Heating System Cost and Performance Analysis

Summary

This paper is an analysis of the heating performance characteristics of the most prevalent heating systems on the market today and examines the costs associated with each heating system including the heating product, installation, maintenance, heating operation, and replacement costs. While every situation is unique, it can still be beneficial to examine systems in a comparable framework. In this case, we used a 3 bedroom, 2000 sf single family ranch style home with a monthly average heating requirement of 3,000,000 BTU as our model system.

The analysis looks at the base Coefficient of Performance (COP) for each system, then multiplies that efficiency by design losses due to non-zonal control, ducting losses, and excessive thermal gradient requirements. Next, the envelope loss differential between radiant systems and non-radiant systems is factored in to account for the fact that radiant systems are run at lower air temperatures with equal human thermal comfort (ASHRE Standard 55). This procedure yields a net COP for each system, which when combined with the relative fuel costs for each system, is used to compute the estimated operating cost of each heating system.

The results of this procedure demonstrates that Ductless Mini-Split Heat Pumps and Radiant Heating Ceiling panels are the two most cost effective heating systems inclusive of operating, maintenance, and replacement costs.

Methodology

Efficiency

Every heating system has a base Coefficient of Performance (COP), a figure which determines the relative production of heat energy to energy consumed by the system. Most traditional systems have COPs less than 1, due to the inherent inefficiencies of transforming one energy type into another. Heat pumps are one notable exception to this rule, as they are not transforming energy between types, but rather use electrical energy to move heat energy from one location to another (outside the home to inside the home). As such, they have a variable COP depending on the temperature difference they are trying to overcome (colder weather means such systems become less efficient, although geothermal heat pump systems get around this by utilizing the ground as the heat source, which is fairly temperature stable year round). For the purposes of this analysis, we also utilized a COP for radiant systems of 1.20, due to the fact that thermal comfort derived from infrared sources is more efficient than convective heating. The final figures of efficiency confirm this assumption when compared to the results of field studies of infrared systems.

Losses due to ducting, non-zonal control, and excessive temperature gradients are factored in next. Ducting losses are estimated to range from 15% to 30% for centralized heating systems. A lack of zone control also results in most central systems heating some space when they are not in use, or over/under heating other areas, wasting energy. The net result of these inefficiencies is estimated to be around 30%. Baseboard and Cadet Wall Heaters, while not central, have losses of 30% and 10%, respectively, due to the thermal gradients they set up in order to perform effectively.

Lastly, the envelope loss differential was calculated by looking at moderate heating loads (outside temperature of 45°F) in our model home that had air infiltration figures that were between a typical home (0.40 air changes per hour) and an energy star rated home (0.05 air changes per hour). Radiant systems losses were modeled at a conservative 66°F indoor temperature and the convective systems were modeled at 70°F. The resulting differential in heat loss was expressed as a percentage of the overall load.

The relative cost per BTU for each system was determined by looking at typical national figures for the cost of electricity, natural gas, oil fuel, and propane. An annual maintenance figure of $120 was added for all systems with mechanical components and was determined based on recommendations from the manufacturers themselves.

Total Cost of Ownership

The total cost of ownership for each system was determined by modeling their operating costs alongside repair and replacement costs. System lifetimes used were from the NAHB Study of Life Expectancy of Home Components.

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Performance and Cost Comparison of Typical Heating Systems

System Type	Geothermal	DMSHP	Radiant Panel	Heat Pump	Furnace - Gas	Wall Heater	Baseboard	Furnace - Propane	Furnace - Oil
Base COP	3.00	2.20	1.20	2.10	0.92	1.00	1.00	0.92	0.75
Design Losses	30%	0%	0%	30%	30%	10%	30%	30%	30%
Convective Infiltration Loss Delta	14%	14%	0%	14%	14%	14%	14%	14%	14%
Net COP	1.81	1.89	1.20	1.26	0.55	0.77	0.60	0.55	0.45
Rel To Wall Heater	43%	41%	65%	61%	140%	100%	129%	140%	171%
Yearly Maintenance	$ 120	$ 120	$ -	$ 120	$ 120	$ -	$ -	$ 120	$ 120
MBTUs Consumed*	1.66	1.59	2.50	2.37	5.42	3.88	4.98	5.42	6.64
Cost per MBTU	$ 29.33	$ 29.33	$ 29.33	$ 29.33	$ 14.56	$ 29.33	$ 29.33	$ 27.18	$ 32.45
Monthly Heating Cost	$ 49	$ 46	$ 73	$ 70	$ 79	$ 114	$ 146	$ 147	$ 216
Annual Heating Cost	$ 585	$ 558	$ 880	$ 835	$ 947	$ 1,364	$ 1,754	$ 1,767	$ 2,587
% Rel To Wall Heater	43%	41%	65%	61%	69%	100%	129%	130%	190%
$ Rel To Wall Heater	$ (779)	$ (806)	$ (484)	$ (529)	$ (417)	$ -	$ 390	$ 403	$ 1,223
Average Yearly Operating Cost	$ 705	$ 678	$ 880	$ 955	$ 1,067	$ 1,364	$ 1,754	$ 1,887	$ 2,707

***System installation and operation costs are based on a typical 2000 sf single family home with a average monthly heating requirement of 3 MBTU**

The table below shows the Total Cost of Ownership (TCO) of various heating systems over a 25-year time span. The TCO includes yearly operating cost (heating & maintenance), system installation cost and system replacement cost. Replacement costs are included based on NAHB standard system lifetimes.

System Type	System Lifetimes**	Install Cost*	Replacement Cost	0	5	10	15	20	25
Geothermal Heat Pump	16	$ 33,000	$ 10,000	$ 33,000	$ 36,523	$ 40,046	$ 43,568	$ 57,091	$ 60,614
DMSHP	16	$ 9,000	$ 8,000	$ 9,000	$ 12,390	$ 15,780	$ 19,170	$ 30,560	$ 33,950
Radiant Panel	**40**	**$ 8,000**	**$ 7,100**	**$ 8,000**	**$ 12,399**	**$ 16,798**	**$ 21,196**	**$ 25,595**	**$ 29,994**
Heat Pump	16	$ 18,000	$ 10,000	$ 18,000	$ 22,775	$ 27,551	$ 32,326	$ 47,102	$ 51,877
Furnace - Gas	15	$ 13,000	$ 5,000	$ 13,000	$ 18,333	$ 23,666	$ 33,999	$ 39,332	$ 44,665
Wall Heater	10	$ 3,000	$ 3,000	$ 3,000	$ 9,820	$ 19,640	$ 26,460	$ 36,280	$ 43,099
Baseboard	15	$ 2,280	$ 2,280	$ 2,280	$ 11,048	$ 19,817	$ 30,865	$ 39,634	$ 48,402
Furnace - Propane	15	$ 13,000	$ 5,000	$ 13,000	$ 22,435	$ 31,870	$ 46,305	$ 55,740	$ 65,175
Furnace - Oil	10	$ 13,000	$ 5,000	$ 13,000	$ 26,535	$ 45,071	$ 58,606	$ 77,142	$ 90,677

*System installation and operation costs are based on a typical 3 bdrm, 2000 sf single family home.

** System lifetimes from NAHB standard guidelines

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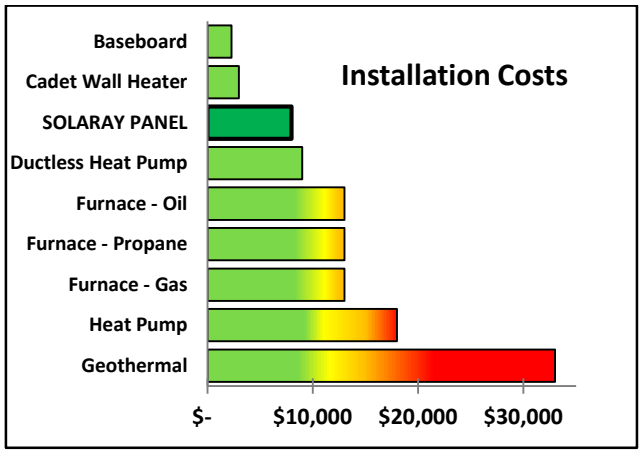
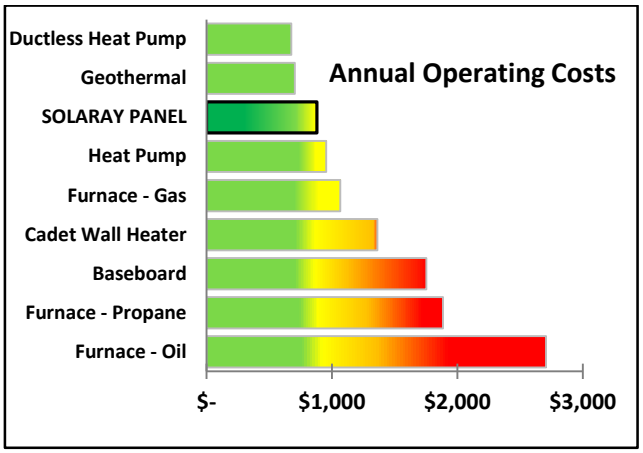
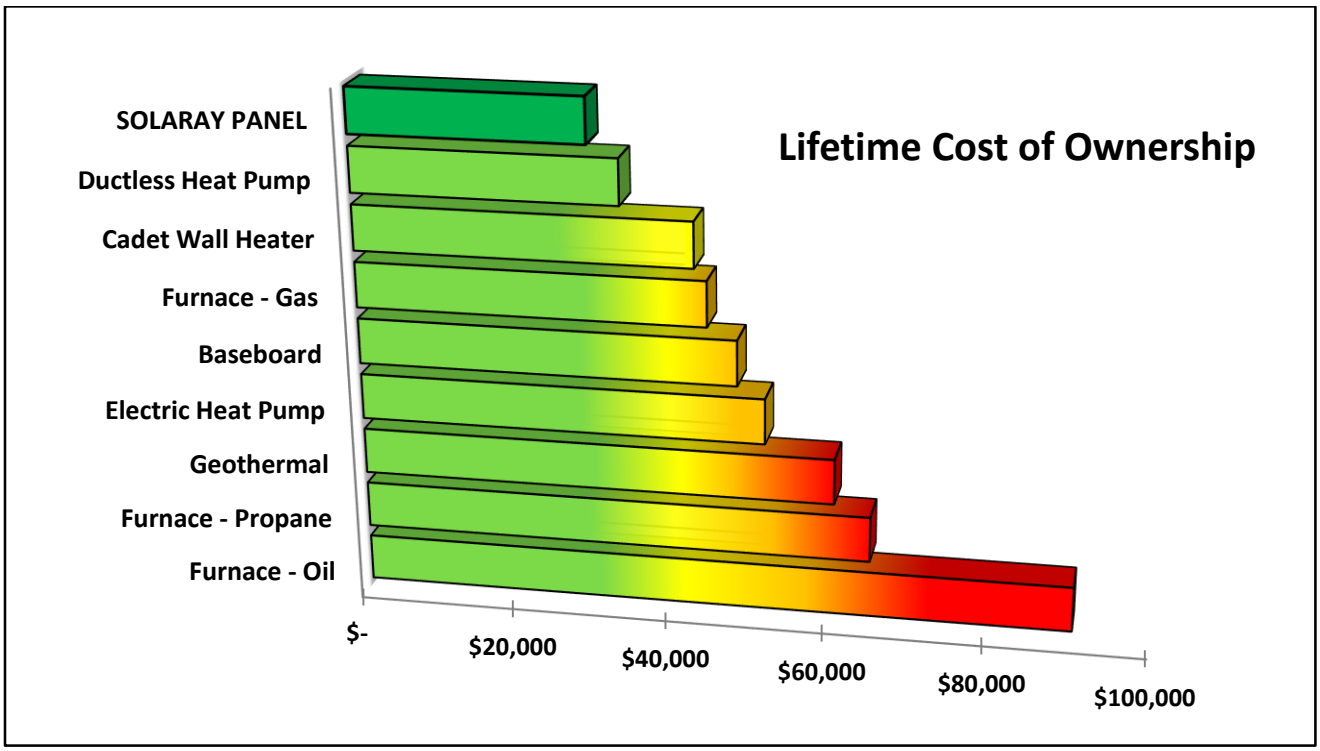
The charts below illustrate the data from the above tables, breaking out the analysis by initial installation costs, annual operating costs, and Total Cost of Ownership (derived from initial installation costs plus 25 years of maintenance, operating costs, repairs, and system replacements) for each heating system examined.







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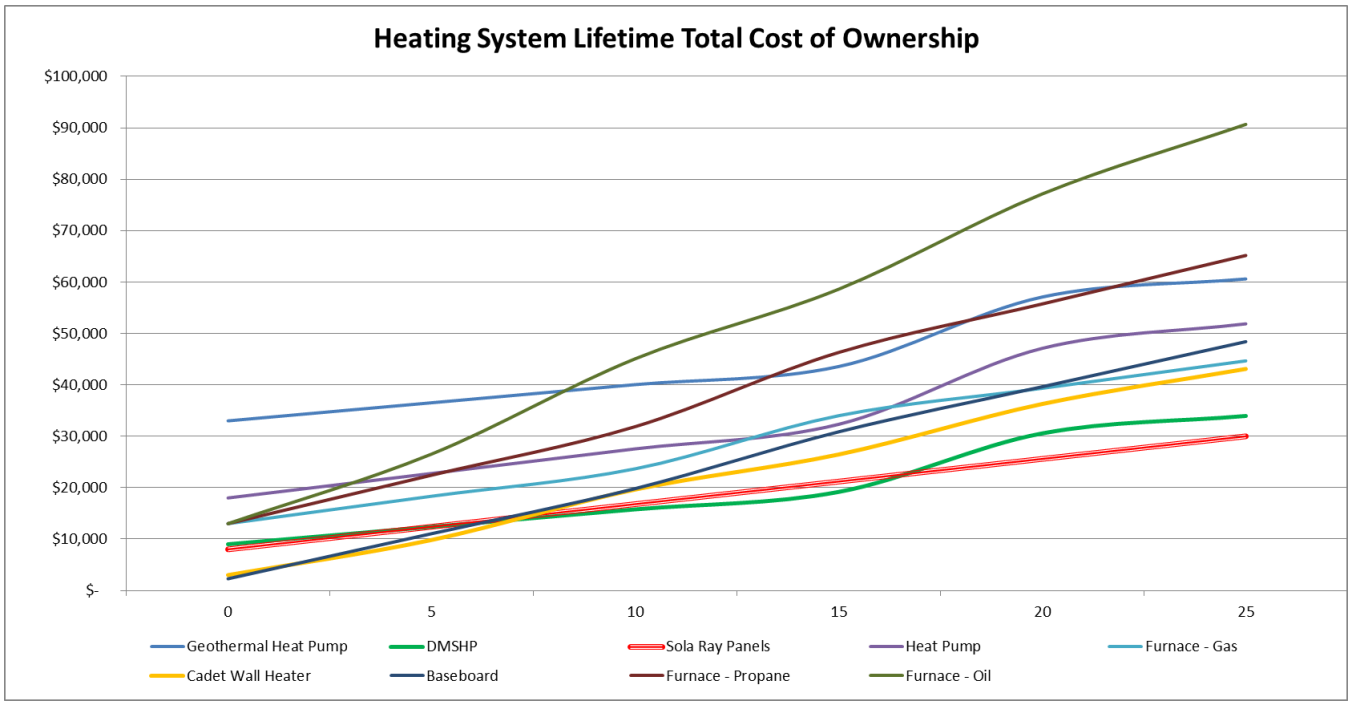
As shown in the chart below, the payback for Radiant Panels or DMSHPs vs Cadet Wall Heaters is approximately 7 years. Both Radiant Panels and DMSHPs are far less expensive than traditional furnaces.



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BTU Analysis of Different Energy Fuels:
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