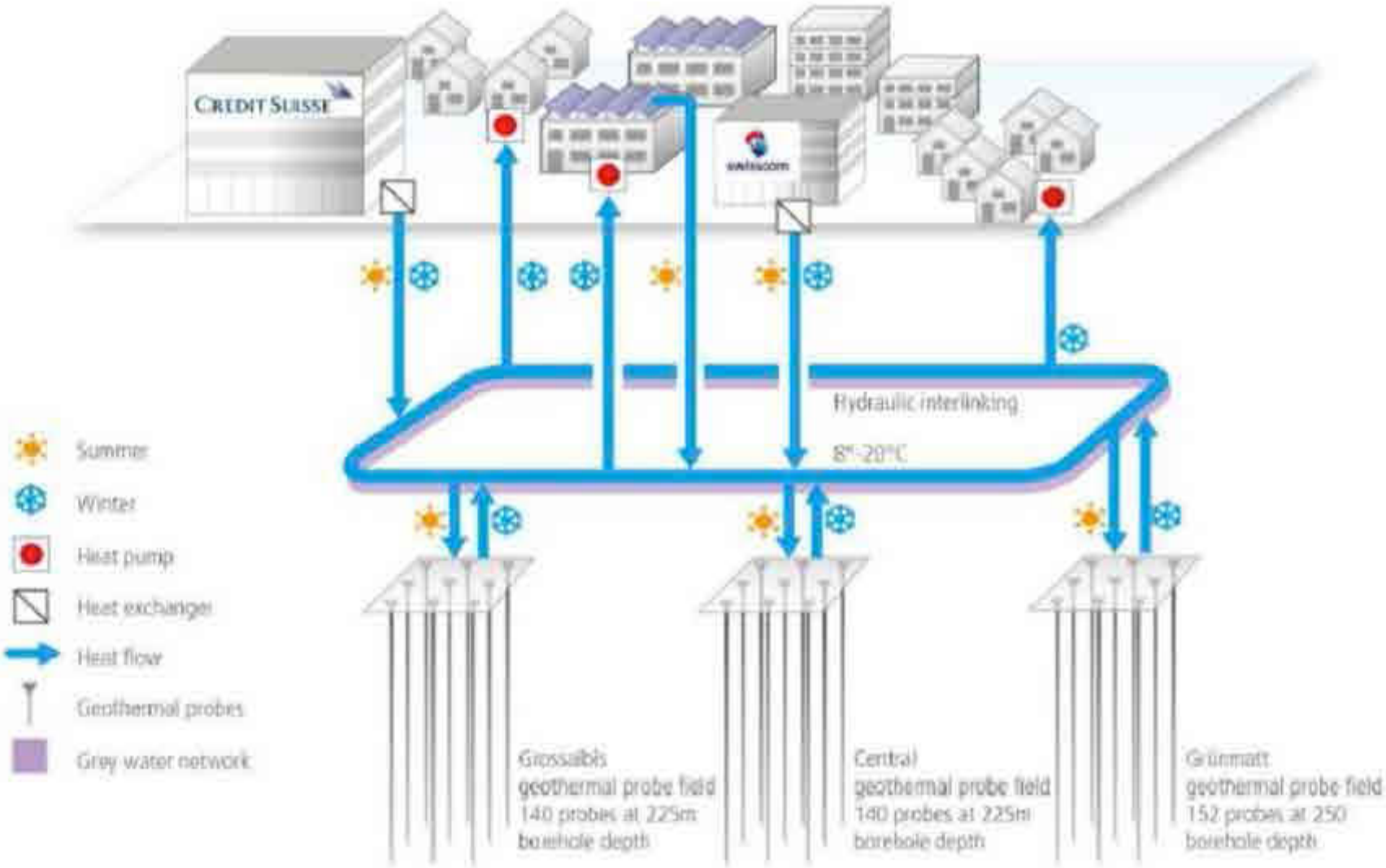
Circulation

GHP systems use traditional HVAC distribution systems, so no reworking is needed.

GHP Systems require subsurface or pond system for accessing or disposing of heat energy.

GHP Systems move heat from the earth to building in winter; from building to earth in summer.

Central, Distributed and District Geothermal Systems



Lotte Engineering and Constrcution:
http://www.lottecon.co.kr/eng/rnd green_technologys_new_renewable_energys

Large Campuses

Ball State University (Muncie, IN)
campus-wide district GHP system

- Single or multiple heat sink/source
- Takes advantage of diversified loads in various builds connected with a common water loop

Fond du Lac High School

- The school is 400,000 square feet, requiring a 700-ton heat pump system.
- Two six-acre ponds, about 20 feet deep, were used for the geo loop. 41 miles of pipe were laid in the ponds.
- Fresh air is delivered efficiently to each classroom using a dedicated outdoor air system with heat recovery.
- Energy savings is estimated to be 30% below a standard VAV system.
- Between energy savings and peak demand reduction from the efficient heat pump system, the district avoids $290,000 in annual costs.
- This includes significant reductions in maintenance – the geothermal system requires only filter changes (quarterly).

http://wisgeo.org/projects/

In 2001, Fond du Lac High School constructed a new facility using geothermal heat-pump system

Kensington High School for the Creative Performing Arts
(Philadelphia, PA)

HVAC System	Baseline	Geothermal	Difference
Construction Cost	$2,700,000	$3,700,000	37%
Operating Cost/Yr	$237,286	$55,478	-76.6%
Maintenance Cost/Yr	$28,000	$9,000	-68.8%
20-Year Life Cycle Cost	$9,101,720	$6,469,560	-28.9%

7* interest for 20 years; No incentives or tax credits
Simple Payback: 7.6 years

Public and commercial buildings, such as schools, universities, prisons, and hospitals, can be retrofitted with geothermal heat pumps and provide cost-savings to the state's – and other utility rate payer's – energy bills. Many school districts – such as Poudre Valley in Colorado – have adopted policies/plans that require all new schools to be heated and cooled with GSHP systems.

Benefits and Challenges

Quiet Operation. Unlike air conditioners, there is no outdoor unit. Geothermal units are very smooth and quiet in operation.

Economic. On average, a typical home of 2000 square feet will require 4 tons of heating and cooling capacity with an average system installation cost between $5,000 and $7,500 per ton.

Sustainable Investment. The lifespan of a geothermal system is usually greater than 24 years. A conventional furnace will last 7-10 years with regular maintenance. The ground loop of the geothermal system has a warranty of 50 years. These loops are made up of high-density polyethylene pipe, the same pipe used in gas lines.

Improved Indoor Air Quality & Safety. There is no combustion in a geothermal heat pump; therefore there is no chance of carbon-monoxide poisoning. By adding high-efficiency air cleaners, these systems can improve inside air quality.

Limited Qualified Designers and Contractors. Geothermal heat pump up-front costs are higher than typical HVAC systems. This can be a deterrent to homeowners and business owners in choosing GHP, despite system benefits.

Energy Efficient. Geothermal heat pumps use 30% to 65% less energy than conventional heating or cooling systems.

Easy Operation. Geothermal heat pumps have simple controls and equipment and lower maintenance costs than traditional HVAC systems.

Carbon Emissions Reduction. One ton (12,000 BTU/hr) of GHP capacity over a 20 year operating cycle avoids 21 metric tons of CO_2 emissions. So a typical home system can avoid 80-100 metric tons of CO_2 emissions.

Locally Produced. Everywhere. Unlike other geothermal technologies, heat pumps are not limited by geography or geology. They can be installed in most locations in any of the 50 states or territories of the U.S. New construction, retrofits; small to large-scale applications.

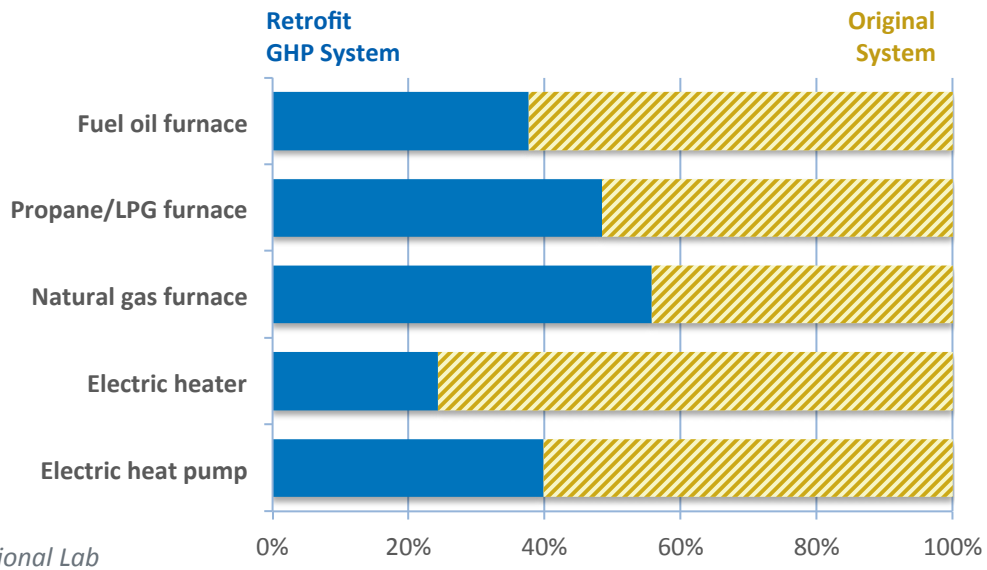
Higher up-front costs. Geothermal heat pump up-front costs are higher than typical HVAC systems. This can be a deterrant to homeowners and business owners inchoosing GHP, despite system benefits.

Benefits to Electric & Other Utilities

- Increase margins with incremental electric sales
- Distributed Systems, so no transmission investments needed (e.g. for natural gas)
- Naturally peak-load reducing - mitigate winter/summer electric peak demand
- Earn loyalty from members for:
  - Helping lower total energy bill
  - Carbon emission reductions
- Enhanced Compliance with Renewable Portfolio Standards and Clean Power Plans
  - Include "thermal" renewable energy
  - Credit for CO_2 reduction (e.g., EPA 1.11b)

Carbon emissions reduction:

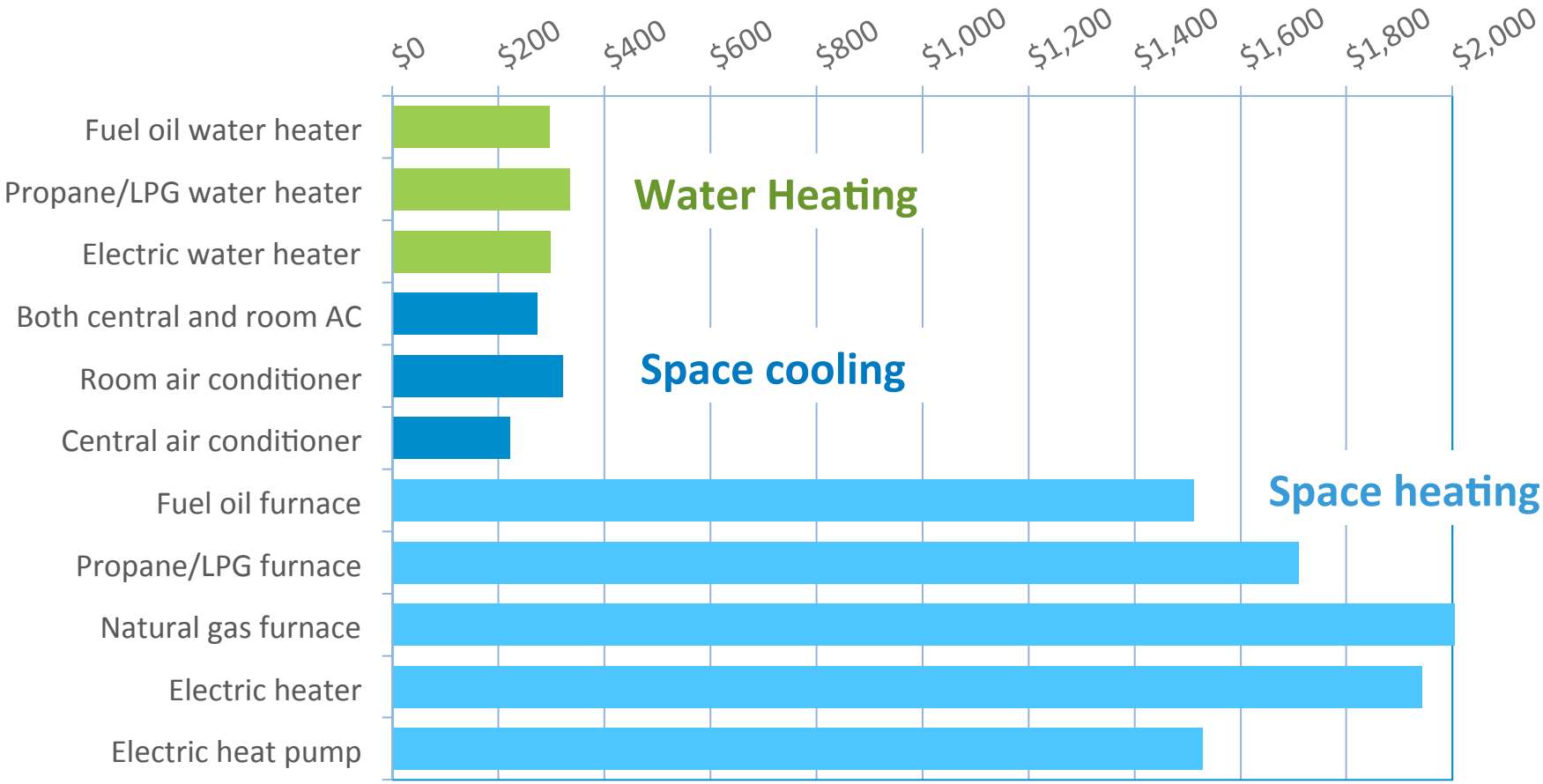
Over 50% for most systems



Percentage reduction of CO_2 emissions from a geothermal heat pump (GHP) retrofit for a typical home in the Western United States. For example, a retrofitting a fuel oil furnace with a GHP system will reduce CO_2 emissions by 62%.

Data from Oak Ridge National Lab

GHP System Annual Savings



Calculations based on 2013-2014 Wisconsin energy prices as reported by EIA

Average annual savings when replacing a household system with a geothermal heat pump. When multiple systems are replaced (e.g., space heating and cooling and water heating), savings are additive.

Federal Tax Incentive for Heat Pumps

Details:

- Tax credit equal to 30% of total system cost
- No limit to the maximum credit amount
- Can be used to offset AMT tax
- Can be used in more than one year
- Can be combined with solar and wind tax credits
- Can be combined with energy efficiency
- upgrade credits

Eligibility:

- Home must be located in the U.S.
- Does not have to be your main home
- Includes houses, apartments, condos, mobile homes
- Geothermal heat pump must be Energy Star® qualified
- Installed between 1/1/2008 and 12/31/2016 (may be extended)

http://programs.dsireusa.org/system/program/detail/1235

State Incentives for Heat Pumps

Wisconsin offers a number of rebate programs for Geothermal customers:

Performance-Based Incentive

- Xcel Energy - Renewable Energy Buy-Back Rates

State Loan Program

- Focus on Energy - Home Performance & Efficient Heating and Cooling Loan Program

State Rebate Program

- Focus on Energy - Efficient Heating and Cooling Cash-Back Rewards

PACE Financing

- River Falls Municipal Utilities - Renewable Energy Finance Program

Utility Rebate Program

- Cedarburg Light & Water Utility - Residential Energy Efficiency Rebate Program
- Eau Claire Energy Cooperative – Residential/Non-Residential Energy Efficiency Rebate Program
- Marshfield Utilities - Heat Pump Rebate Program
- Riverland Energy Cooperative – Residential, Commercial & Industrial Energy Efficiency Rebate Program

http://programs.dsireusa.org/system/program?state=WI
http://www.geothermalgenius.org/states/wisconsin.html

GHP System Cost

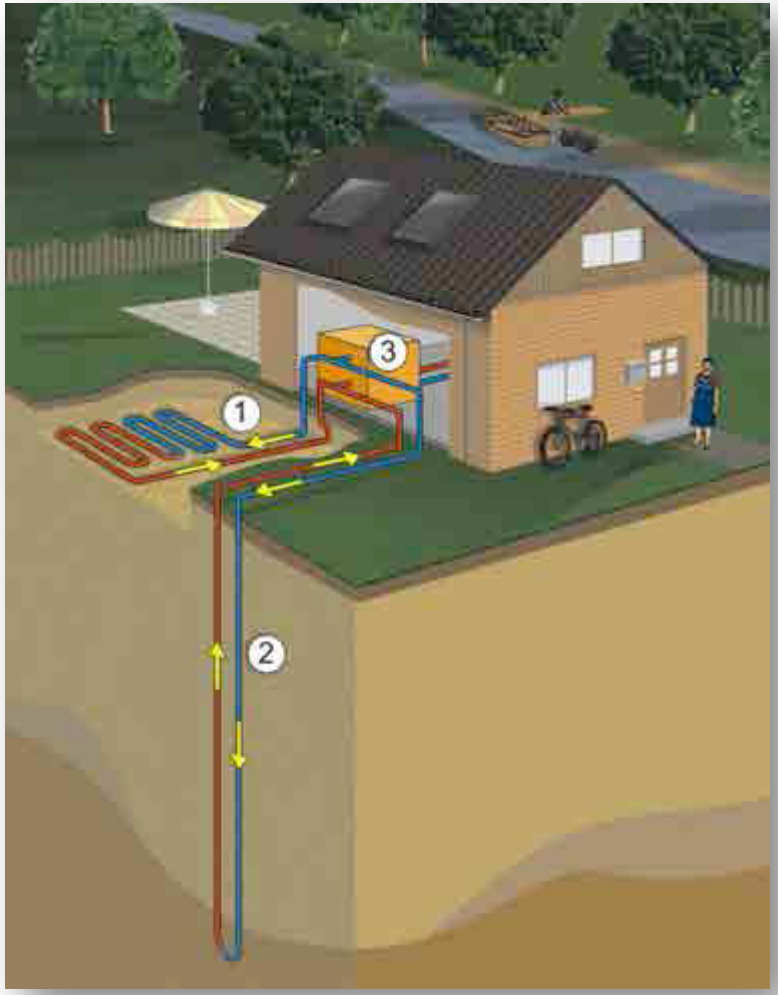
Installed costs vary widely depending on geological conditions, building loads, system designs, and heat pump equipment.

Data from Oak Ridge National Lab

Typical Costs of Common GHP Systems	
Packaged water-air heat pump	$2.5-4/ft^2 [(a)]
Closed loop vertical	$6.76 - 15/ft [(b)]
Total system	**$13 - 26/ft^2 [(b)]**

(a) EIA, 2010. Geothermal heat pump manufacturing activities 2009
(b) Kavanaugh, S., et al., 2012. ASHRAE Journal 54(10)

Example payback calculation	
New Furnace	$3,500
New Geothermal Heat Pump	$20,000
30% Federal Tax Incentive	-$6,000
Geothermal Heat Pump	$14,000
Difference	$10,500
Annual Savings over Natural Gas	-$2,000/yr
Payback time	**5.25 Years**



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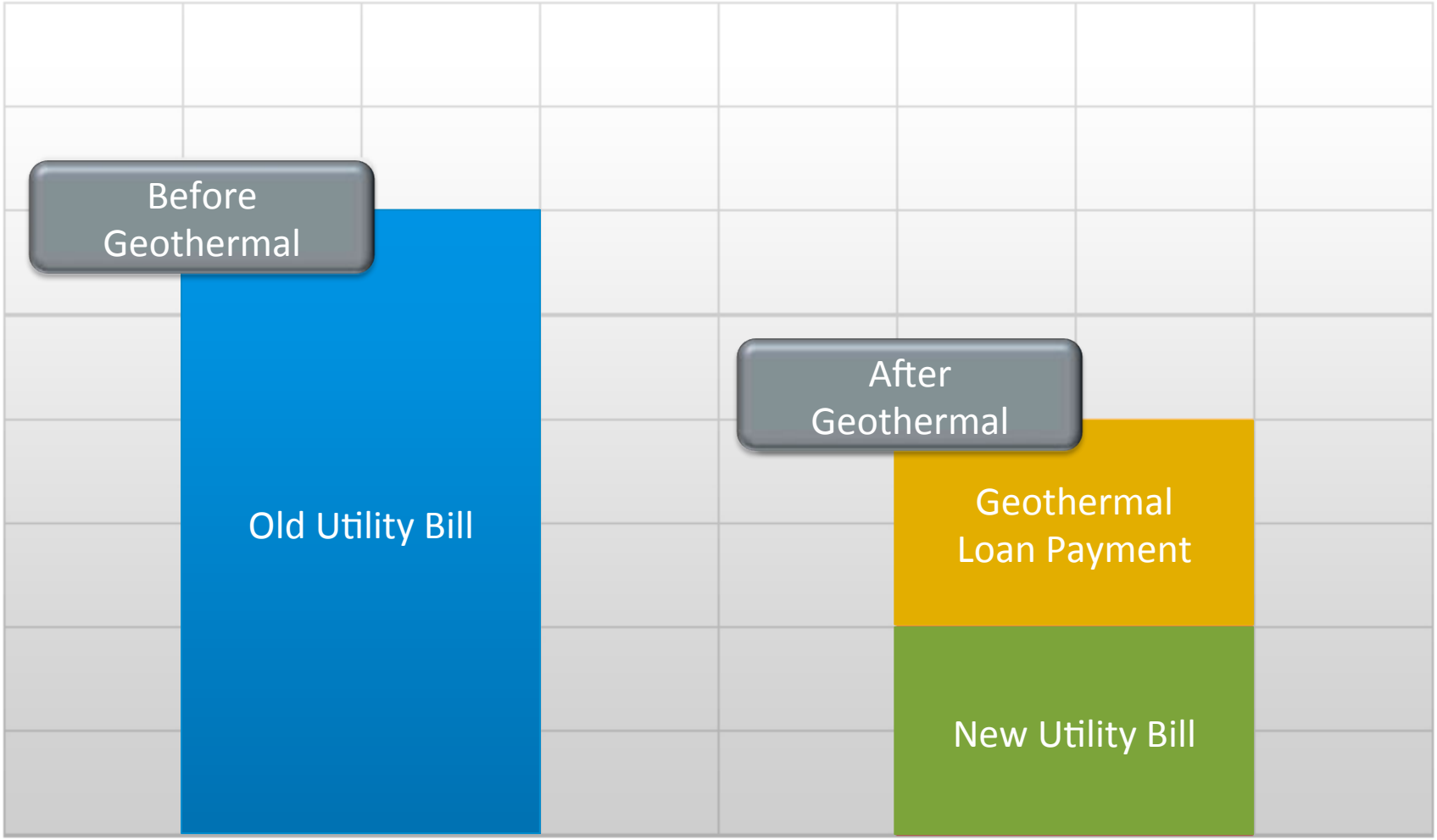
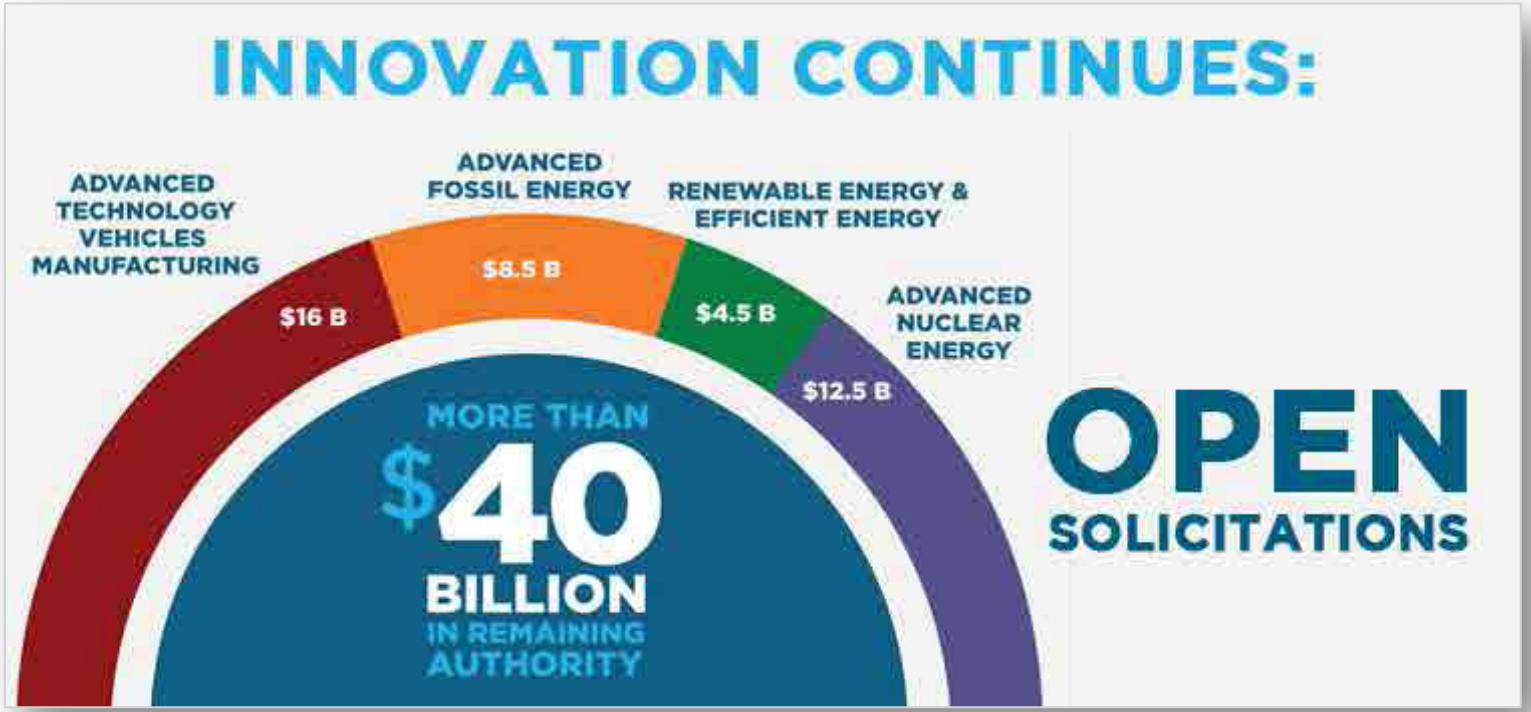


DOE Loan Program



GHPs have outstanding potential for advancement. The Loan Programs Office currently has more than $4 billion in remaining loan authority to help finance innovative Renewable Energy and Efficient projects located in the United States.

Four key eligibility criteria for projects:

1. Be located in the U.S. (can be foreign owned)
2. Utilize a new or significantly improved technology
3. Demonstrate a greenhouse gas benefit
4. Demonstrate a reasonable prospect of repayment

Geothermal heat pumps are the most **energy efficient**, **environmentally clean**, and **cost effective** space conditioning systems available.

EPA Report 430-R-93-004

Thank You!

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