Analysis of Energy Consumption & Space Heating in the Residential Sector

TJ Stephens, James D’Agostino, Nick Buczacki

Presentation Layout

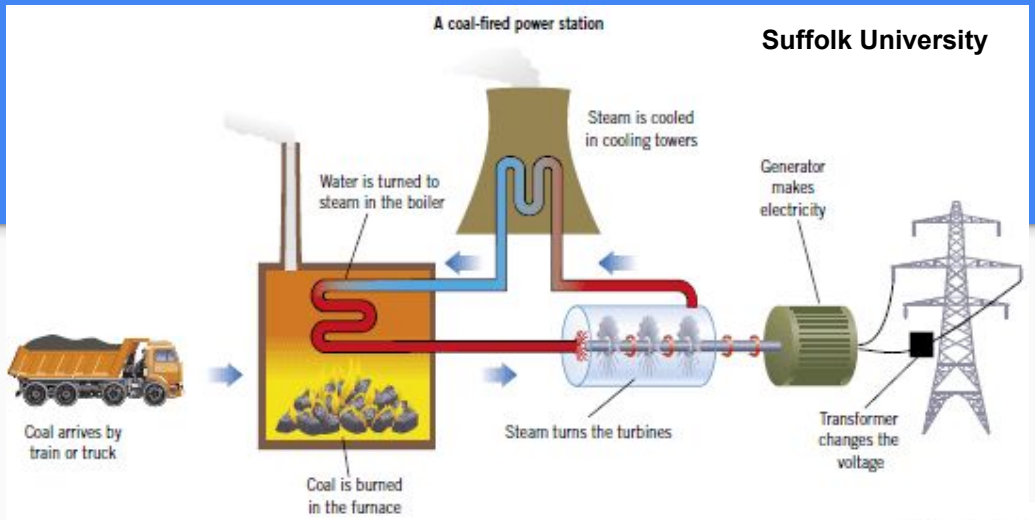
1. Investigate state consumption, energy costs, source of energy, energy cycles
2. Present key calculations and findings regarding space heating efficiency
3. Explain what factors influence these findings
4. Explore and study recently established policies, and suggest action steps for ongoing reductions of CO_2 emissions in Denmark and in the United States

Goal and Hypothesis

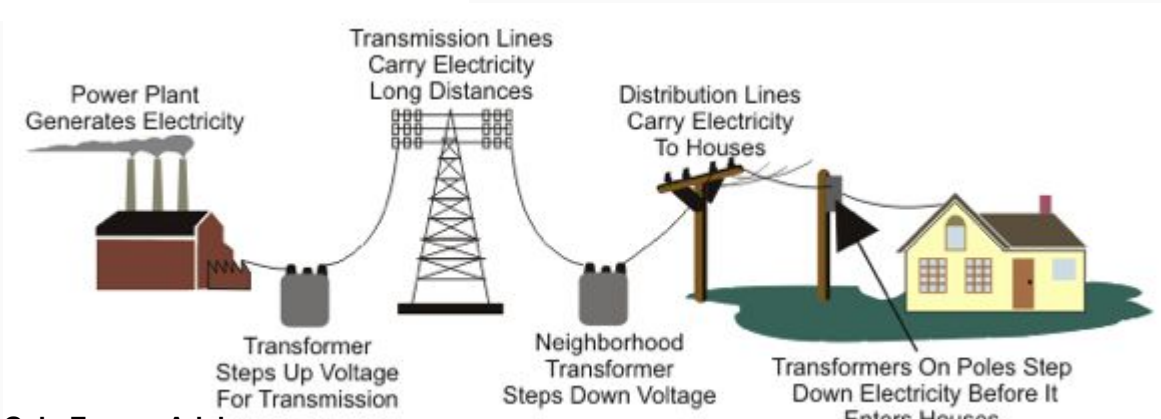
We believe various factors impact the efficiency space heating and intend to look for trends/patterns in efficiency statistics based on the type of fuel used, age/condition/style of structure heated, climate, and heating distribution method (CHP, district heating, private sector).

Hypothesis: We believe Denmark is more efficient in terms of total energy used and CO_2 emitted based on the square foot area of the residential structures in which they heat.

The Process of Electricity Generation and Distribution



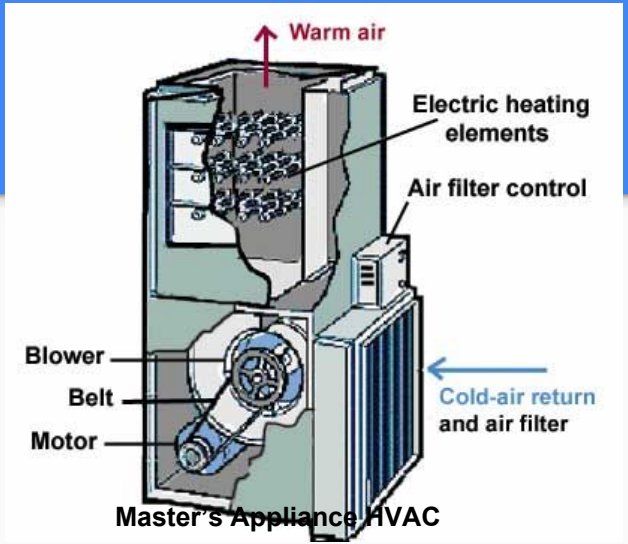
-Easiest variable to change in cost-efficiency is the type of fuel used



NetGain Energy Advisors

The Process of Electric Home Heating

Electric Furnace



Master's Appliance HVAC

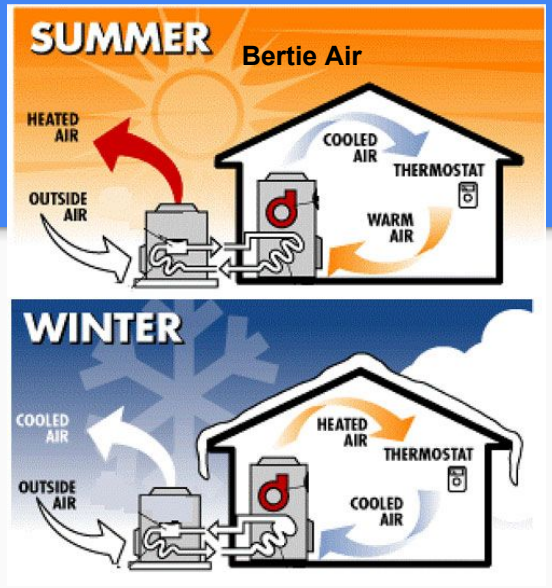
-Most expensive electric system to operate
-Like any other furnace system, forces warm air into home
-Loses heat to duct losses

Baseboard Heating

Energy.Gov

-Allows rooms to be heated separately
-Heat is radiated via aluminum fins within baseboard
-Put under windows

Heat Pump



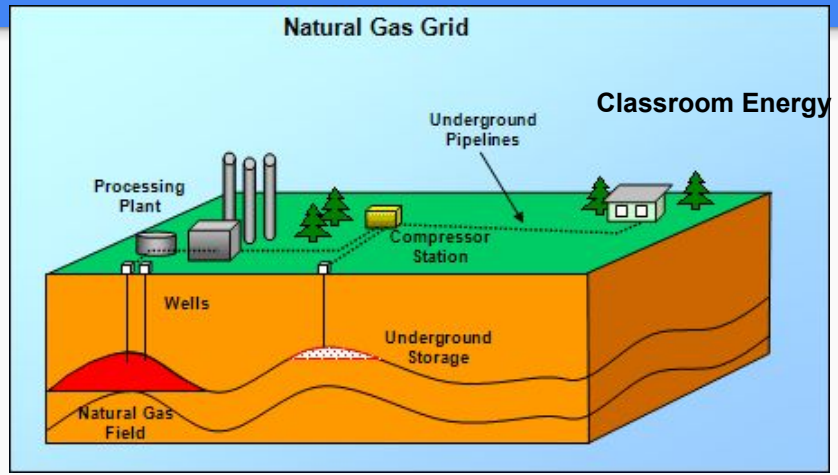
-Up to 50% cheaper than electric resistance heating
-Can be used in all seasons

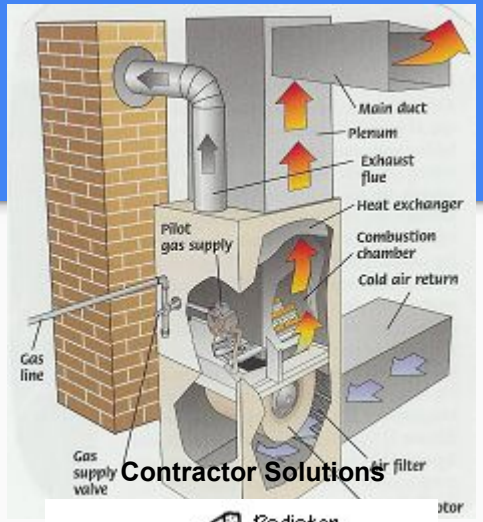
-Electric resistance heating is 100% efficient in that all incoming energy is used, but about 30% efficient after factoring in generation and distribution losses

Source: Department of Energy

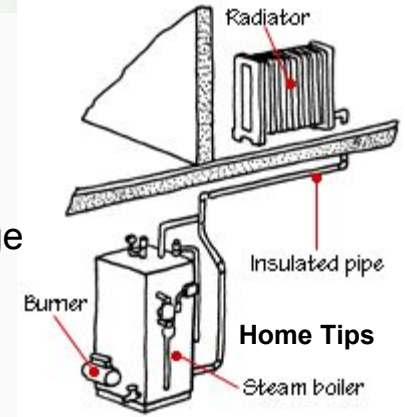
The Process of Home Heat Generation with Gas

Source: Department of Energy



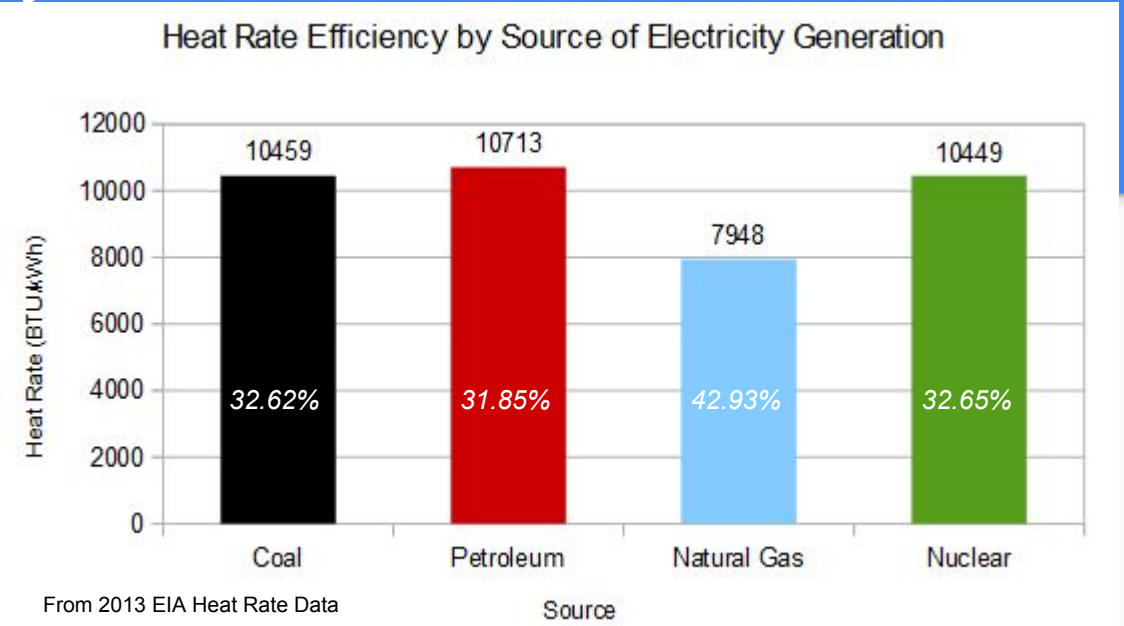


-Furnaces have efficiency ratings of 59%-98.5% AFUE
-Boilers have efficiency ratings of 50%-90% AFUE depending on age
-AFUE= Annual Fuel Utilization Efficiency and is a unit of efficiency, 90% AFUE means that 100BTU of input results in 90BTU of heat



Sources: Energy Information Administration, Powermag

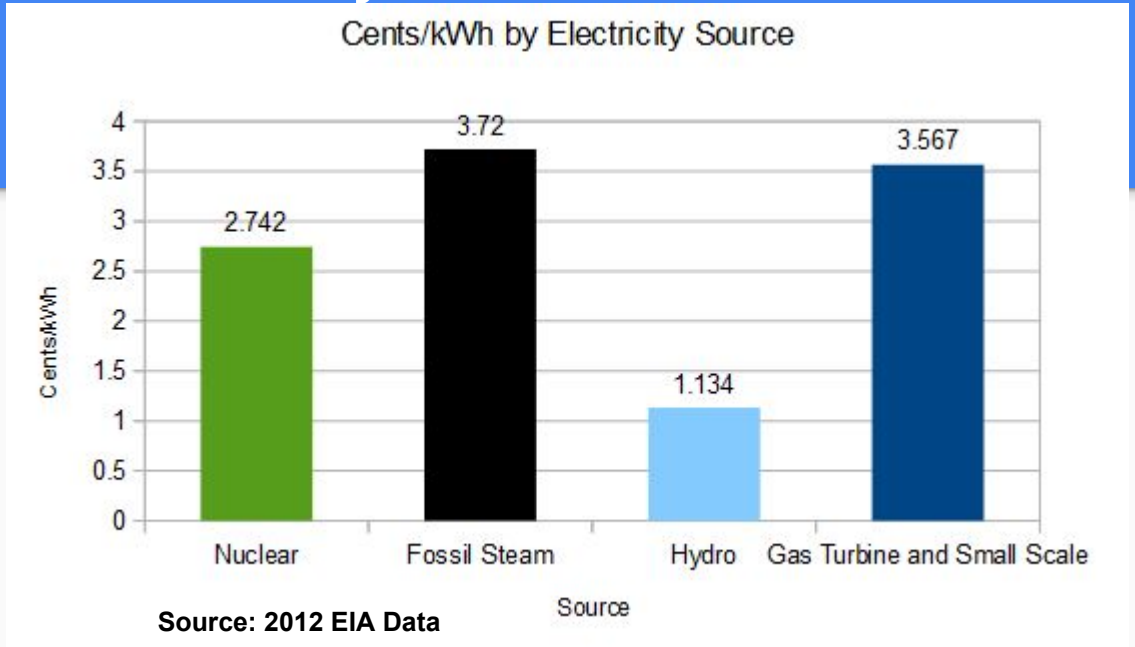
Efficiency of Power Plants



From 2013 EIA Heat Rate Data

- In the United States the efficiency of a power plant is measured via Heat Rate, the amount of energy in BTU used to produce 1 kWh of electricity
- 1 kWh is equivalent to 3412 BTU
- Loss of energy in power plants occurs from friction, loss of heat via flue gas, radiation, and convection losses

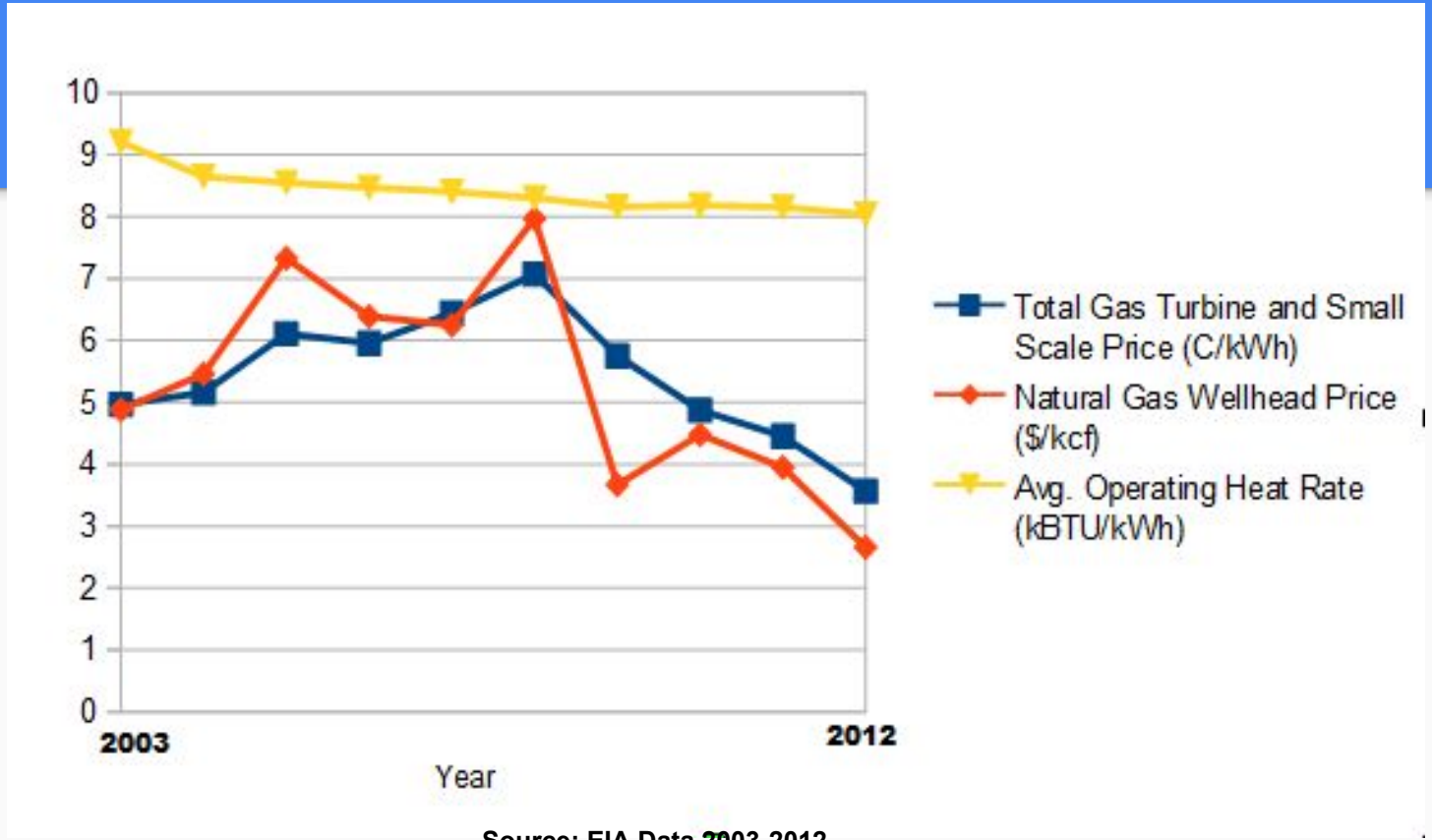
Price of Electricity Production



Source: 2012 EIA Data

- Fossil steam consists of petroleum and coal, gas turbine and small scale consists of natural gas, wind, and solar
- Only includes fuel, maintenance, and operation costs. Not sunk costs like building.
- Can't increase production in nuclear or hydro
- Gas is even cheaper when considering the cost of EPA regulations

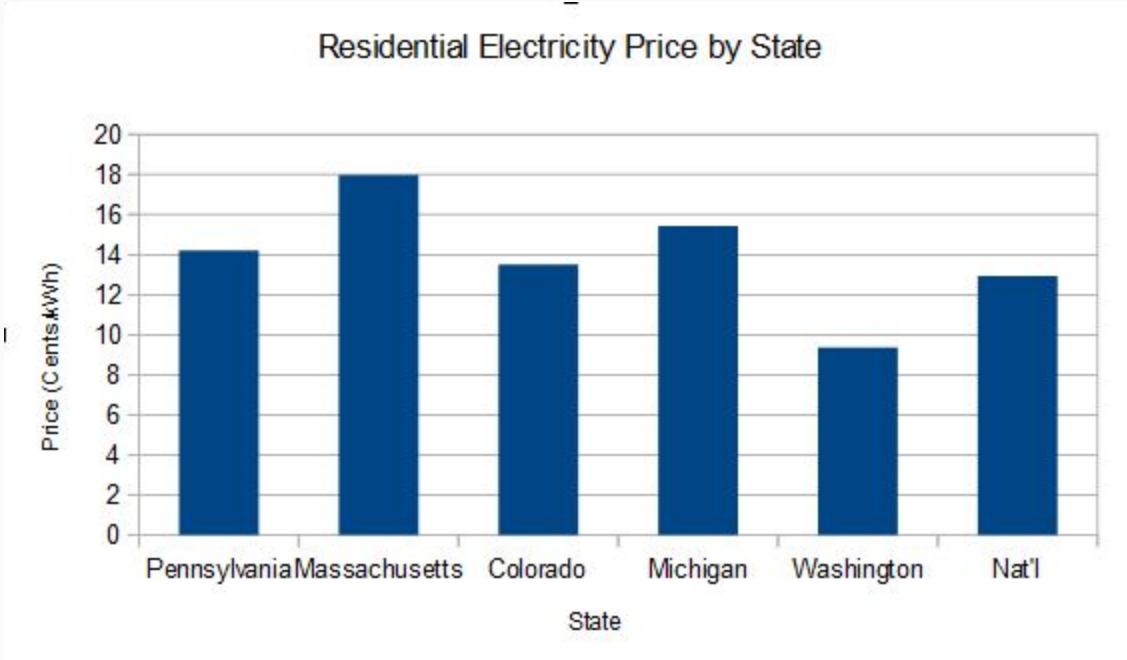
The Rise of Natural Gas Electricity Generation



Source: EIA Data 2003-2012

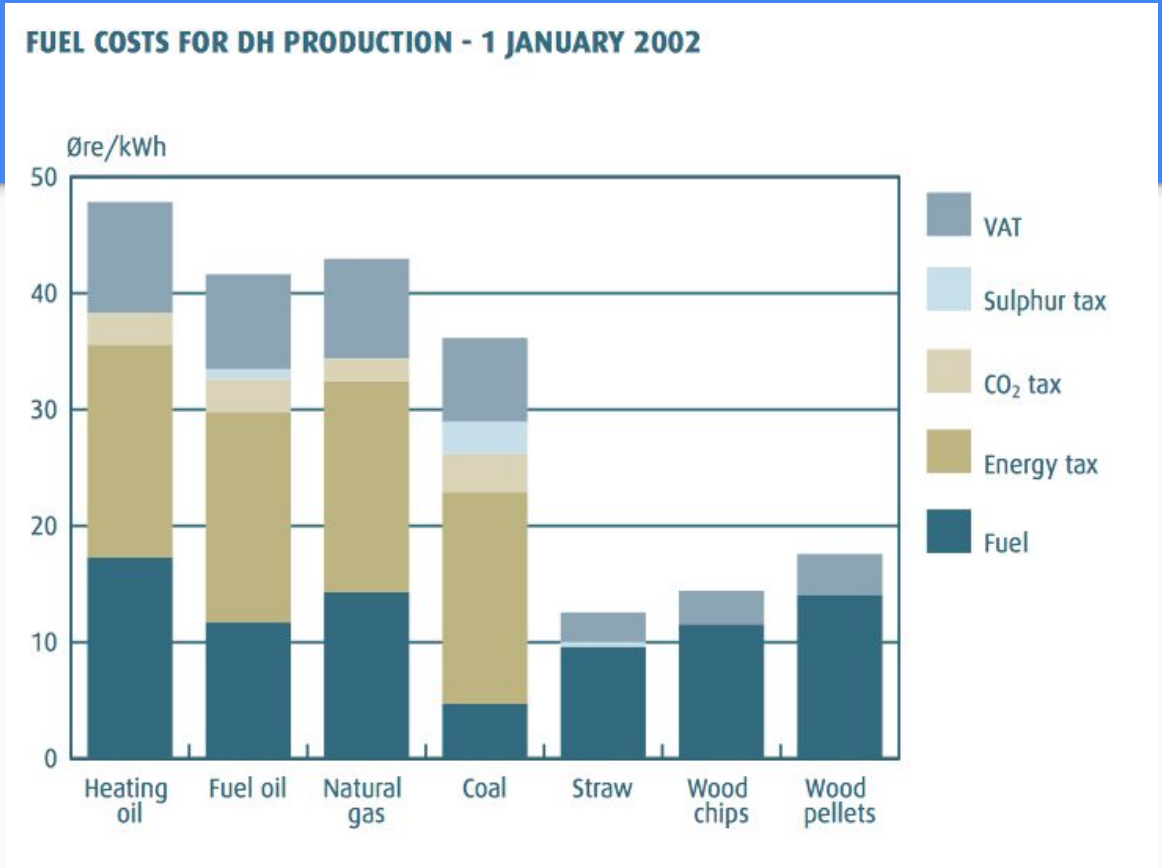
Price of Electricity Consumption

Source: 2013 EIA Data



Final Cost of District Heat Fuel Source- Denmark

Source: Danish Energy Authority

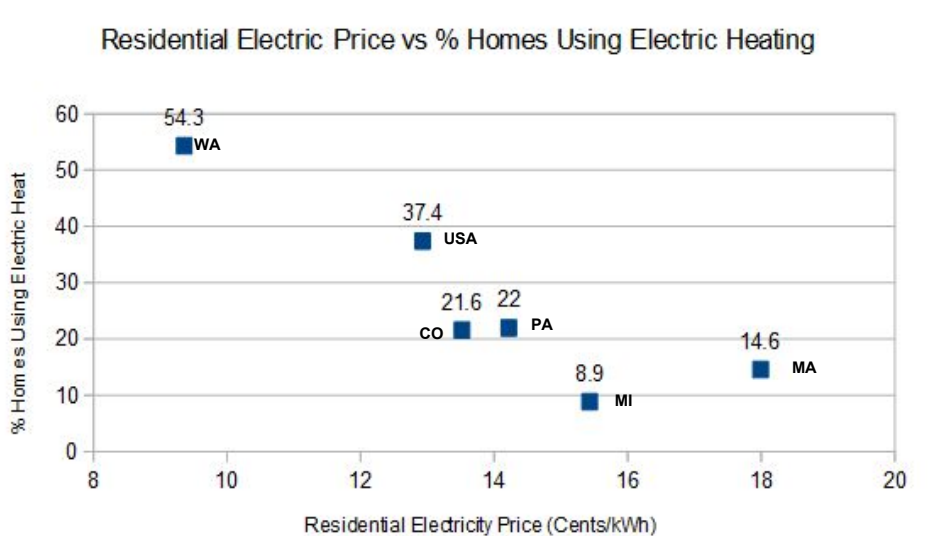


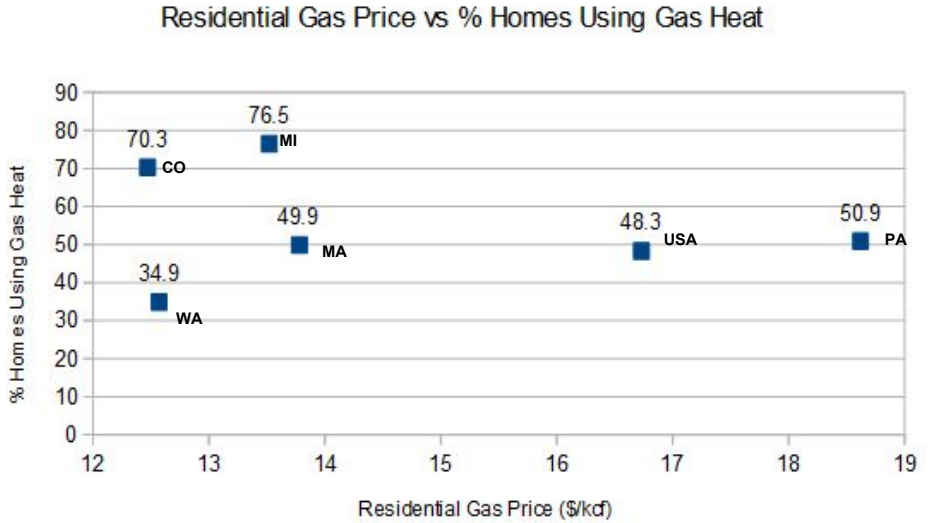
Ore = 1/100th of Dkk
7 DKK = 1 USD
*Danish cent
*December 3rd, 2015 conversion numbers

Price vs Consumption for Heat

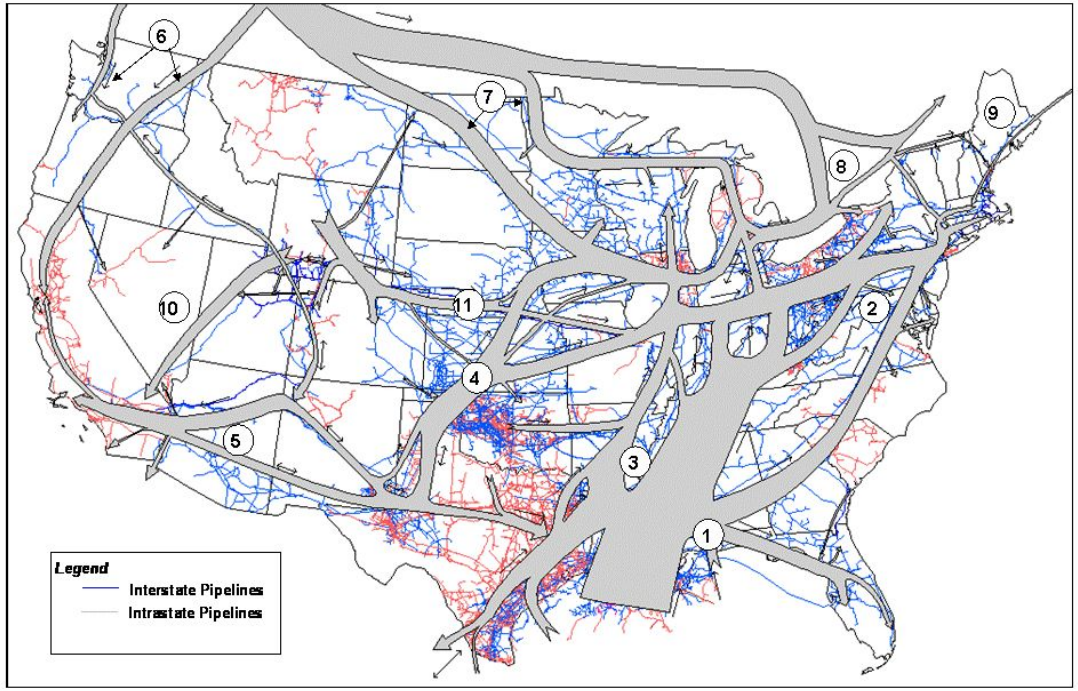
Source: 2013 EIA Information

- Washington has the cheapest electricity and highest percentage of homes heated with electricity
- The electricity vs % graph has a noticeably negative slope
- The gas vs % graph has a much smaller slope
- Colorado and Michigan have very high percentages of homes using gas and very low prices compared to the USA. They also have the coldest climates.





Source: EIA



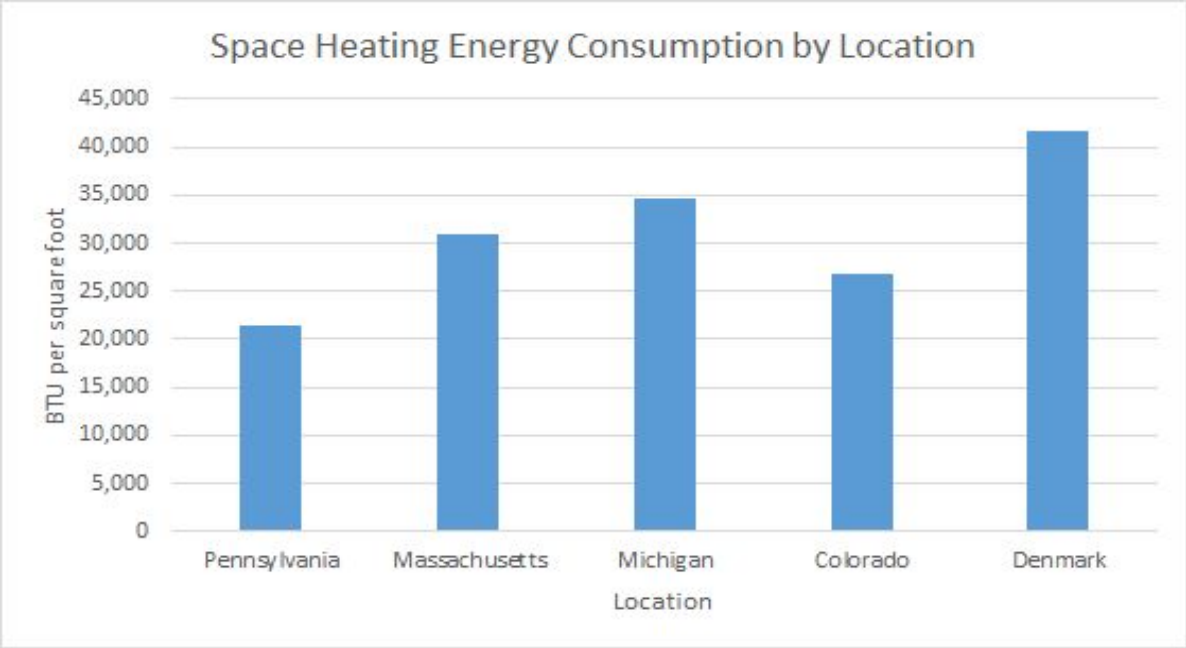
Source: Energy Information Administration, Office of Oil and Gas, Natural Gas Division, GasTran Gas Transportation Information System.

The EIA has determined that the informational map displays here do not raise security concerns, based on the application of the Federal Geographic Data Committee's *Guidelines for Providing Appropriate Access to Geospatial Data in Response to Security Concerns*.

-While Michigan and Colorado either have production or pipelines throughout the state to help increase accessibility, PA's pipelines tend to run through rural areas, perhaps a reason for why its gas costs so much.

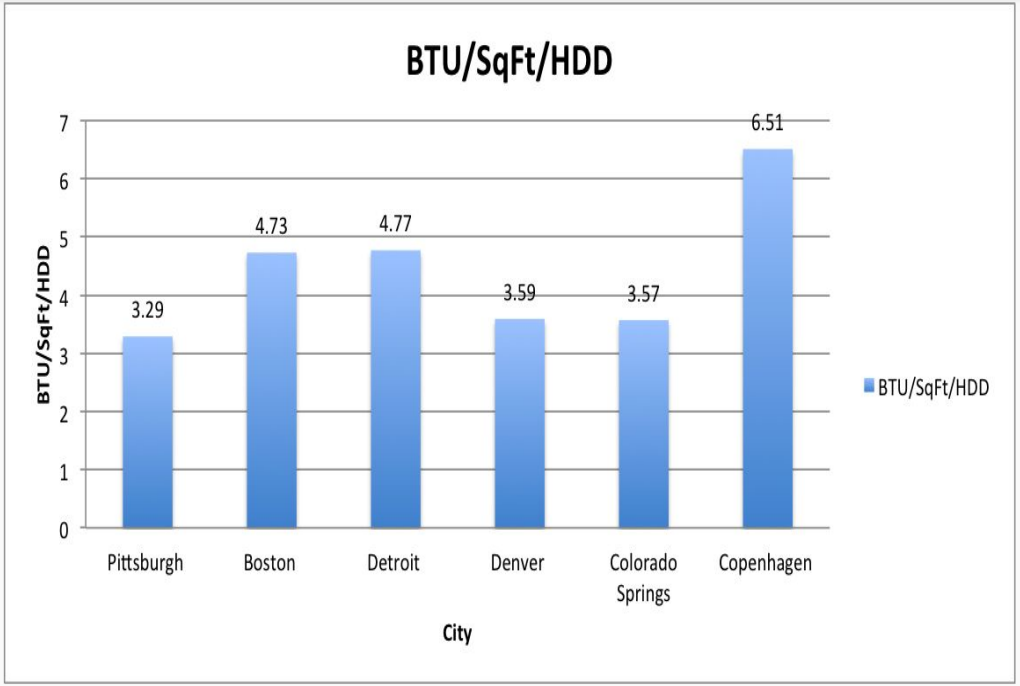
BTU/Sq Ft of Space Heating by State & Nation

Sources: EIA, U.S. Census Bureau, Danish Energy Agency, University of Oxford



Climate Normalized Energy Use: HDD

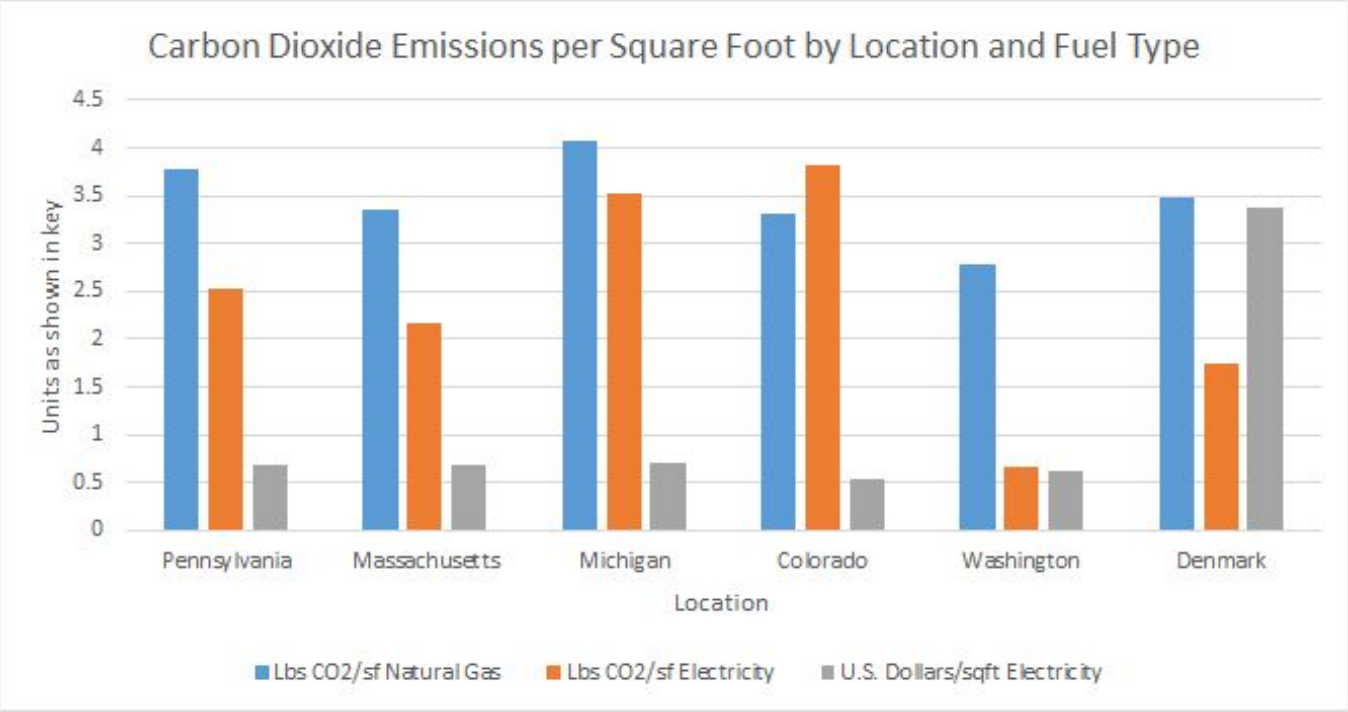
Source: Weather Underground-BizEE Software, EIA



Location	*Heating Degree Days*
Pittsburgh (PA)	6507
Detroit (Michigan)	7263
Denver (CO)	7429
Colorado Springs (CO)	7461
Seattle (WA)	6080
Boston (MA)	6550
Copenhagen (DN)	6420

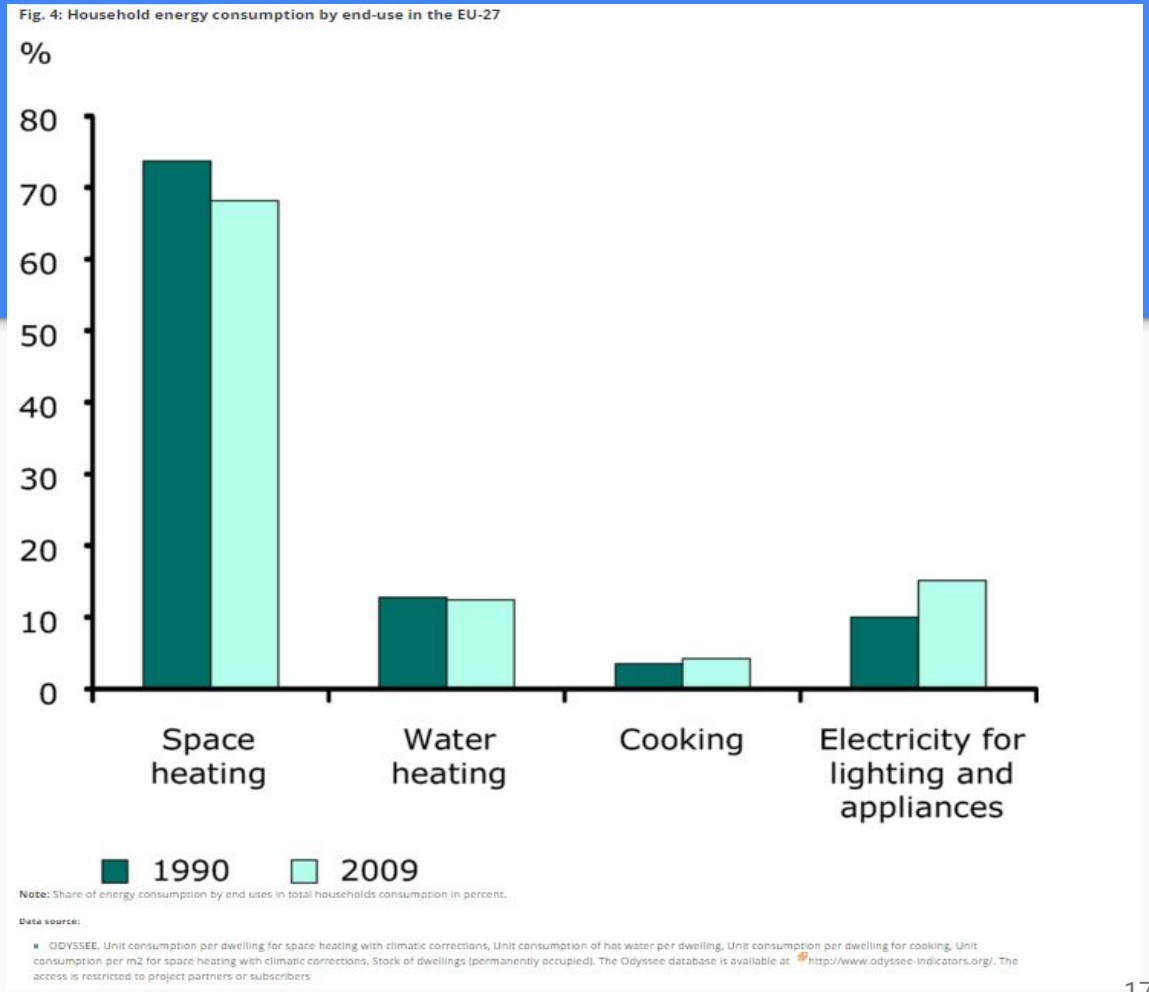
Pounds of Carbon Dioxide Released Per Square Foot (Natural Gas)

Sources: EIA, Danish Energy Agency, US Census Bureau, US Department of Energy, Columbia University, University of Oxford, Encyclopedia of European Union Statistics

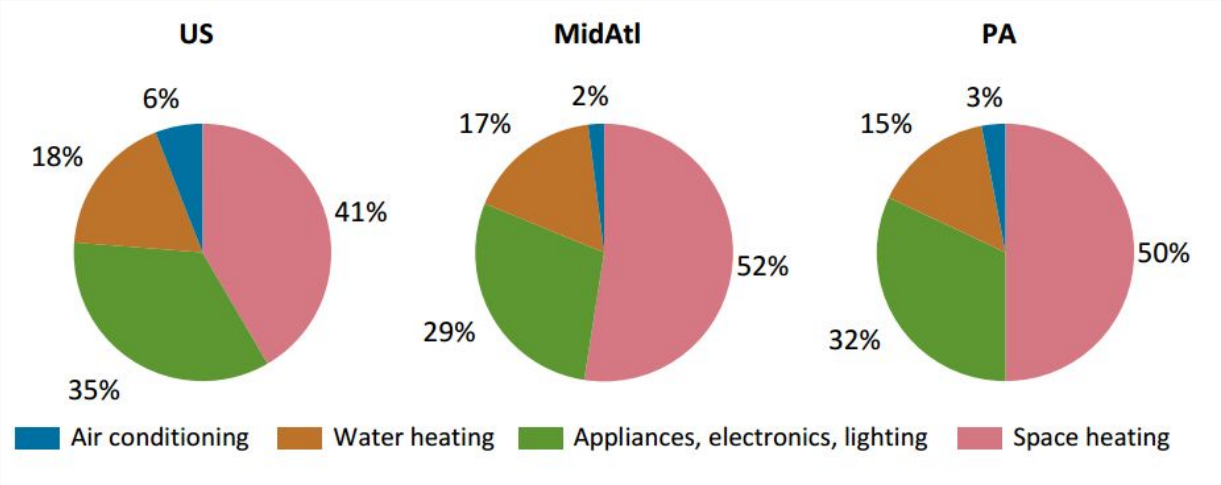


Source: European Environment Agency

Energy Consumption in Homes Within the European Union



Energy Consumption in Homes in the United States



CONSUMPTION BY END USE

Half the energy consumed in Pennsylvania homes is for space heating. Air conditioning accounts for a larger share of household consumption than other Northeast states, but still only accounts for 3% of the total energy used in homes.

Source: U.S. Energy Information Agency

Distribution of Home Age in Denmark

- 79 percent of homes built prior to 1980
- Only 12.1 of homes built since 2000

Source of Danish row: Denmark Ministry of Social Affairs (Chart Published by European Union)

2.4 Age distribution of housing stock

	Year	<1919	1919-1945	1946-1970	1971-1980	1981-1990	1990-2000	> 2000
Austria [1 2]	2009	15.2	8.2	28.0	15.2	11.5	13.6	8.3
Belgium [3 4]	2009	17.1	24.2	24.2	13.7	20.8		
Bulgaria								
Cyprus [5 6]	2001	na	7.4	16.9	20.7	27.4	27.1	-
Czech Republic [1 5]	2005	10.5	14.2	25.4	21.8	15.8	7.9	3.4
Denmark [7]	2009	19.7	16.1	26.4	16.6	9.1	5.4	6.7
Estonia	2009	9.4	14.2	30.0	21.5	19.6	2.0	3.3
Finland [4]	2009	1.5	8.1	27.6	21.5	18.5	11.5	9.8
France [1 8]	2006	17.0	13.2	17.4	25.2	10.2	8.5	8.4
Germany [9]	2006	14.4	13.6	46.3		13.2	9.2	3.3
Greece	2001	3.1	7.2	31.8	24.5	19.1	14.4	na
Hungary [10]	2005	-	20.8	27.2	23.1	17.8	7.9	3.2
Ireland	2002	9.4	8.0	15.9	14.2	13.2	19.5	19.8
Italy [11]	2001	14.2	9.9	36.8	18.8	12.2	7.9	-
Latvia	2008	13.8	13.1	22.1	19.4	20.2	7.0	4.4
Lithuania	2002	6.2	23.3	33.1	17.6	13.5	6.3	-
Luxembourg [3]	2008	21.8	25.6	29.2	11.6	5.1	4.5	2.2
Malta [12]	2005	12.2	10.0	22.1	16.2	19.1	17.0	3.4
Netherlands [13]	2009	6.9	13.9	27.0	17.0	15.4	12.0	7.9
Poland [14]	2002	10.1	13.1	26.9	18.3	18.7	12.9	-
Portugal [3]	2008	7.4	10.0	21.9	16.1	18.8	17.7	8.1
Romania [15]	2002	3.9	11.5	37.3	23.8	14.8	7.3	1.4
Slovak Republic [1 5]	2001	3.4	6.6	35.1	25.6	21.0	6.2	0.6
Slovenia [16]	2004	15.1	7.8	27.7	23.2	16.0	6.9	3.4
Spain [17]	2001	8.9	4.2	33.5	24.1	13.6	15.7	-
Sweden	2008	12.1	14.7	37.0	16.8	9.4	5.5	4.6
United Kingdom [18]	2004/5	17.0	17.0	21.0	21.8	20.0	na	na

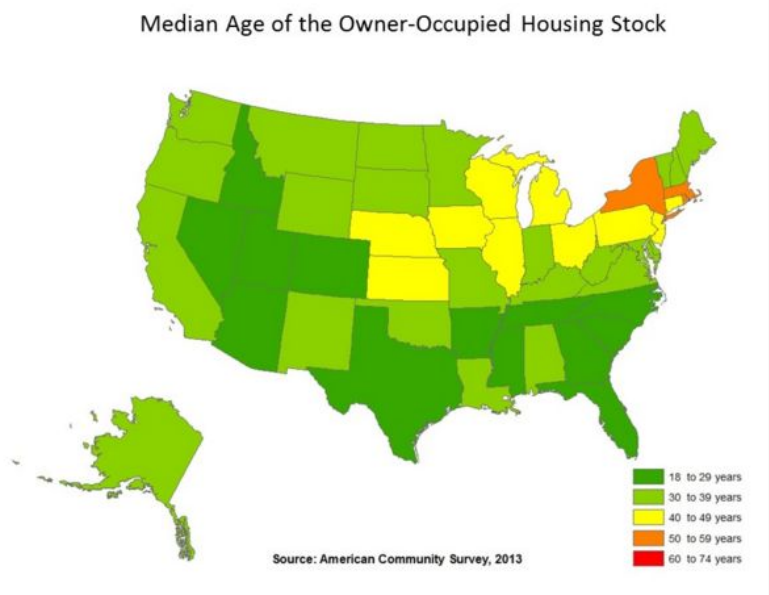
Dwellings classified by the period in which the construction of the building containing them was completed.

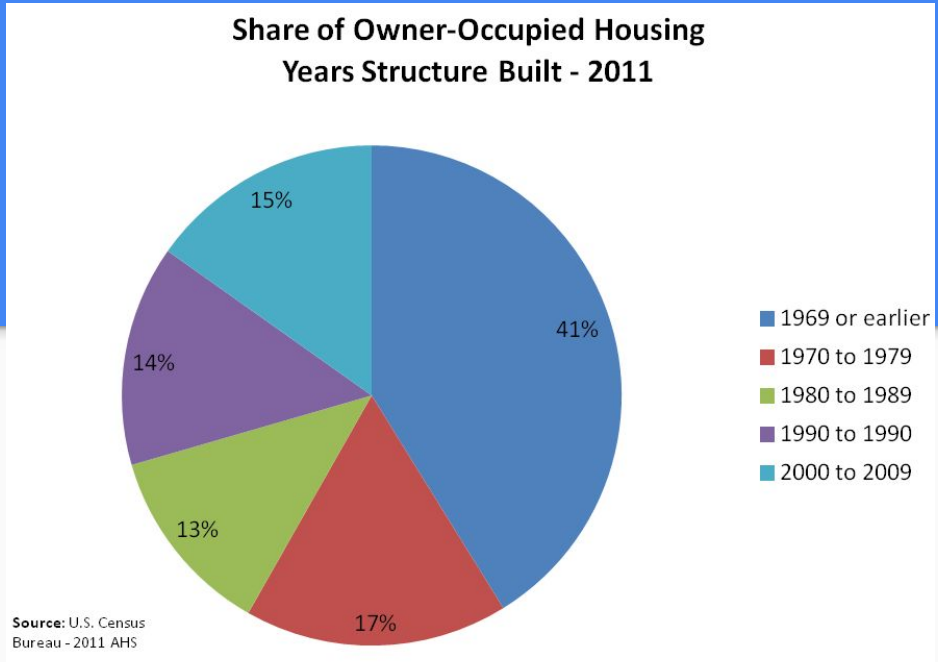
Outdated Homes - Denmark

Source: Danish Ministry of Climate, Energy and Building

- 80% of homes in Denmark were built before 1979
- more than 50% of energy consumption in 2011 came from single family homes
- 1979 Homes use 165 kWh/m^2 -80% for heat - 132 kWh/m^2 for heat
  - ~41,844 Btu/ft^2
- new homes to be built following EU standards 37 kWh/m^2
  - ~11,729 Btu/ft^2
- Set renovation plan in place in 2014, acknowledges need for renovations

Distribution of Home Age in the United States





- 58 percent of homes built prior to 1980
- Median age of homes: 35 years

2015 American Clean Power Plan

Source: The White House, President Barack Obama

Highlights:

- First ever standard on carbon dioxide emissions from power plants in human history
- Reduce national CO_2 emissions by 32% (2005 levels) by 2030
- Grow the renewable energy production industry by 30% by 2030
  - Job creation
- Save the average American family 85 dollars each year in energy bills

**Tuesday, the HOR set forward a resolution to the act that the President has plans to veto

What the Clean Power Plan Means for Pennsylvania

- Goal to increase renewable energy generation to account for 18% of the state energy profile by 2021
  - Continue increase to 30% by 2030 (in line with national goal)
- Builds on past progress; 12% emissions cut since 2008; increasing to 32% by 2030
- Since 2008: funding for 1,170 new renewable energy projects, powering the equivalent of 240,000 homes

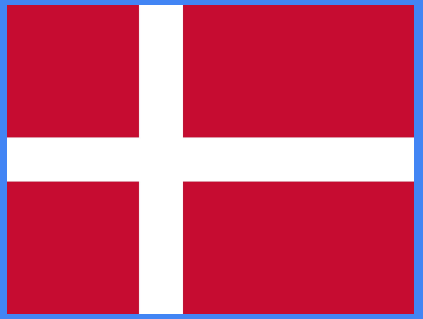
Source: The White House, President Barack Obama

Happening in our Backyard… Elizabethtown College

Source: Elizabethtown College

- Secured state grant to build PA's largest higher education owned solar farm
    - $500,000 from Pennsylvania Energy Development Authority
- 2.6 MW DC ground-mounted solar voltaic system (Community Energy)
- 10 acres, 20% of college needs, equivalent of 300 homes

The 2012 Danish Energy Agreement



- Entire energy supply (electricity, heating, industry & transportation) supplied by renewable energy by 2050.
- Initiatives to be reached by 2020:
  - 35% of final energy consumption from renewable energy
  - 50% of electricity consumption from wind energy
  - 34% reduction in GHG emissions from the 1990 level
- Major area of focus: Home energy consumption. Additional policies enacted in 2014

Source: The Danish Ministry of Climate, Energy, and Building Design, Oak Ridge National Laboratory

Waste Energy - Denmark

Source:
Zero Waste Europe,
Danish Energy Agency

- Incineration of household waste to produce heat energy
  - accounts for 20% of heat production
  - leader in European Union of most waste per capita
- Outdated method, needs to be replaced to fit the European Union's Law to have new buildings be carbon neutral by 2020
- Waste may release less CO_2, but releases more NO_x which is a more harmful GHG

Fuel	Coal	Gas oil	Natural gas	Waste
CO_2 (kg/GJ)	95	74	57	18
CH_4 (g/GJ)	1,5	1,5	15	0,6
N_2O (g/GJ)	3	2	1	1,5
SO_2 (g/GJ)	45	23	0	23,9
NO_x (g/GJ)	130	52	50	124

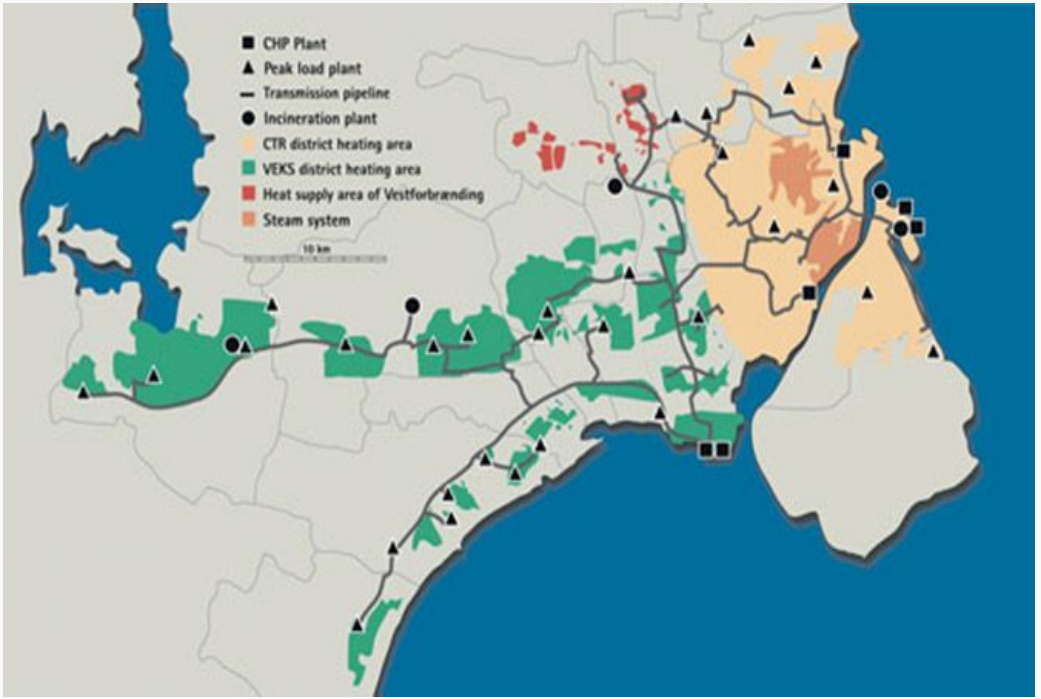
Recycling Heat - Denmark's District Heating

Source: International District Energy Association (Robert P. Thornton), Danish Board of District Heating, U.S. EPA, DONG Energy

- 80% of the heat recovered from electricity generating stations
- 97% of buildings without boilers/water heaters. Hot water & steam directly delivered to home
- This system causes 665,000 metric tons of CO_2 and 1.4 million barrels of oil to be saved per year
- Ideal CHP plants ~ 90% eff. while electric only ~ 40% eff.

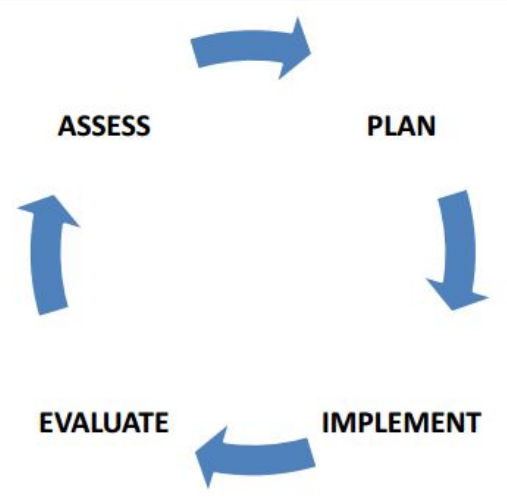
**Difference between "total system efficiency" and "effective electric efficiency"

- EEE: 51-69% range
- Avedore (DONG): TSE 94%



Better Buildings Initiative, February 2008: U. S. Residential & Commercial Retrofitting

- Increase energy efficiency in buildings by 20% by 2020
  - Tax incentives, financing opportunities
- Goal: “Install measures or equipment in existing homes in order to increase the energy efficiency”
- Emphasis on retrofitting, residential & commercial energy use accounts for 40% of consumption in the U. S.



Source: U.S. Department of Energy, The White House: President Barack Obama

The Pittsburgh City-Council Building

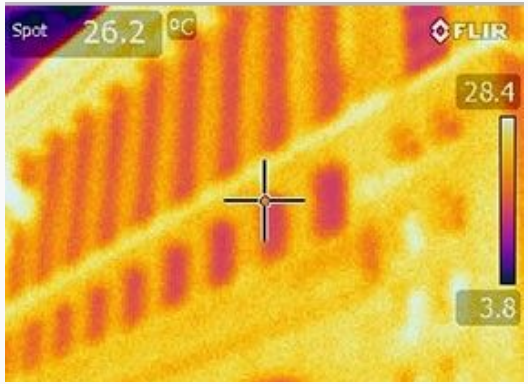
Source: Better Buildings, The U.S. Department of Energy, The City of Pittsburgh Local Government

Phase I: HVAC, Steam tunnel, window upgrades

Phase II: Advanced lighting control upgrades

Phase III: Roof replacement, automation, performance monitoring system

- Initial Cost: $5 million
- energy efficiency: increased 20%
- Annual energy cost savings: $200,000



Energy Renovation Strategy for Danish Buildings, May 2014

Source: Danish Ministry of Climate, Energy and Building

- Goal: renovate 85% of buildings by 2050
- Lead to a 28% reduction in net heating demand by 2050
- Final Building Regulations to be established in 2015
  - Reported net energy consumption in households could be reduced up to 35% by 2050.

1. Retrofit insulation, renovate/replace roofs and exterior walls, replace windows when appropriate

2. Continuously upgrade regulations past 2020 and simplify to cater to public understanding

3. Optimize large buildings through automation of heating and lighting systems & connect to smart grid

4. Establish classes; an energy labeling scheme A-G

Denmark Policy Reimplementation

Source: Danish Ministry of Climate, Energy and Building, US Department of Energy

- Replacement of windows
  - Mostly to larger, more glassed window
  - Allows better daylight lighting and insulation
  - U-Factor: rate window conducts non-solar heat flow (lower factor, more efficient window)
- Use in US with building of new homes to have best windows and implement renovation plans for older homes

GLAZING TYPE	U-FACTOR (Btu/hr-ft^2-°F)		
	Wood or Vinyl Frame (with insulated spacer)	Alum. Frame with thermal break (with conventional spacer)	Aluminum Frame without thermal break (with conventional spacer)
Single glass	-----	1.07	1.30
Double glass, 1/2-inch air space	0.48	0.62	0.81
Double glass, e = 0.20*, 1/2-inch air space	0.39	0.52	0.70
Double glass, e = 0.10*, 1/2-inch air space	0.37	0.49	0.67
Double glass, e = 0.10*, 1/2-inch argon space	0.34	0.46	0.64
Triple glass, e = 0.10 on two panes*, 1/2-inch argon spaces	0.23	0.36	0.53
Quadruple glass, e = 0.10 on two panes*, 1/4-inch krypton spaces	0.22	-----	-----

Denmark Policy Reimplementation

Source: Danish Ministry of Climate, Energy and Building, US Green Building Council

- Current energy-labeling guidelines for newly built homes and it is updated after sold
- This resembles LEED certification in United States
- Plan to implement LEED certification to residential homes more predominantly in United States
    - Americans love to put up new homes, make getting newly built homes LEED certified upon completion

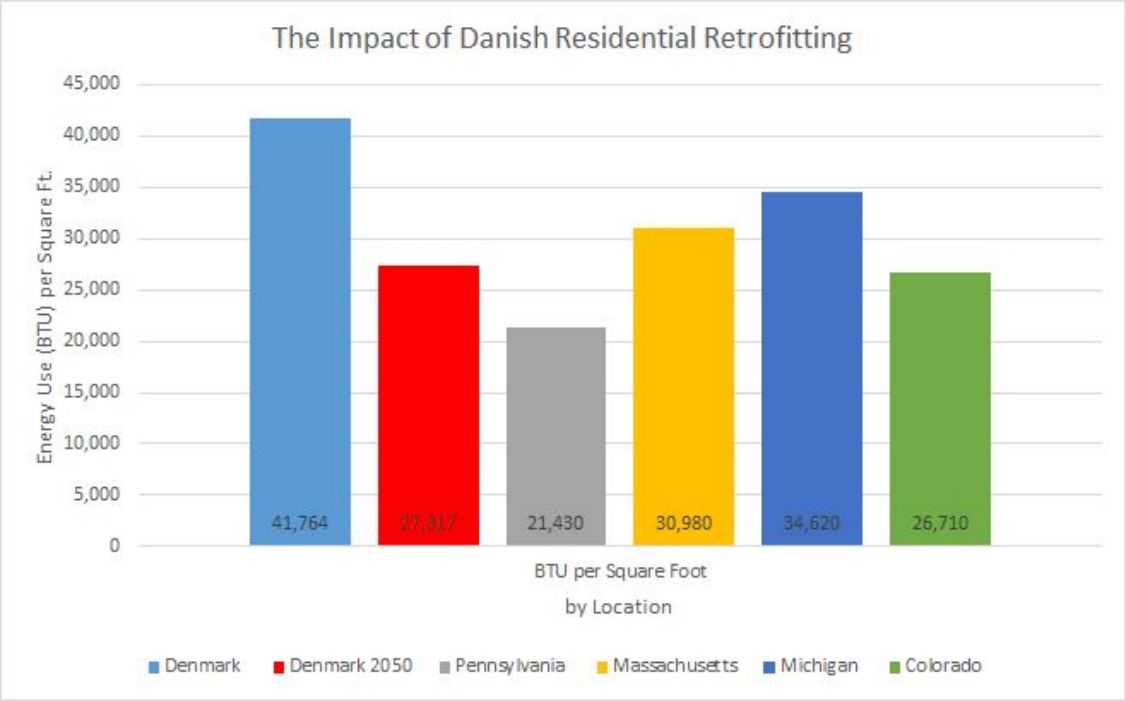
Denmark Policy Reimplementation

Source: Danish Ministry of Climate, Energy and Building

- BedreBolig Organization was set up by the Danish government to work specifically to help homeowners with energy renovations
- Set up similar organization in US to help homeowners make similar renovations (ie. Windows) and with new buildings to follow LEED certification
- Follow Denmark's policy of prohibiting oil/gas fired boilers in places that are supplied by Natural Gas in US

The Impacts of Danish Retrofitting

A 35% increase in efficiency makes Denmark homes more efficient than MA and MI, equal to CO.



COP21: Climate Change Summit, Paris France

- 195 countries, 150 world leaders, 40,000 delegates
- Mission: legally binding agreements to reduce carbon emissions
  - hold global average temp below 2 degrees centigrade from pre-inds. level
- Russia: to cut emissions 70% by 2030
- EU: decarbonization of world economy by 2100

Source: CNN News, European Union, World Press

Re-evaluating our hypothesis based on the numbers:

When focusing on space heating only, we have determined the U.S. to be more energy efficient than Denmark.

- End use consumption of energy and age of building are leading factors in energy efficiency, not fuel type used or climate.

Energy efficiency and CO_2 emissions improvements through:

- Denmark: building consumption/retrofitting
- United States: energy production

Bottom Line: Both can learn from, and incorporate policy aspects from the other moving forward

Our Conclusions

1. Our hypothesis was partially incorrect. Denmark is **less efficient** in terms of energy use for *residential space heating*
2. **Age of home** is the most critical factor in terms of space heating efficiency, as opposed to fuel used & climate
3. Our hypothesis was correct in that Denmark is **more efficient** in terms of *total* CO_2 *emissions* and their future plans to curtail emissions
4. We conclude that Danish policies moving towards carbon neutrality could be a reference for a **second wave** of the U.S. Clean Power Plan
5. **Major Danish home renovation** is critical to improving *consumer efficiency*