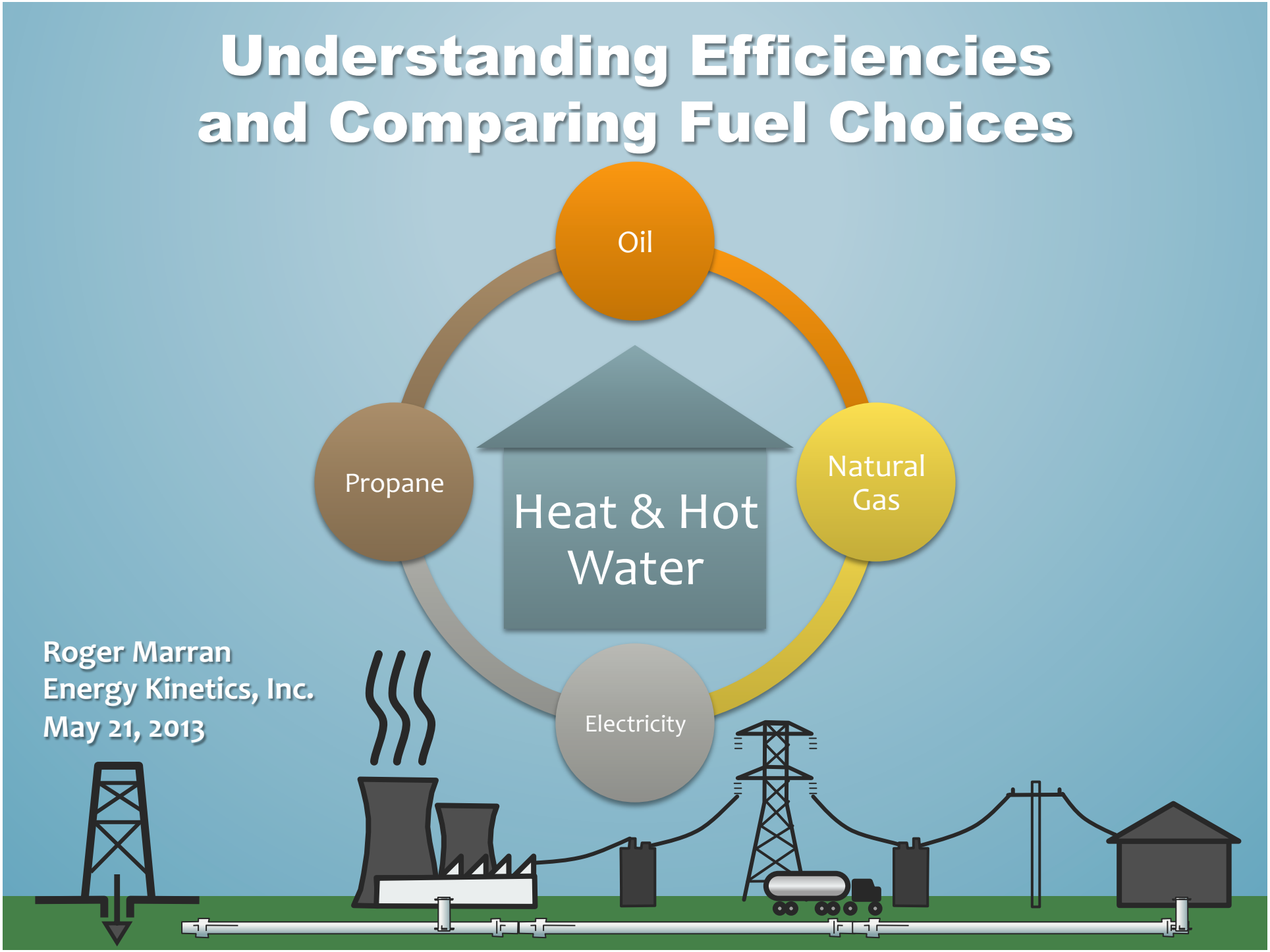
Understanding Efficiencies and Comparing Fuel Choices



Roger Marran
Energy Kinetics, Inc.
May 21, 2013

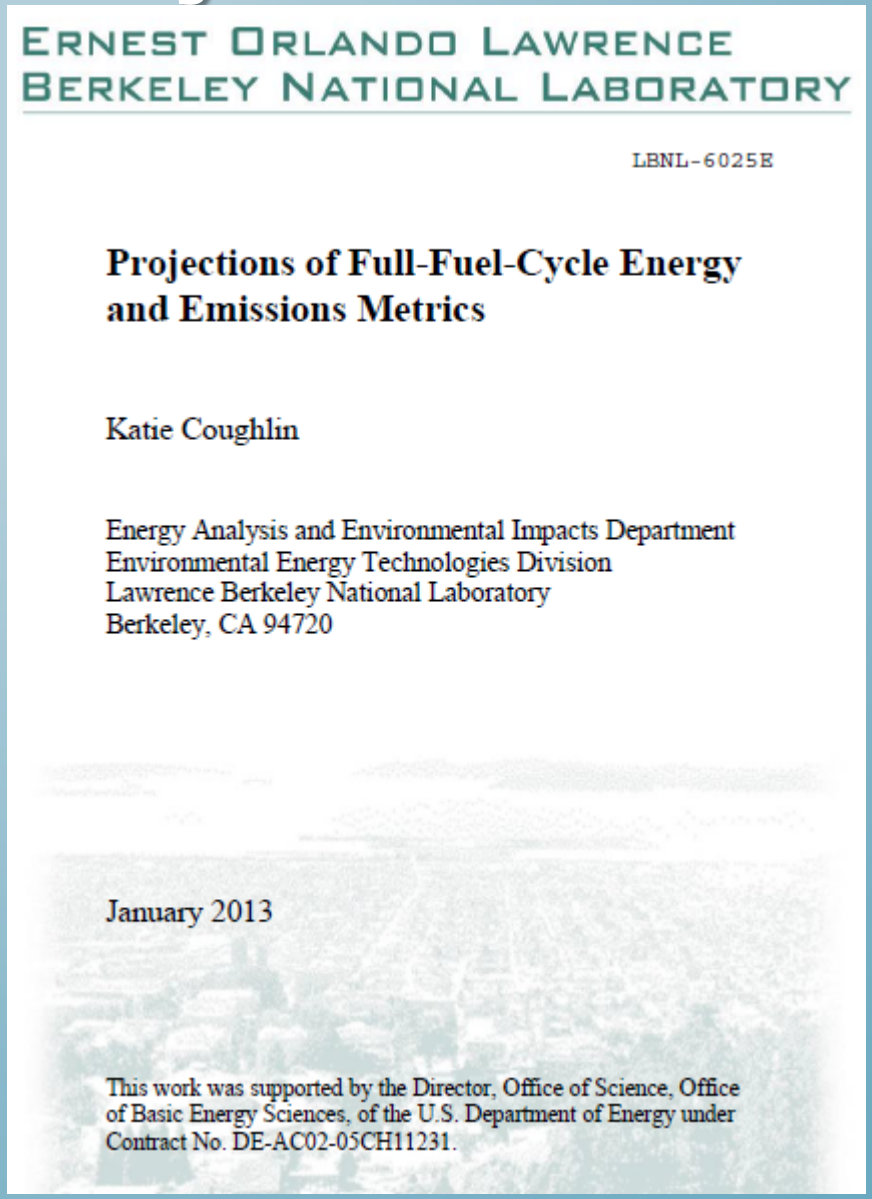
Dept. of Energy LBNL Study Jan. 2013

Table 12 Energy multipliers for 2010, 2020 and 2030

μ	Coal	Petroleum	Natural gas	Electricity
2010	1.025	1.134	1.107	1.036
2020	1.026	1.145	1.103	1.035
2030	1.026	1.161	1.099	1.035

The next slide does not include the electricity factors above

RM note: Figures in the chart on the next page are actually a bit better now than they were with more coal source electric from just a few years ago.



ERNEST ORLANDO LAWRENCE
BERKELEY NATIONAL LABORATORY

LBNL-6025E

Projections of Full-Fuel-Cycle Energy and Emissions Metrics

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January 2013

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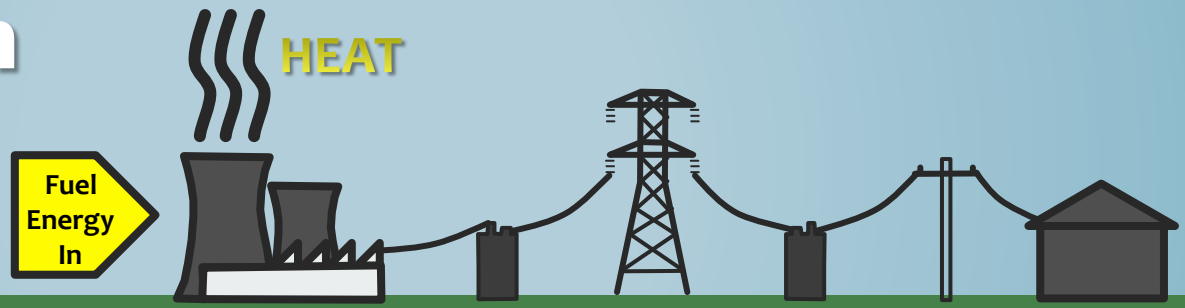
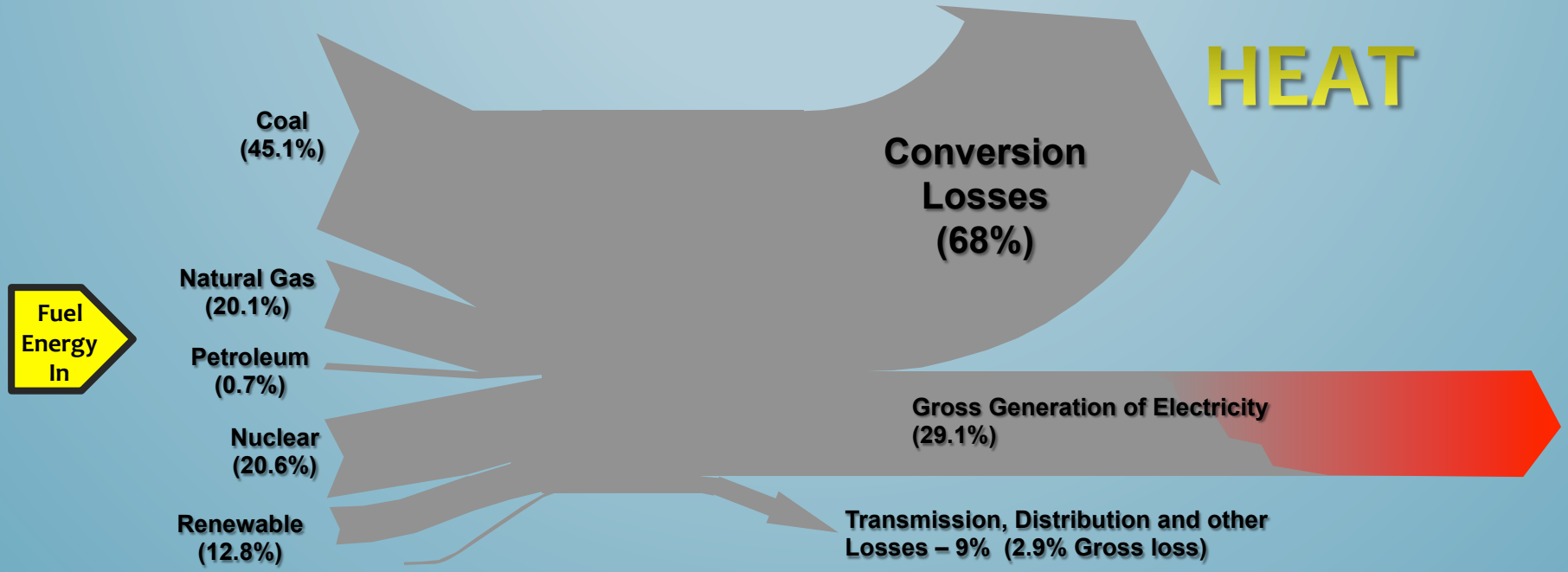
Electricity: Generation and Distribution





Nuclear Power Plant note: EIA document of power plant efficiency "One measure of the efficiency of power plants that convert a fuel into heat and into electricity is the heat rate, which is the amount of energy used by an electrical generator or power plant to generate one kilowatt-hour (kWh) of electricity."

www.eia.gov/tools/faqs/faq.cfm?id=107&t=3

EPA Individual Waste Reduction Model (iWARM) www.epa.gov/waste/conserve/tools/iwarm/iwarm.xls

Annual Energy Review 2011 DOE/EIA-0384(2011) | September 2012 www.eia.doe.gov/emeu/aer/pdf/aer.pdf

Coal plants: http://www.netl.doe.gov/energy-analyses/pubs/Impr_Effcy_of_CFPP_CO2_Redctns_1109.pdf

Mini Split Performance

- Testing of two high performance mini split systems
- Heating COP rating of 3.9 and 4.2
- Actual performance generally better than ducted systems
- Does not include distribution losses from the condensing unit to the indoor unit

Cold Climate COP approx. 2

Cold Climate Heating Capacity Limited

Cyclic testing with the defrost cycle can have a significant impact

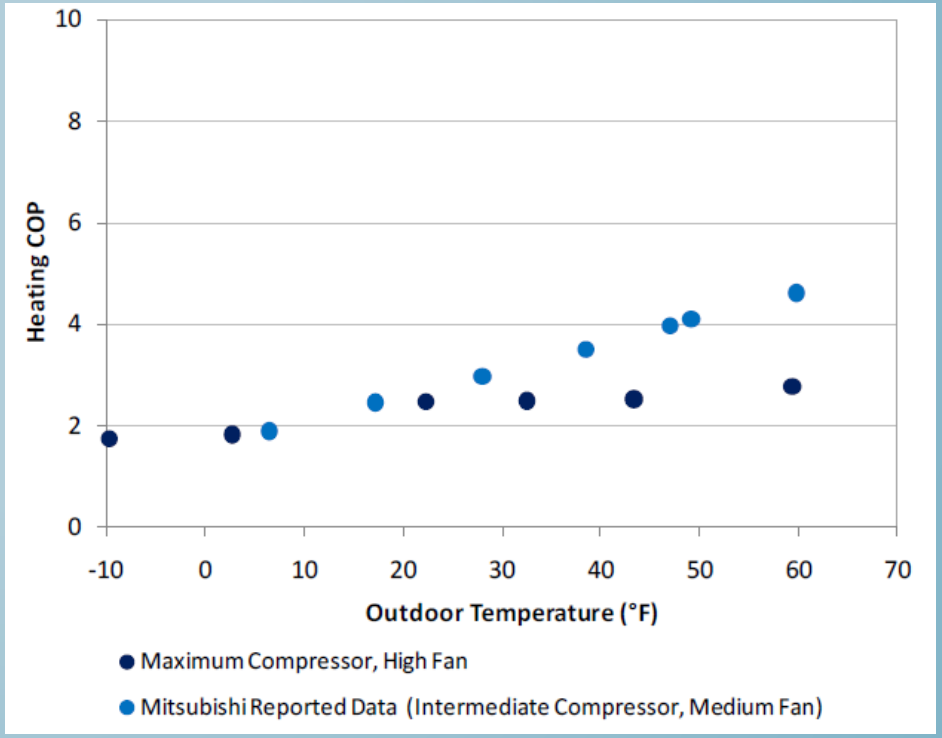


Table 3. Defrost Test Results

MSHP	Test Code	Total Cycle Time (min)	Defrost Time (min)	Integrated Cycle COP	Integrated Heating COP	Defrost COP Penalty
12RLS	H-DF-35-M-MX	117	10.3	3.26	3.38	3.5%
	H-DF-17-M-MX	142	14.9	2.90	3.06	5.0%
FE12NA	H-DF-35-M-MX	90	3.3	1.76	1.78	1.4%
	H-SS-27-H-MX	79	2.0	1.72	1.74	1.3%
	H-SS-17-H-MX	91	3.8	2.24	2.28	1.8%
	H-SS-17-M-MX	90	3.3	0.88	0.89	1.4%
	H-SS-7-H-MX	31	2.2	1.08	1.13	4.7%
	H-SS-7-L-MX	23	2.5	1.53	1.60	3.9%
	H-SS-n3-H-MX*	47	10.2	1.35	1.52	11.5%

Air Source Heat Pumps

HSPF 9 in Wilkes Barre, PA - EIA Spreadsheet

179% Efficiency

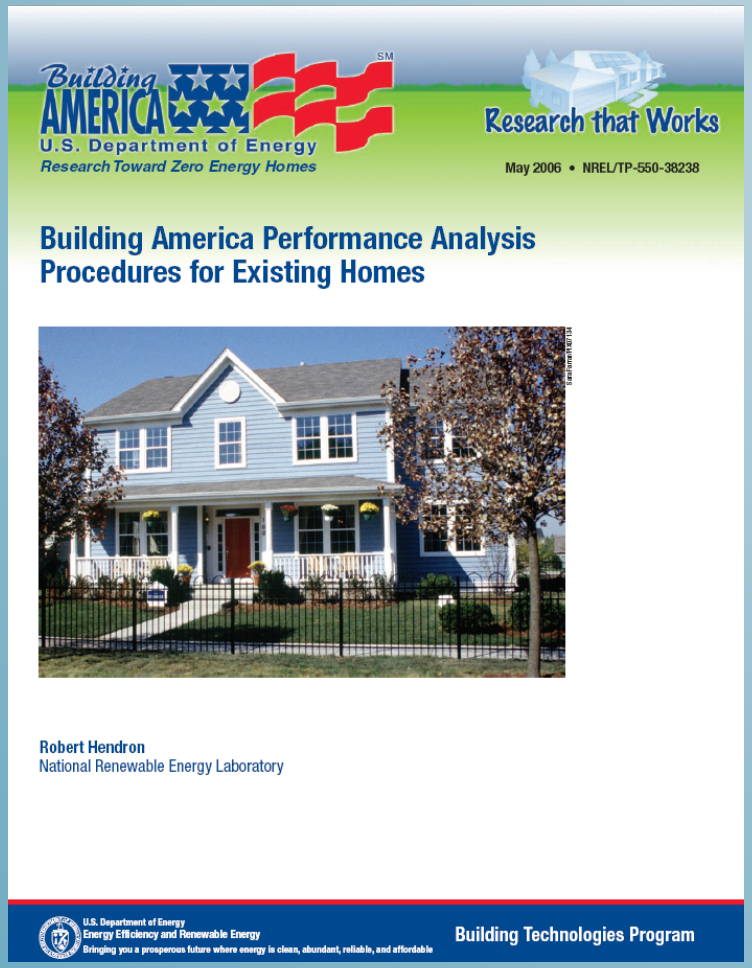
Fuel Type	Fuel Unit	Fuel Price Per Unit (dollars)	Fuel Heat Content Per Unit (Btu)	Fuel Price Per Million Btu (dollars)	Heating Appliance Type	Type of Efficiency Rating [4]	Effiency Rating or Estimate [5]	Approx. Efficiency (%)	Per Million Btu (dollars)
Fuel Oil (#2)	Gallon	3.60	138,690	$25.96	Furnace or Boiler	AFUE	85.0	85%	$30.54
Electricity	KiloWatt-hour	0.158	3,412	$46.31	Furnace or Boiler	Estimate	98.0	98%	$47.25
					Air-Source Heat Pump [6]	HSPF [6]	*6.1*	179%	$25.90
					Geothermal Heat Pump	COP	2.7	270%	$17.15
					Baseboard/Room Heater	Estimate	100.0	100%	$46.31
Natural Gas [1]	Therm [2]	$1.52	100,000	$15.20	Furnace or Boiler	AFUE	85.0	85%	$17.88
					Room Heater (Vented)	AFUE	65.0	65%	$23.38
					Room Heater (Unvented)	Estimate	100.0	100%	$15.20
Propane	Gallon	$2.55	91,333	$27.92	Furnace or Boiler	AFUE	85.0	85%	$32.85
					Room Heater (Vented)	AFUE	65.0	65%	$42.95
Wood [3]	Cord	$200.00	22,000,000	$9.09	Non-Catalytic, Room Heater	EPA	63.0	63%	$14.43
					Catalytic, Room Heater	EPA	72.0	72%	$12.63
Pellets	Ton	$250.00	16,500,000	$15.15	Room Heater (Vented)	EPA	78.0	78%	$19.43
Corn (kernels) [3]	Ton	$200.00	14,000,000	$14.29	Room Heater (Vented)	EPA	78.0	78%	$18.32
Kerosene	Gallon	$4.41	135,000	$32.65	Room Heater (Vented)	Estimate	80.0	80%	$40.81
Coal (Anthracite)	Ton	$200.00	25,000,000	$8.00	Furnace/Boiler/Stove	Estimate	75.0	75%	$10.67

"The actual heating efficiency and seasonal performance of an air-source heat pump that uses electric resistance heating as the auxiliary heat source may vary significantly from the rating it receives when tested under the standard procedures and conditions that manufacturers use to determine heat pump efficiency."

www.eia.doe.gov/neic/experts/heatcalc.xls

"Climate Impacts on Heating Seasonal Performance Factor (HSPF) and Seasonal Energy Efficiency Ratio (SEER) for Air Source Heat Pumps," Fairy, et al, ASHRAE Transactions, American Society of Heating, Refrigerating and Air Conditioning Engineers, Inc., Atlanta, GA, June 2004.

Heat and Hot Water System Distribution Efficiency

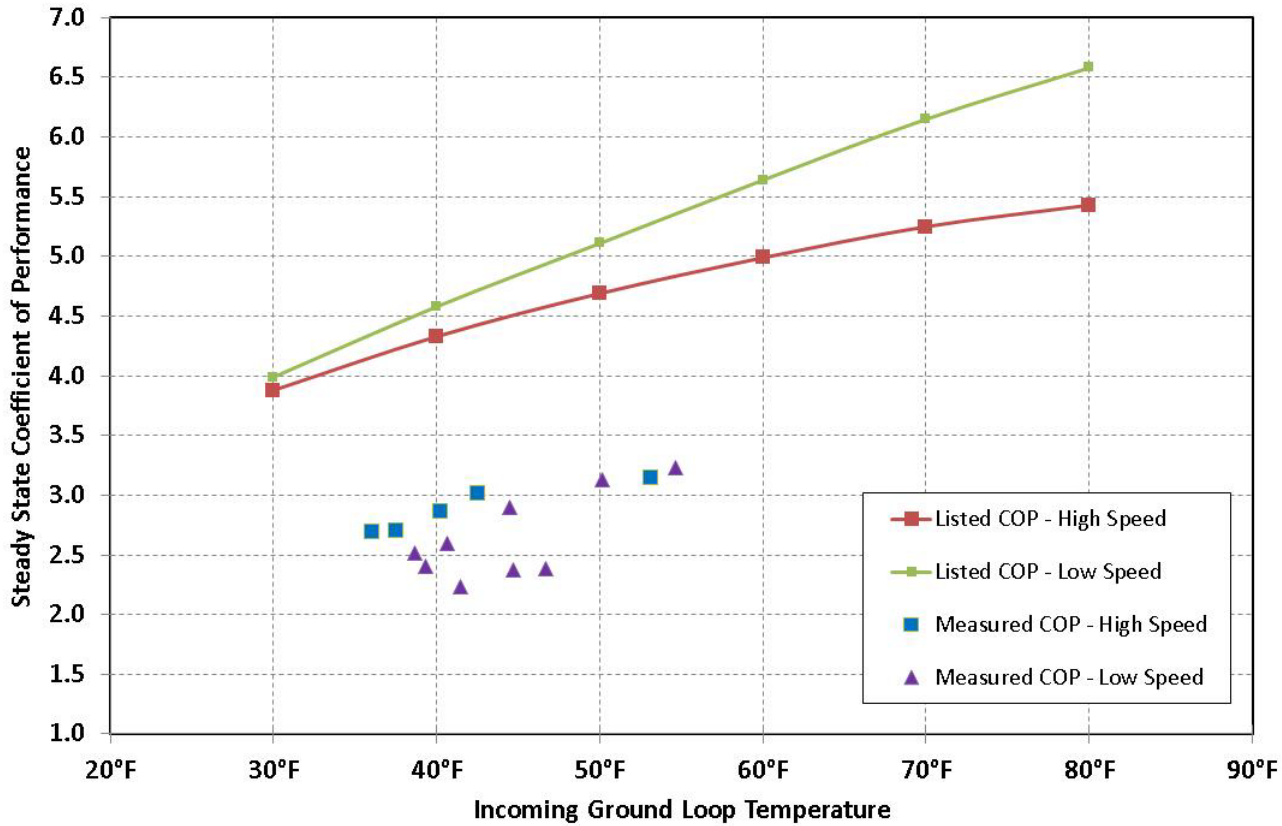


1. NREL: Duct efficiency typically 25%-40% Losses
2. PG&E Study: faulty ductwork accounts for more than 25 percent of the heating loss in an average California home
3. LBNL integrating ducts in conditioned space (still 15% losses, although some regain benefits)
4. NREL: Hydronic distribution efficiency of 95%

Building America Performance Analysis Procedures for Existing Homes, May 2006 • NREL/TP-550-38238 and NREL report 30506.
www.nrel.gov/docs/fy06osti/38238.pdf
http://www.pge.com/myhome/saveenergymoney/resources/heating/ductwork/index.shtml
Integrating ducts into the conditioned space: Successes and challenges; Jeffrey Siegel, Iain Walker, LBNL-55675 (2004).

Ground source heat pumps are way off of rating… worse than boilers possibly

"Based on the discrepancy between the rated and measured efficiencies, the overall efficiencies of these GSHP systems are not significantly higher than alternative space conditioning methods, especially compared to the new inverter driven compressor air-source heat pumps available in the market."



One case indicates 47% lower performance than rated COP.

This means it will consume almost twice as much energy.

Issues:

Fan power used in the calculation of a unit's COP/EER does not include flow resistance from ducts, nor does pump power include the resistance of the ground loop.

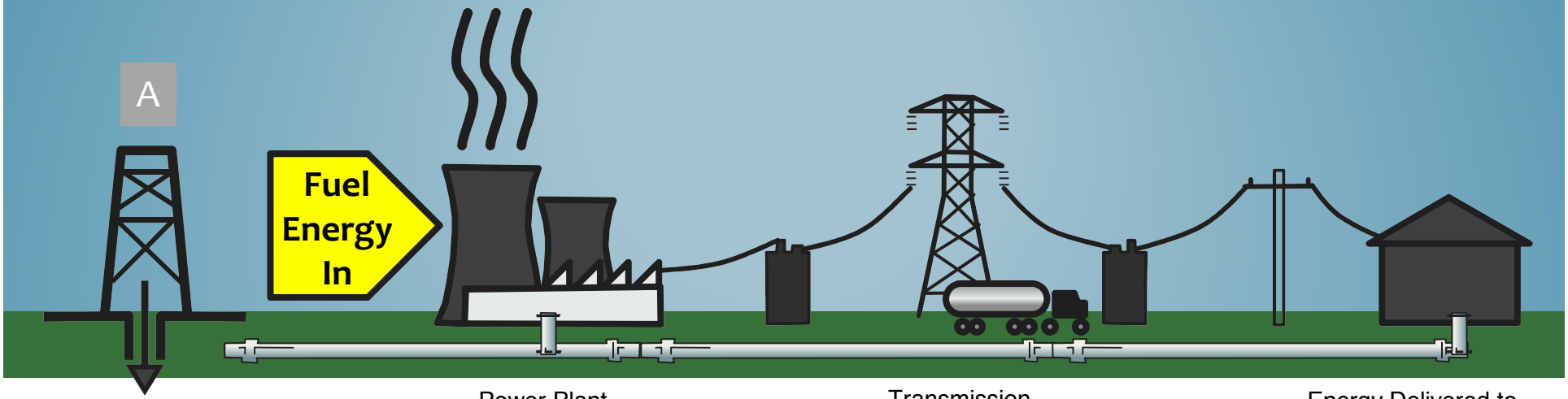
Table 7. Rated Versus Measured System Efficiencies

	ISO/ARI Rated Heat Pump Efficiency (COP/EER)		Measured Steady State Efficiency (COP/EER)		Performance Difference (COP%/EER%)	
	Low Stage	High Stage	Low Stage	High Stage	Low Stage	High Stage
Black River Falls	4.5/23.7	4.0/18.5	3.1/18.1	3.1/15.9	31%/23%	23%/14%
Stoughton	5.1/30.0	4.2/20.1	2.7/16.7	2.7/–	47%/44%	36%/na

http://www.nrel.gov/docs/fy12osti/54240.pdf

Full Fuel Cycle – Cost to Operate & Source Fuel

Step 4: Delivered energy, appliance efficiency, fuel cost, overall energy consumed from source fuel



Oil/gas well or coal mine to produce and transport energy

Power Plant Generates Electricity

Transmission And Distribution Electricity or Fuel

Energy Delivered to Building or Home