Economic Analysis

of

Geothermal Heating and Air-Conditioning Systems

for the

The Jackson Public Library

Prepared by

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for

The Friends of Jackson Library, Building Committee

Jackson, NH

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Jackson Public Library

Payback Analysis for Geothermal HVAC Systems

Summary

This revision, Rev. 7, reflects updated seasonal heating and cooling loads based on analyses conducted by Design Day Mechanicals, Inc. in late January 2010 (using the latest information on the Library construction techniques). It also incorporates projections based on the 2010 energy costs and 20-year cost projections published by NH OEP and DOE/EIA.

The major conclusion of this study is that 5-ton geothermal HVAC system using a propane full-backup/supplement can economically satisfy the Jackson Public Library heating and cooling requirements. That is, payback of the initial capital outlay is achieved in approximately 7.1 years and the 20-year energy cost savings are $77k.

The estimated capital cost of the Geothermal HVAC system is $35,000. This estimate uses labor rates that are consistent with that required by the Grant Application issued by the State of New Hampshire Office of Energy and Planning as part of the American Recovery and Reinvestment Act, Energy Efficiency and Conservation Block Grant Program, dated Jan. 8, 2010.

This revision is intended to provide supporting information for use in any reply to the grant request that might be issued by the Town of Jackson.

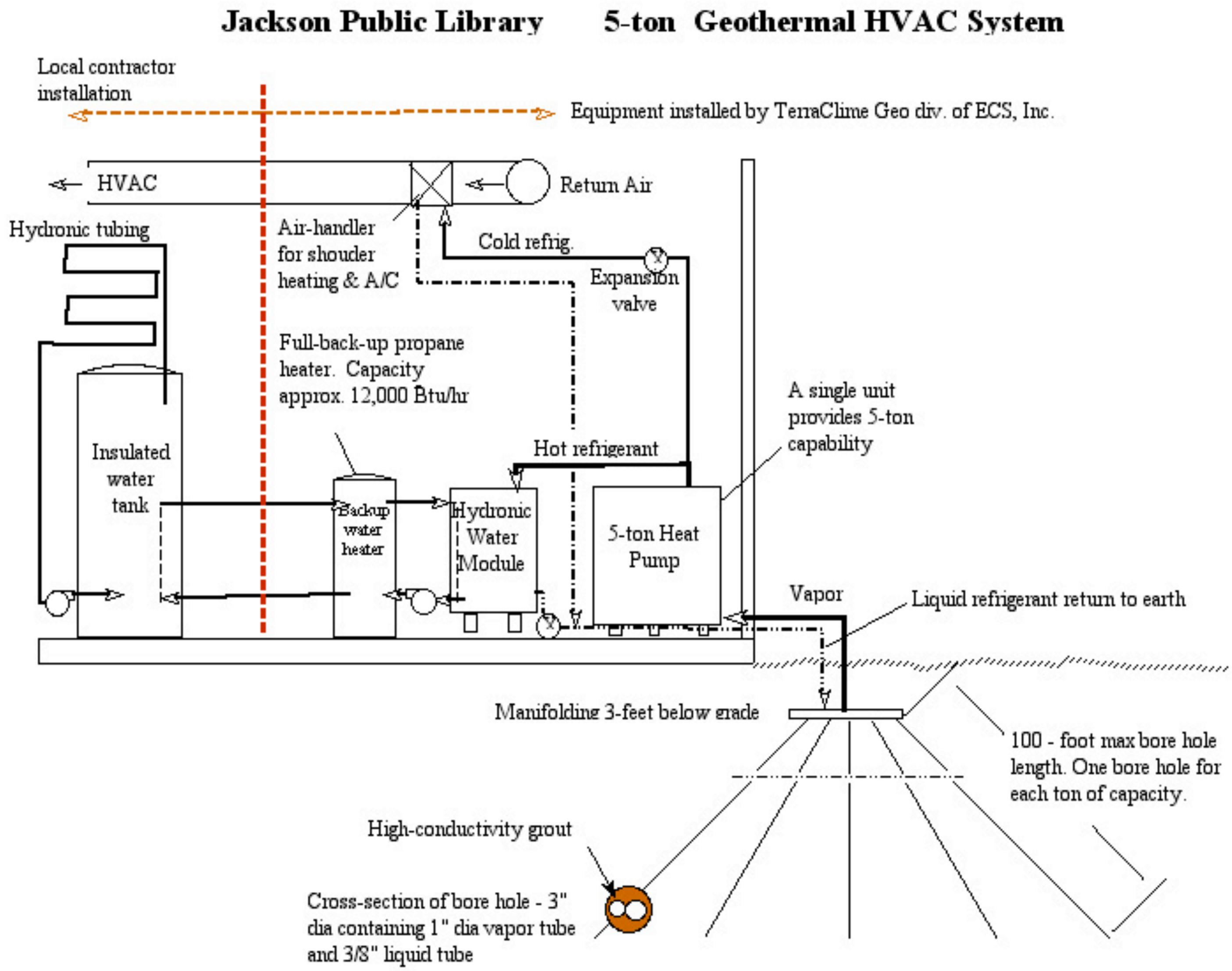
The bottom line is that installation of a geothermal system for the Jackson Public Library will reduce HVAC energy costs over the life of the system. It will contribute to the nation-wide energy-independence movement. It will involve the Jackson populace in the 'green energy' revolution, and will help shield the Jackson taxpayers, who pay the heating bills, from the actions of speculators and outside interests that drive the petroleum markets.

This document presents the details of payback analyses for various geothermal heating and air-conditioning configurations applicable to the proposed library building. The objective of the study was to:

- Identify optimum system configurations.
- Estimate the payback periods.
- Estimate the 20-year term energy savings resulting from employing geothermal energy.

Throughout this document there are references to Year 2009 and Year 2010 assumptions. The differences reflect increased knowledge on the Library needs and characteristics gained between 11/1/2009 and 2/4/210. See ***Assumptions*** for details. Needless to say, Year 2010 reflects current (Rev. 7) thinking. Much of the background work showing the sensitivity of payback results to input parameters was performed using Year 2009 assumptions and is still valid and is therefore retained in this report.

The elements of system are illustrated in the following figure.



Summary figure. Schematic diagram of the recommended geothermal HVAC system for the JPL.

Introduction

In the winter, a geothermal HVAC system uses a heat pump to raise the temperature of a refrigerant, vaporized in the earth, to the temperature required by the building heating system – be it forced hot air, baseboard or radiant (hydronic).

In the summer, the action of the heat pump is that of a standard air-conditioner. Heat is absorbed from the room air and pumped to a temperature higher than ambient and is rejected to the outside air in the condenser.

The heat pump module, Fig. 1, is about the size of a dishwasher and is usually located inside the structure (the unit is quiet – unlike many outdoor air-conditioner condenser units). The Hydronic Water Module (see Fig. 2) is a heat exchanger that delivers heat to the water used in the radiant heat water storage tank – that module can be integrated within the tank to minimize the area occupied by the mechanical units. An “air handler” receives room air from the HVAC ducting system and cools it in the summer, and with required valving and controls in place, can heat the air during the shoulder seasons.

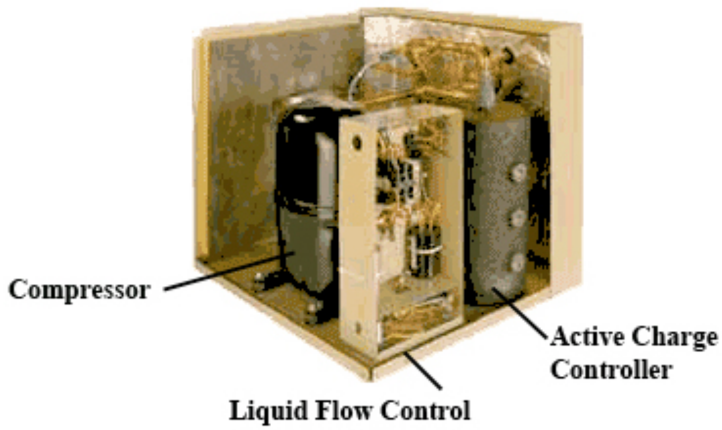


Figure 1 The internal components of a Heat Pump by Earthlinked Technologies

In the heating mode, energy is retrieved from the ground using an “earth loop”. Two of the commonly used earth loops are shown in the Fig. 2. (A third option is a field containing many coils of water/glycol lines – the field requires a relatively large area and is unsuited for the Jackson Public Library installation.)

In general, the DX system is now being employed in areas where significant numbers of geothermal systems are being installed. A DX system installation requires blast hole drilling equipment, Fig. 3, (a $400k investment) which traditional well-drillers do not possess. Equipment of this type, is not uncommon however – it can be seen being used on any major highway construction project to effect the blasting of rock formations. There is such equipment available in southern New Hampshire for use in drilling DX installations – well within the reach of Jackson.

The DX and the deep-well systems have different capital costs, and the deep-well requires energy to drive the circulating pump. A payback analysis can determine if these differences are significant. Investment payback occurs when the cumulative (capital + operating) costs of the geothermal system are below the cost of the competing conventional heating and cooling systems. Typically, the results are shown in terms of cumulative cost as a function of years of operation (Fig. 4). Payback is achieved when the curves cross.

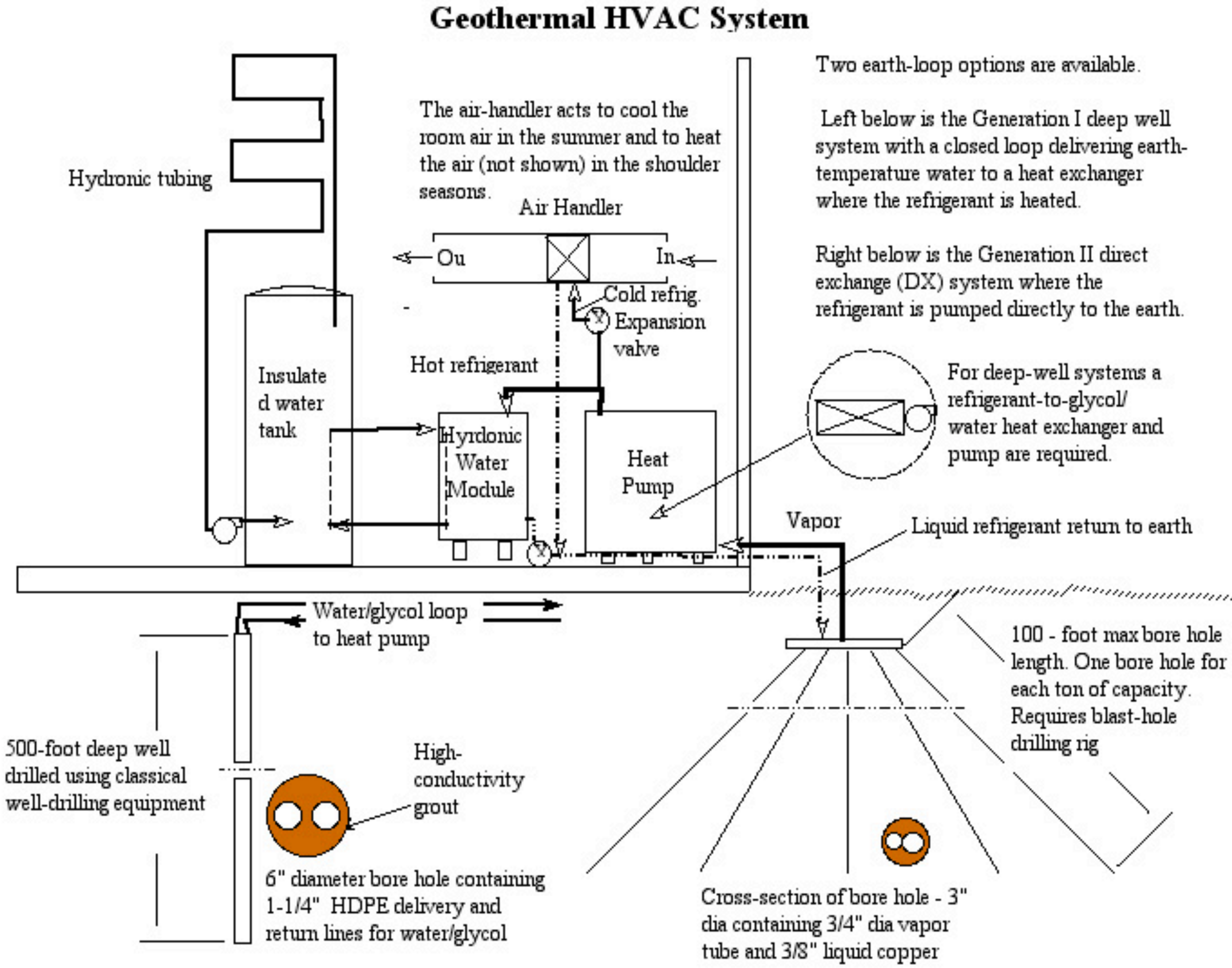


Figure 2. Schematic Diagram of a general Geothermal Heating System.

Figure 3. Blast-hole (bore-hole) drilling rigs are designed to be mobile and compact for working close to structures.

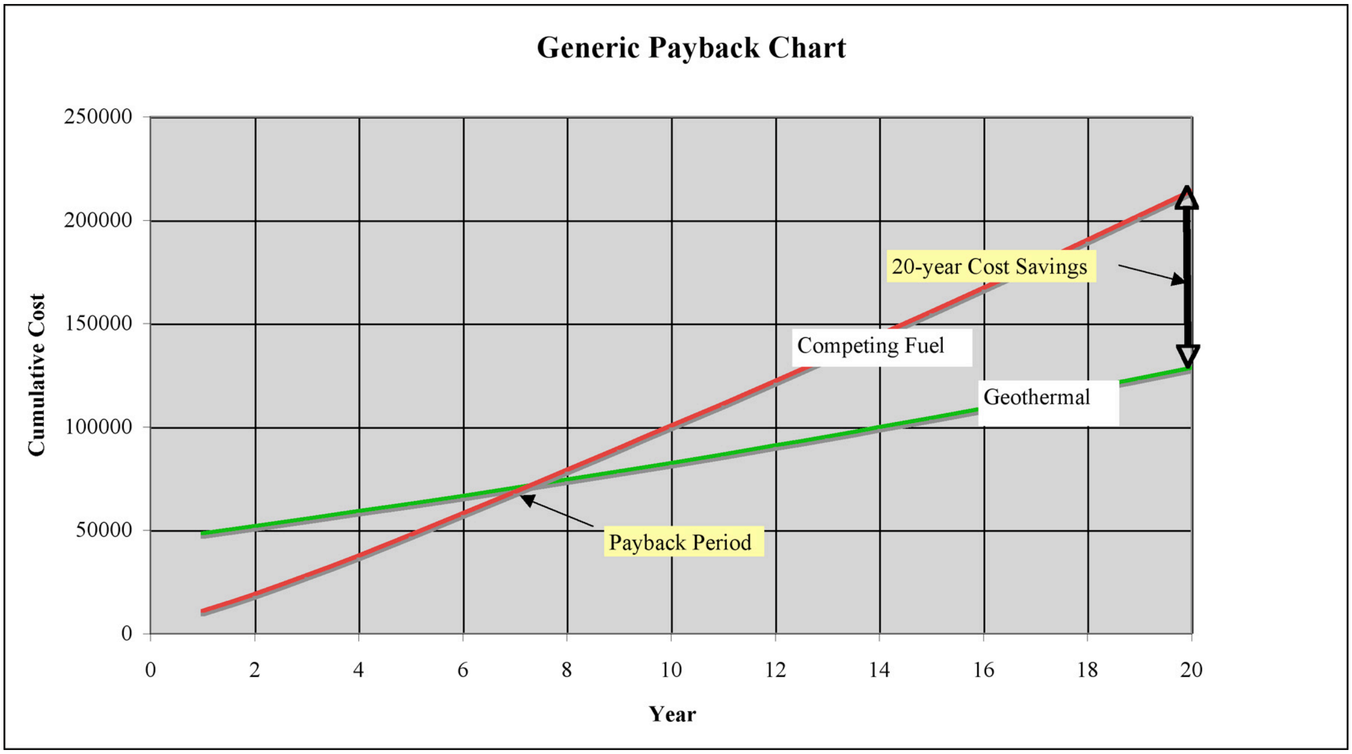


Figure 4. Typical Payback Chart

A payback analysis is commonly used by businesses to judge the potential of a capital improvement to a factory or other facility used in the production of goods and services. The cost of financing the borrowed capital is normally factored into the business case. That capital financing cost was not included in this analysis as the objective of the JPL Building Committee is to finance the installation through up-front contributions and possibly government grants.

The following sections are included in this document:

- Assumptions – a listing of assumptions and a discussion of the major assumptions
- Results – Payback charts for the primary geothermal configuration candidates; plus discussion of results
- Conclusions

Assumptions

Following are the principle assumptions used in the payback analysis. Those having the greatest effect are italicized and are further discussed in this section.

- Seasonal heating loads. Two levels are used in the analysis – one based on 2009 requirement estimates and one based on 2010 estimates. The 2010 estimate takes into account the latest information on building construction techniques and internal heat loads.

  Year 2009 – The seasonal *heating load requirement* was estimated to be 160 MMBtu. The peak rate of 6.25 tons (75,000 Btu/hr) was based on Design Day Mechanical's Energy Audit performed in 2009). The *seasonal cooling load requirement* was 49 MMBtu, based on the Audit energy need using a SEER rating of 13 for the A/C unit.

Year 2010 - Seasonal heating load of 103 MMBtu. Seasonal cooling requirement of 31.3 MMBtu. Values based on Design Day Mechanical's Energy Audit performed January 2010.

- Capital costs. Again two estimates are employed – Year 2009 estimates applicable to privately-funded sources and Year 2010 estimates for government-funded sources. The 2009 estimate for the geothermal heat pump and installation is based on **the *ECS TerraClime Geo*** cost proposal of Aug. 12, 2009. The 2010 estimate is based on TerraClime's cost analysis dated 2/5/2010.
- Rough estimates of the capital cost of conventional heating equipment.
- *Annual energy (electricity, petroleum) cost and cost increases* based on DOE/EIA projections. Again, both 2009 and 2010 estimates are used depending on the comparison being illustrated.
- Heat pump *Coefficient of Performance*; the 2009 best estimate for a DX system was COP = 4. This is based on an Earth temperature of 45F – according to published geothermal data. That COP level was considered appropriate for hydronic heating system using a circulating water temperature of 100F. For the 2010 estimate this has been reduced to 3.5 – there is insufficient data at this time to establish which level is the more appropriate. Use of the 3.5 level gives a more conservative look at the benefits of a geothermal system.

Seasonal Energy Requirement - Heating The seasonal heating requirement depends on the size of the structure, the tightness of construction, and the climatic conditions to which the structure is exposed. For rough estimating purposes, the relationship Btu = HEI * HDD* Sq.Ft is used.

- Btu – Seasonal heating load.
- HEI is the Heating Energy Index – a factor that depends on the tightness of construction (from an air infiltration standpoint) as well as other construction parameters.
- HDD is the Heating Degree Days for the building locale.
- Sq-Ft is a measure of the building footprint.

The heating degree days are 7758 in North Conway (Ref 1).
The building footprint is 2960 sq. ft.
The HEI may can range from less than 5 to over 25 depending on the age of the building and the construction technique employed. For modern construction, a survey conducted by DOE in 1997 (Ref. 2) - produced the values shown in Table 1.

Range of Energy Use	Realtive Frequency
Under 5.0 BTUs/HDD/Sq.Ft.	12.2 percent
Between 5.0 and 10.0 BTUs/HDD/Sq.Ft.	39.4 percent
Between 10.0 and 15.0 BTUs/HDD/Sq.Ft.	23.9 percent
Between 15.0 and 25.0 BTUs/HDD/Sq.Ft.	14.7 percent
Over 25.0 BTUs/HDD/Sq.Ft.	9.8 percent

Table 1. Heating Energy Index for Modern Residential Construction

The tightest construction techniques – foam insulation, taped joints for all sheeting, etc. can produce HEI's less than 5. For the Library it was assumed that fairly tight construction was to be used – a value of 7 assumed in the Year 2009 estimates. As time evolved, it was decided that the building would be made very tight – the use of blower-door procedures that will unveil any infiltration paths will be used. Therefore, Heating Energy Index of 4.5 has been used for the Year 2010 projections.

A second technique and much more rigorous process used to predict seasonal heating loads is by use of energy audit software (Ref 3). Here details of the building dimensions, the insulation R-factors, the window dimensions, etc are entered into a computer program and an energy audit produced. Such an analysis was conducted in early 2009 for the proposed library and these results transmitted to the Building Committee (Ref. 4). The audit was repeated in January 2010 using updated information. Indeed, it is the result of this analysis that leads to the HEI value of 4.5 being selected for the 2010 heating and cooling load estimates. .

To re-iterate, a value of HEI of 7 – representative of tight, modern construction was used for the baseline, Year 2009, calculations. A value of 4.5 is used for the latest (2010) projections.

Seasonal and Peak Energy Requirements – Cooling The 2/16/09 energy audit (Ref. 4) projected that the electrical energy required to drive a conventional A/C system was 3766 kw-hr. Assuming a seasonal energy efficiency ratio of 13, this translated to a cooling load of 48.96 MMBtu. The January 2010 projections indicate that the seasonal cooling load will be 31.3 MMBtu.

That same energy audits give the peak rate of cooling required as 75,000 Btu/hr (2009) and 45,000 But/hr (2010). For both estimated peak cooling loads it was determined that the cooling could be provided by the heat pump alone -- no additional mechanical air-conditioning capacity was needed for cooling.

Energy Costs The payback period will be dependent on the relative price of petroleum products and of electricity. The Department of Energy (DOE), Energy Information Agency (EIA) issues yearly forecasts of prices of these commodities (Ref 5). Fig. 5 shows the forecast for petroleum issued in mid-2009 when the cost of a barrel of oil was $60. For purposes of facilitating the payback analysis and of not over-emphasizing the (unpredictable) cost of petroleum , the non-linear forecast price trend was represented by a constant annual increase over a 20-year term – the final price (about $130/barrel) being the same as the non-linear DOE forecast. The result was a 3.8 % annual increase. This is the cost increase assumed in all the calculations except (a) those expressly designed to illustrate the effect of the more rapid early increase predicted by DOE; (b) those reflecting more recent DOE (2010) forecasts – see Fig. 6.

2009-year energy costs assumed were:

- Propane $2.69 / gal. (See Ref 6)
- Oil $2.41 / gal. (See Ref 6)
- Electricity 16.0 cents/kw-hr. (See Ref 7)

2010-year energy costs are: (See Ref. 8)

- Propane $2.99/gal
- Oil $2.78 / gal.
- Electricity 14.5 cents.kw-hr.

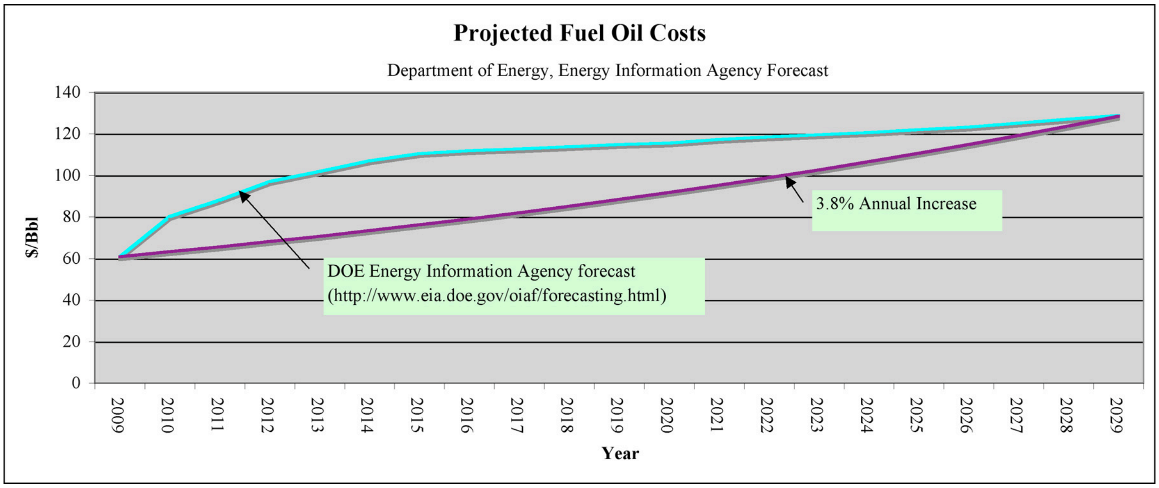


Figure 5. Petroleum Product Prices 2009 Forecast – Annual Increase of 3.8%

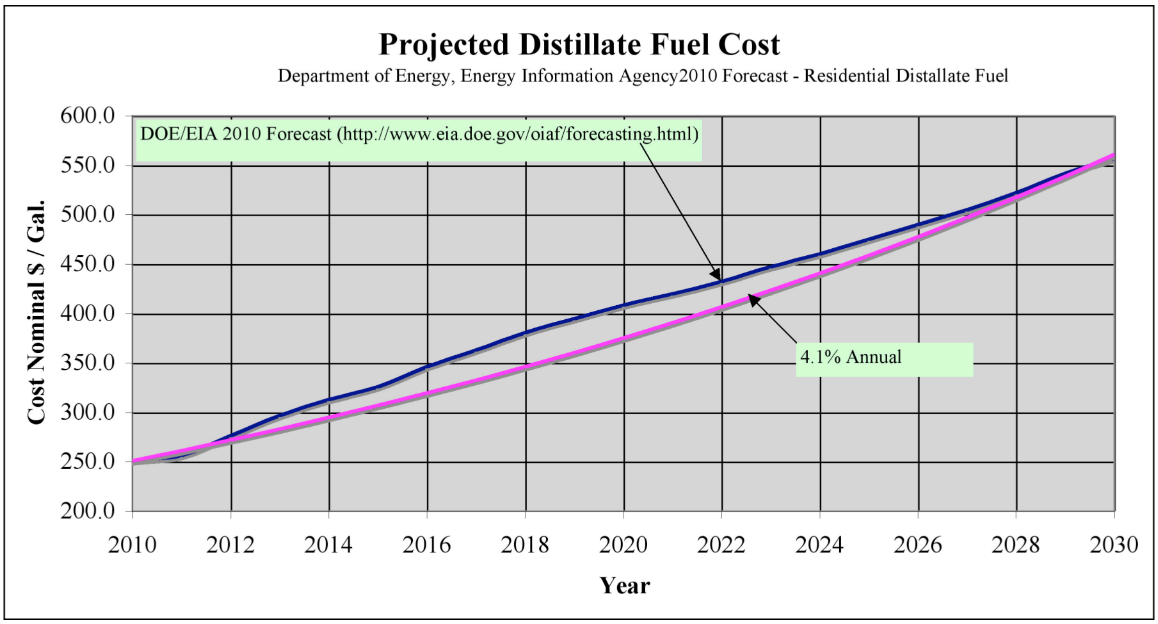


Figure 6. Petroleum Product Prices 2010 Forecast – Annual Increase of 4.1%

Note that the Year 2009 DOE forecast for petroleum price increases projects a much higher rate of increase for the initial 5-year period than for the out years. This means that the increase rate assumed over these early years is quite conservative and that the payback periods calculated therewith will be longer than what would be realized in practice should that DOE forecast prove accurate. Payback period results showing the dramatic effect of this level of price increase are included below.

That initial rapid rise in pricing is not predicted using the Year 2010 forecast. The linearized annual rate increase is 4.1% - a bit higher than the 3.8 % of the Year 2009 forecast.

Figs. 7 and 8 show the data for the projected price of electricity. Here the DOE forecast and the modeled linear increases correspond with one another fairly well over the 20-year term (except for the dip in 2011 prices in the Year 2010 forecast). The absolute prices shown are for the national average. For prices in the state of New

Hampshire, the prices in the beginning year were taken to be those from the NH OEP – see above – and the out-year prices were determined by applying the linear increase factors. Note that the Year 2010 prices are both lower initially and have a lower projected annual increase. This favors the use of electrical equipment such as a GSHP.

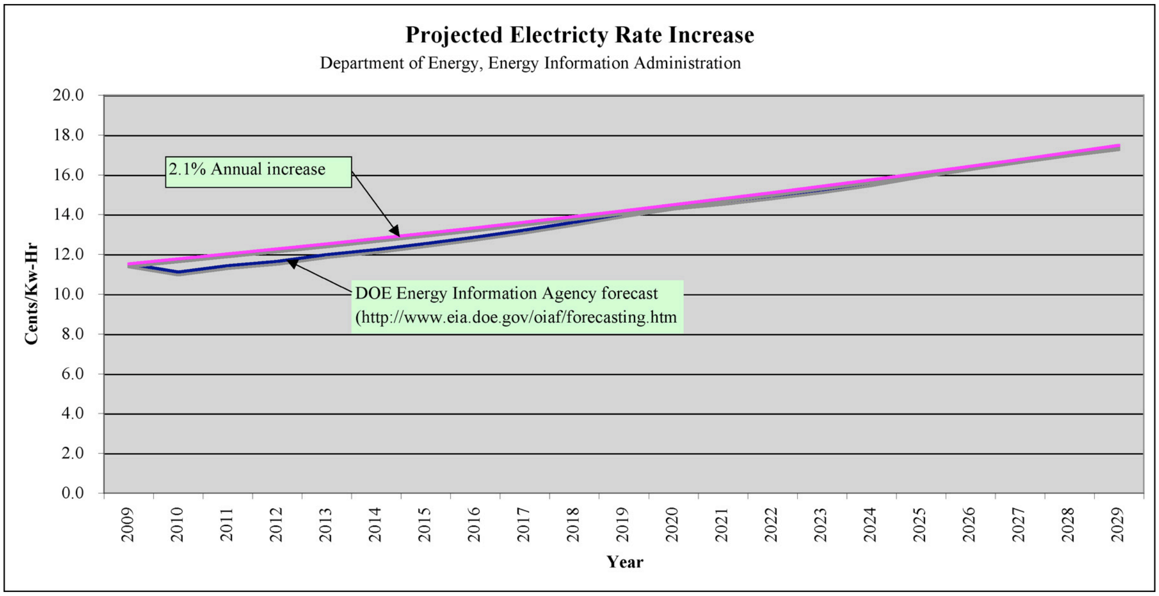


Figure 7. Electricity Price Forecast – 2009 – Annual Increase of 2.1%

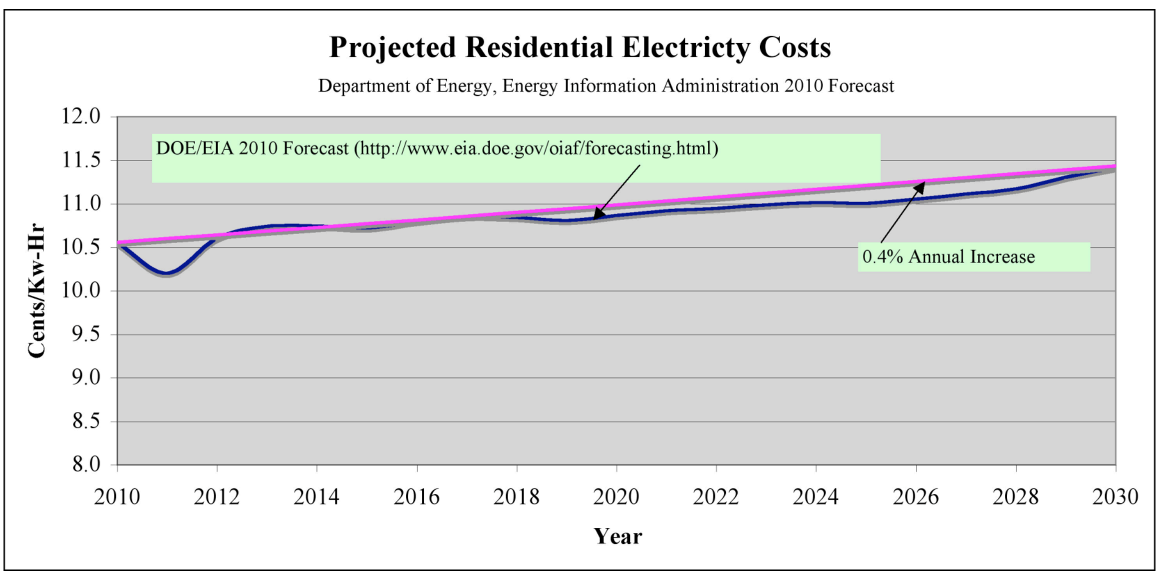


Figure 8. Electricity Price Forecast – 2010 – Annual Increase of 0.4%

Coefficient of Performance (COP)

The COP of the heat pump system is an important parameter in establishing the payback period. Indeed, the COP is the ratio of the heat delivered by the heat pump to the energy required to drive the heat pump. The COP can be estimated by carrying out thermodynamic cycle analyses using the published properties of the working fluid (the refrigerant) and appropriate values for the temperature of the heat source (the earth) and the temperature of the medium used to heat the building -- water for a hydronic (radiant) system -- air for a forced hot air (FAH) system.

The COP of a heat pump system is highly dependent upon the evaporator (the earth) temperature and the condenser (the unit that transfers heat from the refrigerant to the building heating system media (water, air, etc.)) temperature. For the Jackson, NH area, available data for both subsurface earth temperatures and ground water temperatures indicate a temperature of 45F is the appropriate design level. See Figs 9 and 10.

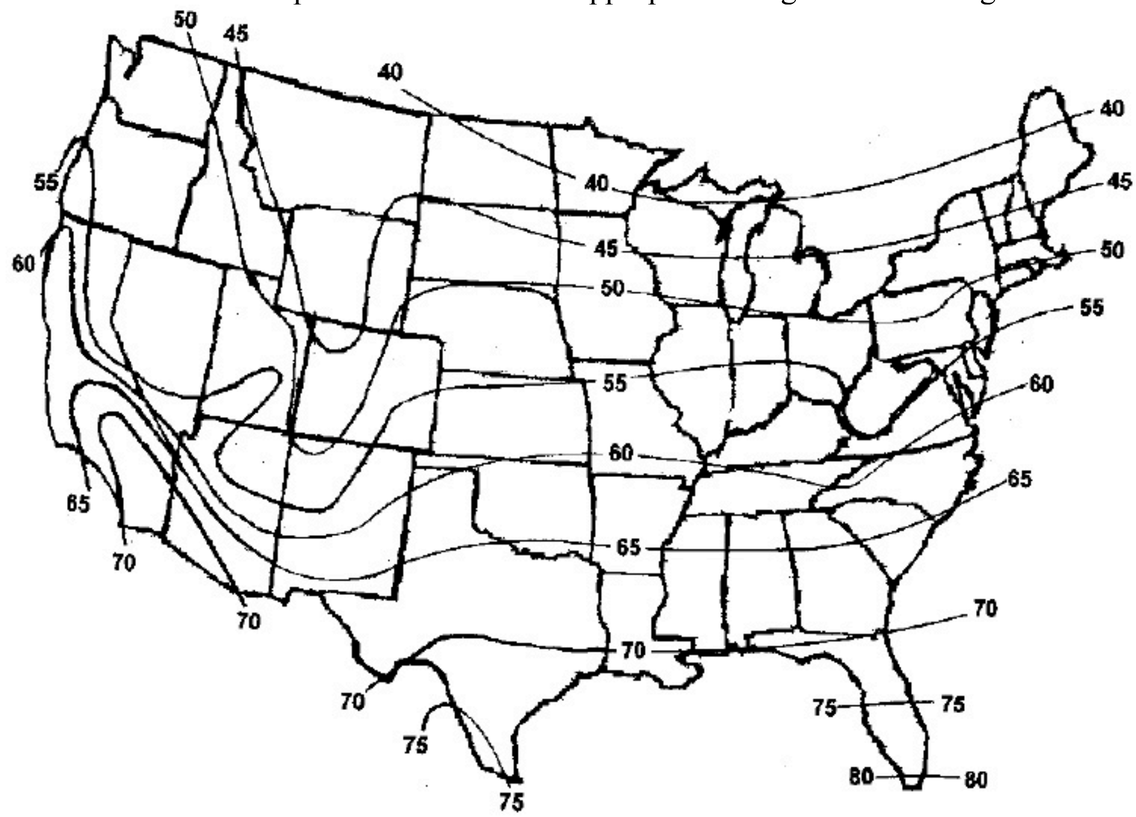


Figure 9. Subsurface Earth Temperatures – *Source : Earthlinked Technical Manual*

But there are other parameters that are difficult to estimate – such as the temperature differential between the earth and the refrigerant as it flows in the tubing embedded in the earth. In order to gain information on these other parameters, ***ECS TerraClime Geo*** uses heat pump equipment that provides the capability for deploying temperature and pressure sensors which can be monitored with the result that the thermodynamic analyses can be adjusted to reflect actual measurements.

To obtain a preliminary indication of the effect of the reduced earth temperatures found in northern New Hampshire on COP, ECS analyzed data from an installation near Broadbrook, CT (T_{earth} = 53F) and the ***ECS /Terraclime Nonotuck Mill*** facility in Florence, MA (T_{earth} = 50F). The data (Fig. 11) indicate that for these

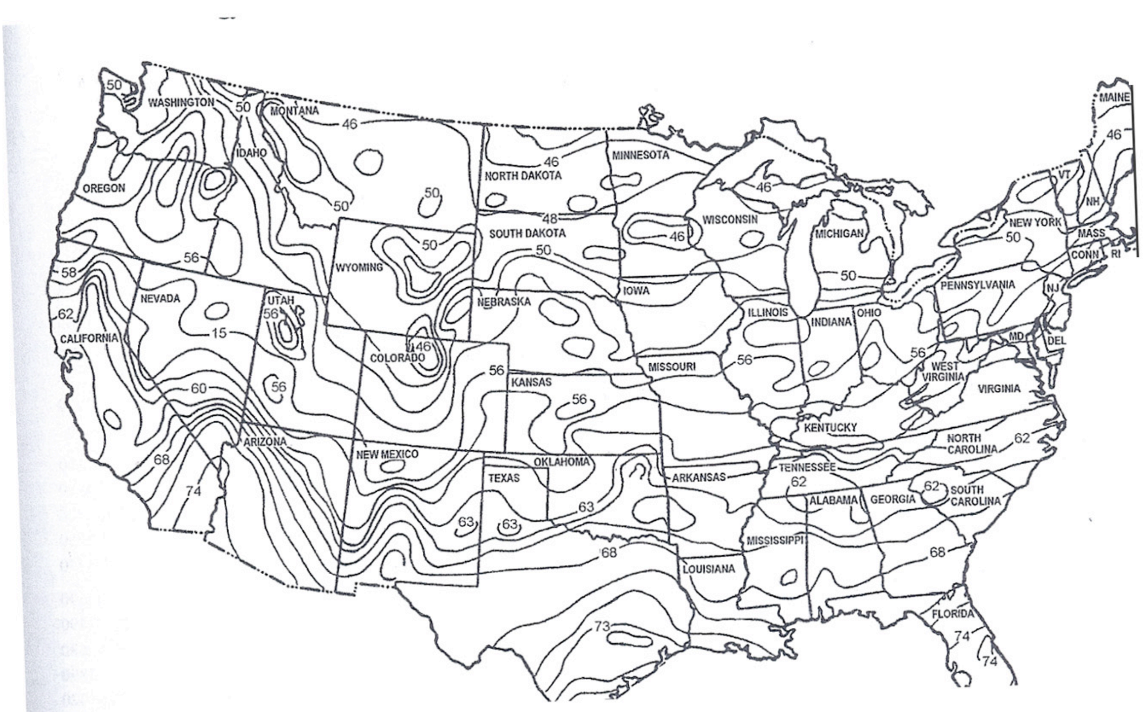


Figure 10. Ground water temperatures *Source ASHRAE Manual*

DX installations, the effective evaporation temperature is 25F lower than the earth temperature. Applying this information in a thermodynamic cycle analysis indicates that a COP of 3.71 could be achieved in Jackson. Further analyses of this type will be required to obtain a firm estimate to be used to refine the results. In the meantime, comparitive payback analyses will be conducted using a COP of 4.0. However, checks should be made using lower values – such as 3.5. Indeed the assessment made as of the date of the latest revision of this report (2/4/2010) is that use of a COP of 3.5 would give the most realistic values for payback.

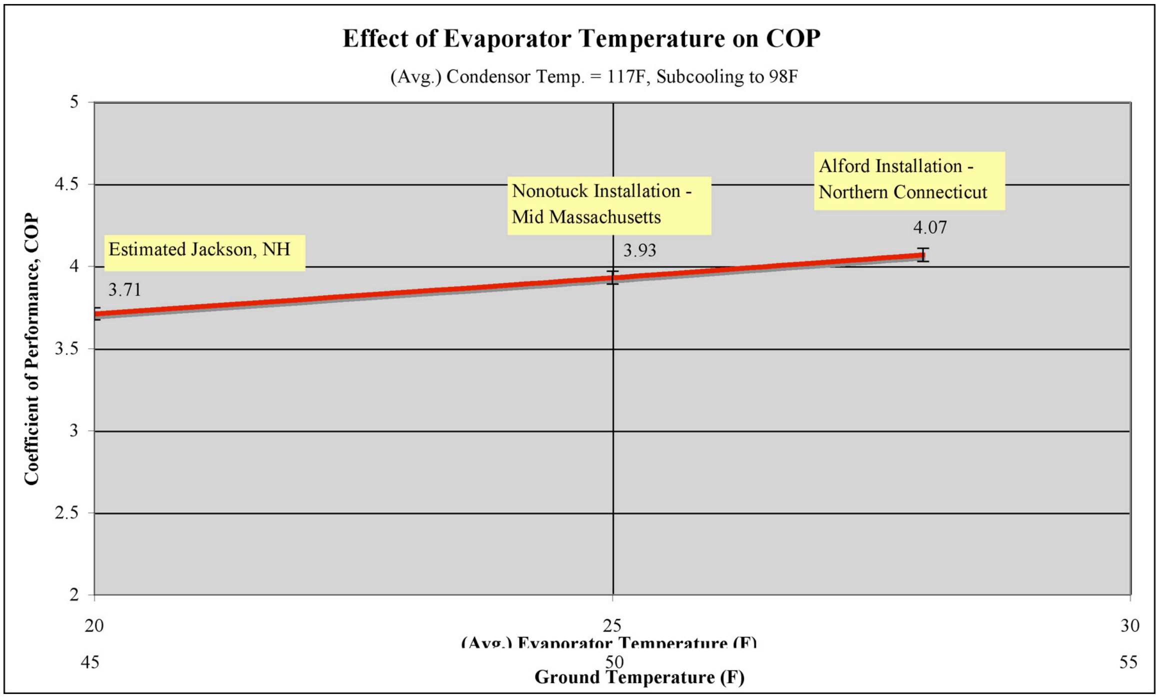


Figure 11. COP Estimates for Different Climate Zones – Based on ECS Recorded Data

Seasonal Energy Efficiency Ratio (SEER)

Just as the COP is the standard rating that reflects the efficiency of a heat pump in the heating mode, the SEER is the standard rating measure for cooling – both for heat pumps and for conventional A/C systems. The SEER rating is the Btu of cooling output during a typical cooling-season divided by the total electric energy input in watt-hours during the same period. (It is not unit-less, as are most useful measures of efficiency.)

SEER is related to the Energy Efficiency Ratio (EER), which is the ratio of output cooling in Btu/Hr and the input power in watts at a given operating point. SEER is a seasonal rating – a measure of the average efficiency over all operating conditions experienced during a typical season. The SEER is calculated at a part loaded standardized ARI test point (a defined on/off cycle). Thus, SEER more closely represents the performance from equipment cycling, instead of the steady state conditions under which the EER is measured.

SEER in fact is related to the coefficient of performance (COP). Just divide the SEER by 3.413 to get COP. A SEER of 13 is approximately equivalent to a COP of 3.43. A SEER value of 13 is the lowest value that air-conditioners must exhibit based on U.S. regulations effective January, 2006.

Just like COP, the EER (not the SEER) rating depends on how hard the system must work; i.e., on the temperature of the medium from which the heat is extracted (the room air) to the temperature of the medium to which the heat is rejected (the outside air temperature)., In Jackson, the outside air temperature will be lower than in Southern New England, and thus in actuality, the efficiency of the proposed Library geothermal heat pump will be greater here than that reflected by the SEER. Nonetheless, SEER has been adopted by the industry to estimate the power requirement of the heat pump, given the seasonal cooling load.

For this analysis a SEER of 20 has been used. This is an accepted value for efficient systems. It may be the case that the effective SEER is greater for this installation. Some geothermal heat pump manufactures quote values in the high 20's. We at ***ECS TerraClime Geo*** are still evaluating the SEER for the three heat pump units installed at our Nonotuck office facility. It is our intention, if awarded the contract, to install instrumentation on the Library heat pump to help us evaluate the SEER for installations in the North Country. Until further data is collected, we will use a value of 20 to estimate payback periods.

Results

The following figures give the results of the payback analysis for the Jackson Library based on the above assumptions.

Fig. 12 shows the relative cost of four different HVAC systems fueled/powered by: electricity, propane, oil, and geothermal. Electric heating is the most expensive, with propane not far behind. Oil is the best competitor with geothermal for long-term savings, but oil is not considered appropriate for the Jackson Public Library because a basement for oil storage tanks is not available and underground storage is not advisable due to long term maintenance and environmental liabilities. The competing fuel for the Library is propane – a propane storage tank can be buried beside the building in a safe and environmentally acceptable manner.

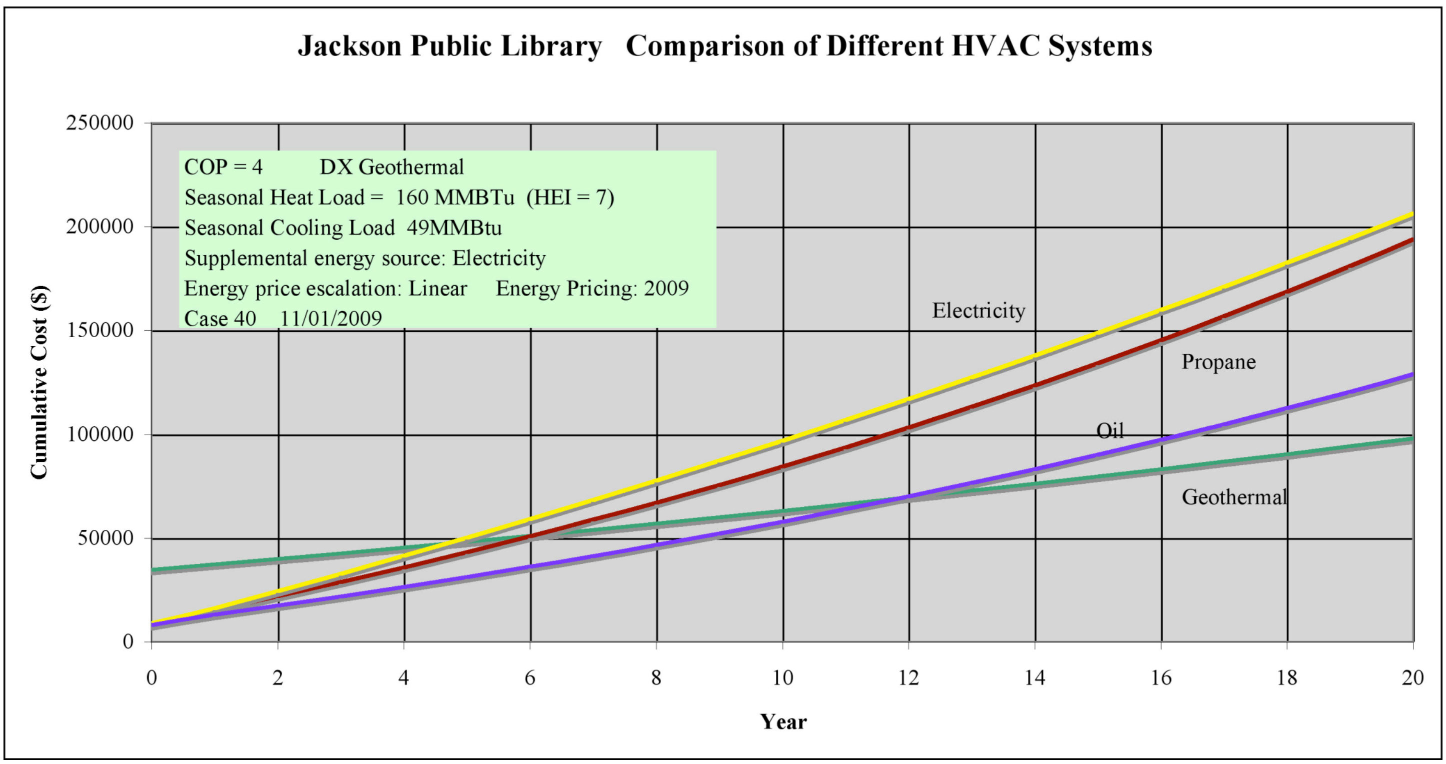


Figure 12. Effect of Fuel Type

The results of payback analyses conducted using 2009 load and pricing assumptions and the more recently available 2010 assumptions are shown in Figs. 13 and 14.

Year 2009 payback period results for this building (Fig. 13) assume reasonably tight construction and a peak heating load of 75,000 Btu/hr (6.25 tons) A 6-ton heat pump is required for these conditions. The geothermal heat pump is a 6-ton unit using electricity as the supplement during peak demand. Generally, a heat pump is sized to yield 90% of the peak heat load with the balance being supplied by a supplementary source. In most cases, that supplement is electricity – primarily because of the low capital cost of the heating coil.

Note that no manufacturer of geothermal heat pumps recommends specifying a system having a capacity greater than the peak load. The reason is that under most load conditions encountered the heat pump will short-cycle – turn on and off many times putting undo stress on the electrical and mechanical systems. *Earthlinked*, for example, will not warrant a system unless a capacity undersized by about 10% is used together with a supplementary heat source. That supplement is only used infrequently – when the climatic conditions are most severe. Most frequently an electric supplement is used because the capital cost of an electric heating coil is low. Alternatively, for this installation, a propane supplement has certain advantages – see below.

For these calculations the geothermal field is assumed to be a direct exchange field as opposed to a deep-well field. The effect of field type is analyzed later.

For the year 2009 assumptions, the payback for a geothermal HVAC system is achieved in 6 years. The cumulative cost savings at the end of a 20-year span is almost $100k.

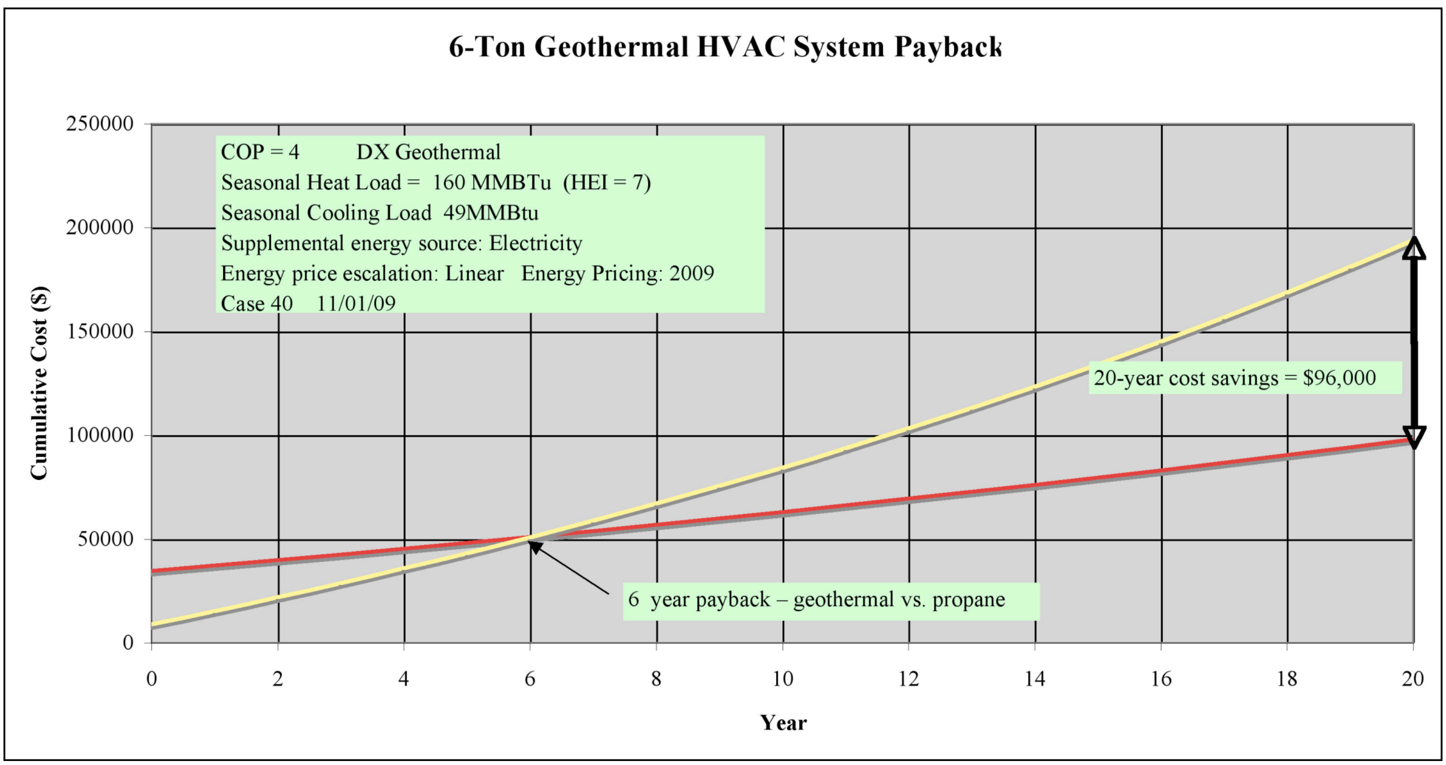


Figure 13. Payback vs. a propane system is achieved in 6 years using Year 2009 assumptions.

For the more recently available Year 2010 assumptions (tighter building, lower peak thermal loads, revised energy pricing, lower COP), the payback is achieved in 7.1 years (Fig. 14). However, the cumulative cost savings at the end of the 20-year period are reduced to $77k. The longer payback compared to the Year 2009 assumptions is to be expected, because with the lower heat load, less energy is used and therefore less is saved each year. Also the performance of the heat pump (COP) has been reduced to be more realistic. The payback of 7.1 years is still quite favorable.

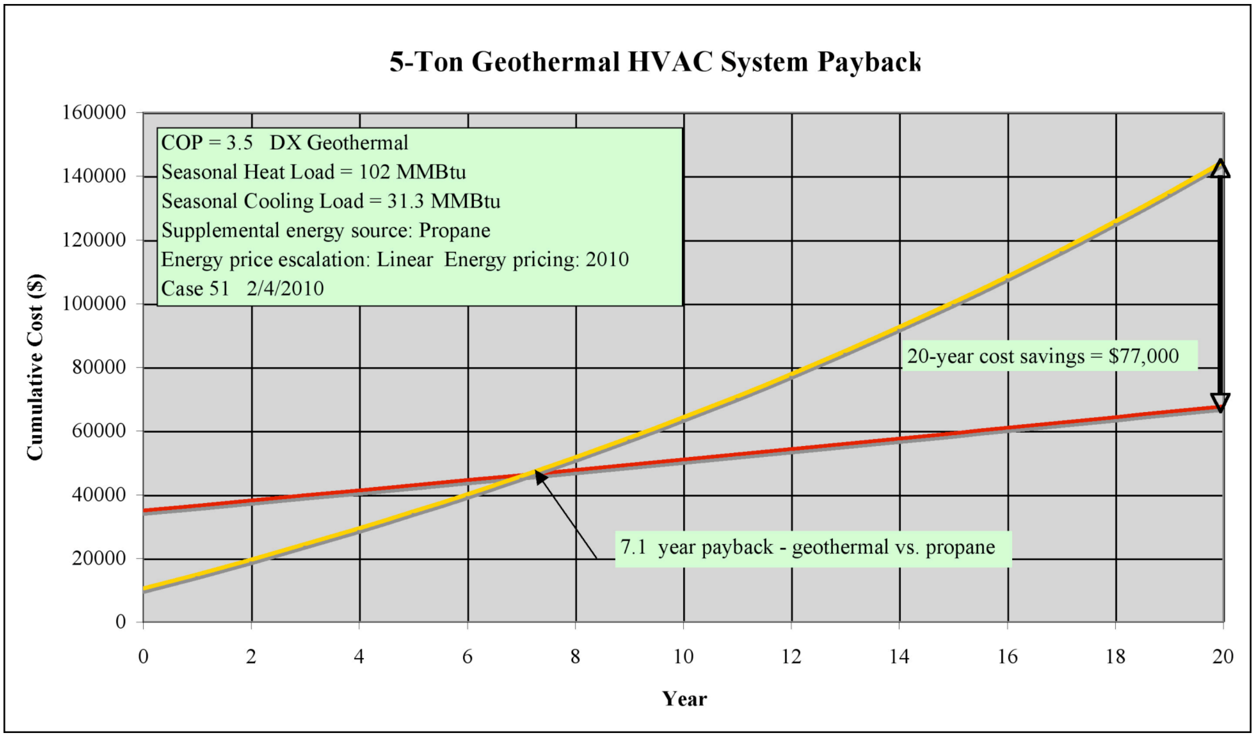
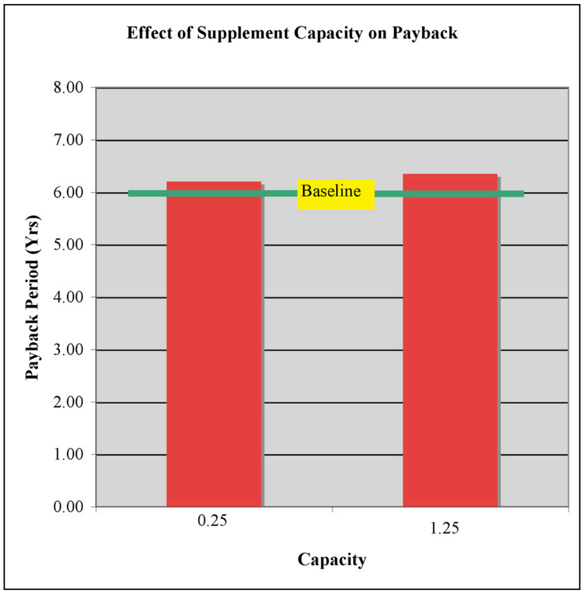


Figure 14. Payback vs. a propane system is achieved in 7.1 years using Year 2010 assumptions.

Propane as the Supplemental Fuel

A hybrid system – comprised of a 5-ton or a 6-ton heat pump to cover the base load heating operations plus a supplementary propane system to handle the peak loads -- has certain advantages for this installation. First, the initial cost of a 5-ton system is lower – a factor high in the minds of the fund-raisers. Second, the supplementary propane system would be capable of sustaining non-freezing conditions in the event of an extended power outage, which does occur on occasion in all parts of New England. (The propane system requires only nominal electric power which could be supplied by a portable power generator). Third, the propane heater could also be utilized for a domestic hot water source.

Calculations were carried out for two levels of propane supplement – 0.25 tons (6-ton heat pump) and 1.25 ton (5-ton heat pump) using the Year 2009 assumptions. The 0.25 ton propane supplement represents the same system as the baseline shown in Fig. 13 except that propane is used instead of electricity as the energy supplement. The results, Fig. 15, show that going to the lower initial cost 5-ton system with a 1.25 propane supplement does not pay – the 20-year savings are reduced by more than $15k. A 6-ton system is preferable. Furthermore, using propane for the small (0.25) ton supplement required for the 6-ton system shows only a change over the baseline. Use of propane rather than electricity would therefore be based on one of the other two reasons cited in the previous paragraph.



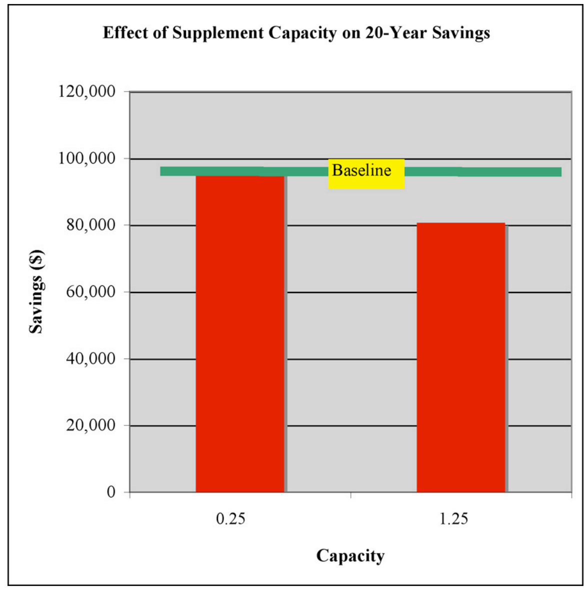


Figure 15. Effect of Supplement on Payback Period and 20-Year Cost Savings. Year 2009 system assumptions.

Effect of COP

For these calculations, the Coefficient of Performance (COP) of the heat pump is an important number.

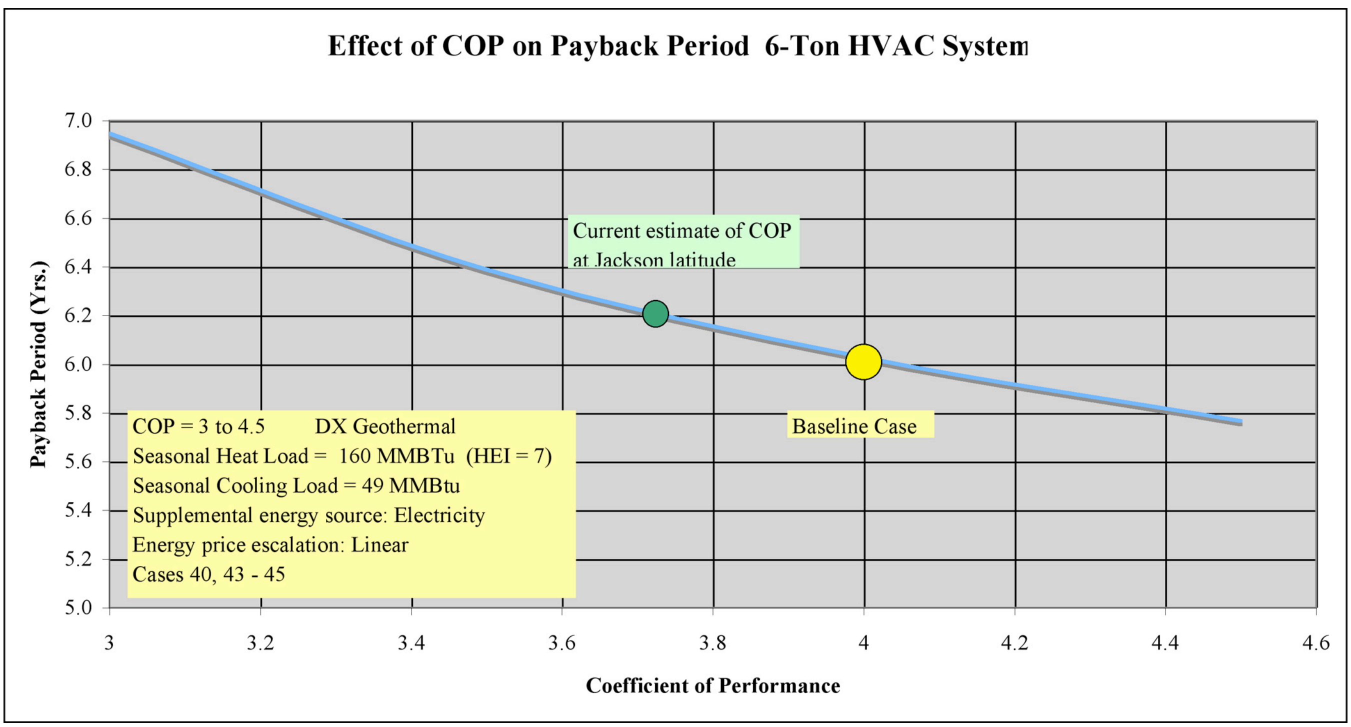


Figure 16. COP influence on Payback Period.

Based on thermodynamic analyses of the refrigerant cycle using best estimates of the ground temperatures, the hydronic heating water temperature requirement, the temperature differentials in the heat exchanger, pump efficiency, etc. a COP of 4.0 was considered to be an appropriate value for geothermal installations in the North Country. However, as noted in the section on ***Assumptions***, on-going analyses of ***ECS TerraClime Geo*** installations in Southern New England indicate that a somewhat lower figure of 3.5 may prove to be the best achievable level. Fig. 16 shows the variation of the payback period with COP for the 6-ton heat pump system (Year 2009) assumptions). The payback period would be reduced by only a few months if a COP of 3.5 materializes.

Likewise, Fig. 17 shows a small influence of COP on the 20-year cumulative cost saving. These calculations were conducted using the Year 2009 assumptions, but the conclusions would be the same based on Year 2010 assumptions.

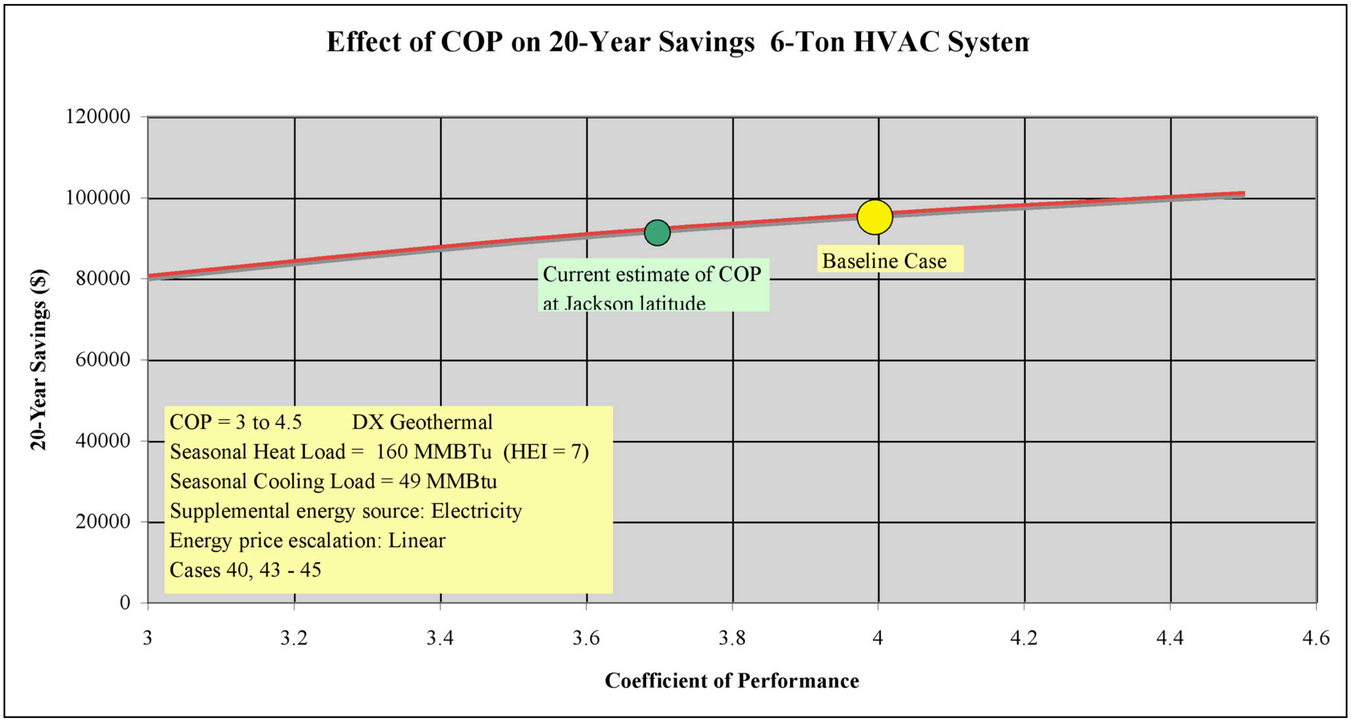


Figure 17. COP influence on 20-year Cost Saving.

Effect of Near Term Petroleum Price Increases

The primary reason for the rapidly growing interest in geothermal energy systems is to reduce dependence on the geopolitically-induced petroleum pricing. As noted in ***Assumptions***, in order to not to overstate the case for geothermal systems, the baseline case for the Year 2009 assumptions assumes that the petroleum prices will increase at a constant annual rate (3.8%) over a twenty year term so that the price in 20 years is equal to that forecast (in mid-2009) by DOE/EIA.

As of the date of this set of calculations (11/01/2009) the price of a barrel of oil had risen from $60 to $80/bbl – an increase of 30%. Indeed, that was in line with the DOE forecast – See Fig. 5. (However, the prices of refined products such as oil and propane, have not risen to that degree – yet.)

So based on the actual DOE 2009 pricing forecast, what would the payback period? It would be a very short 3.7 years (Fig. 18). And the 20-year cost saving is a whopping $158,000. Indeed, the vagaries of petroleum pricing lead many who are informed and who can afford the up-front capital costs to invest in geothermal systems. For the Year 2010 pricing, where a rapid rise in prices in the near-term is no longer forecast, this exaggerated payback does not materialize - the results are effectively those shown in Fig. 14.

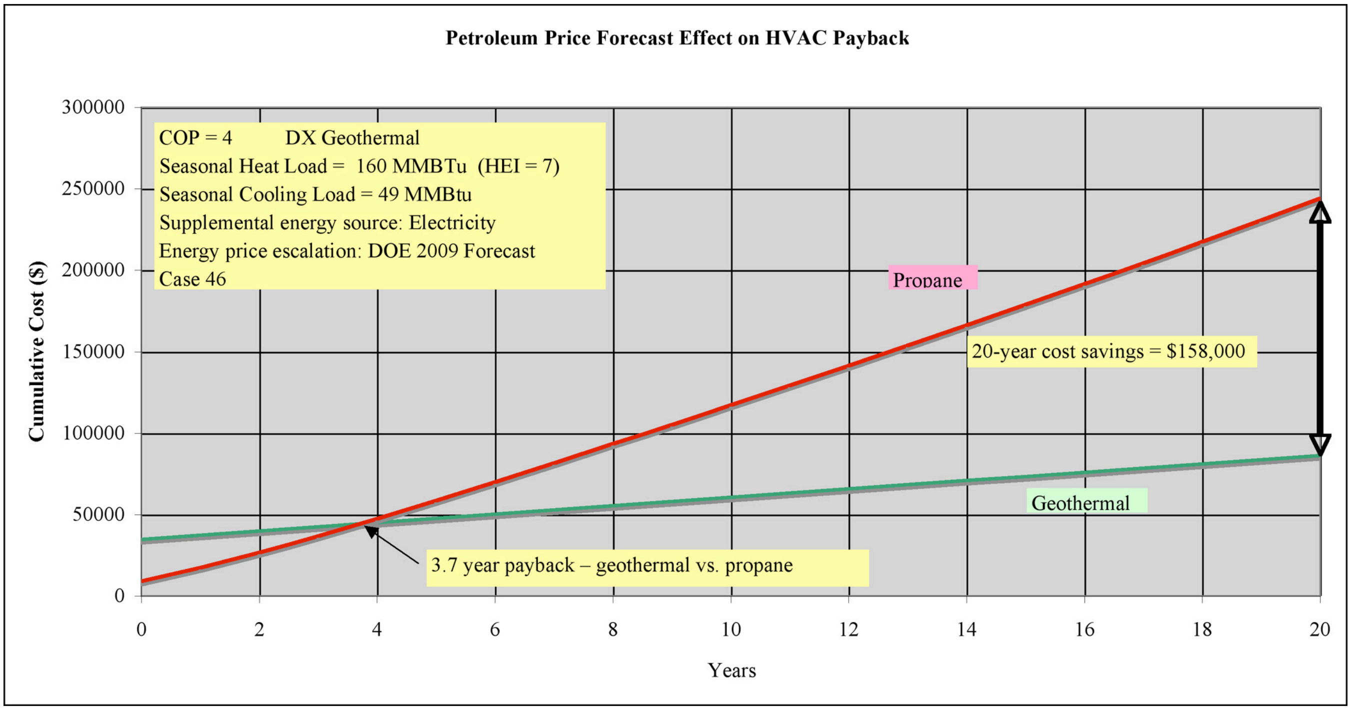
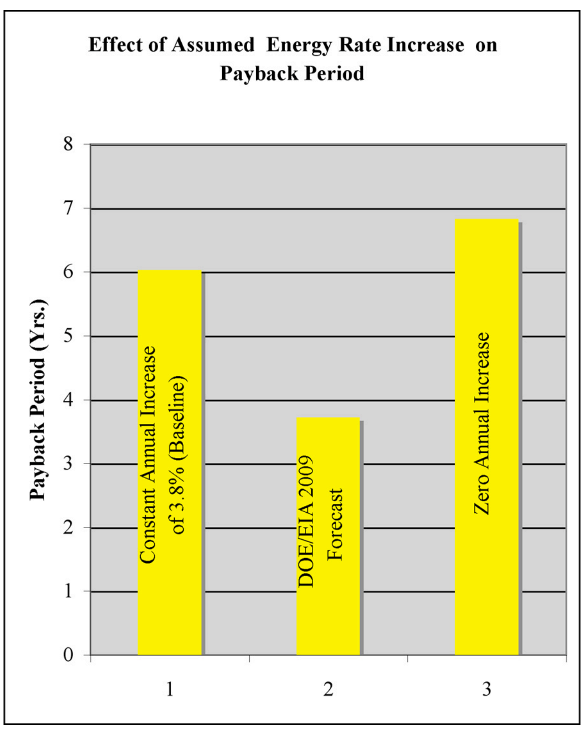


Figure 18. Payback based on the DOE/EIA 2009 Petroleum Rate Increase

Because of the difficulty of accurately predicting rate increases, some payback analyses are carried out assuming no rate increase. As shown in Fig. 19, (for Year 2009 pricing) the payback period is increased by somewhat less than a year using this assumption, but the 20-year savings are greatly understated.



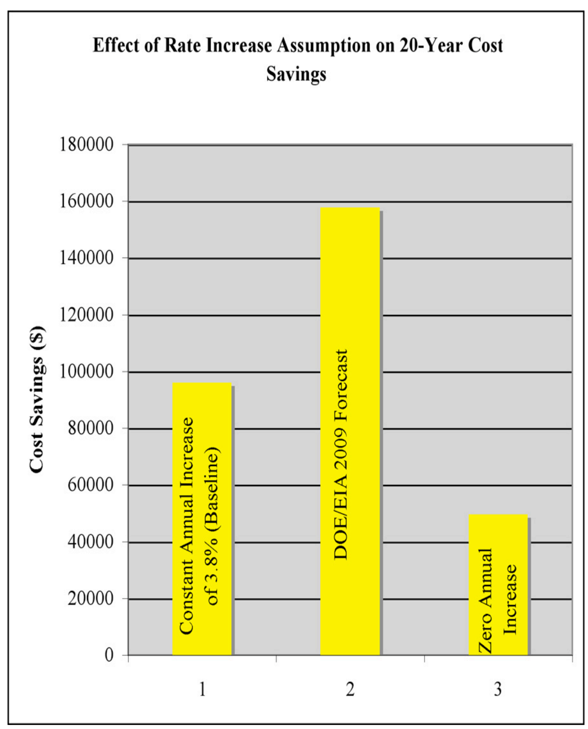
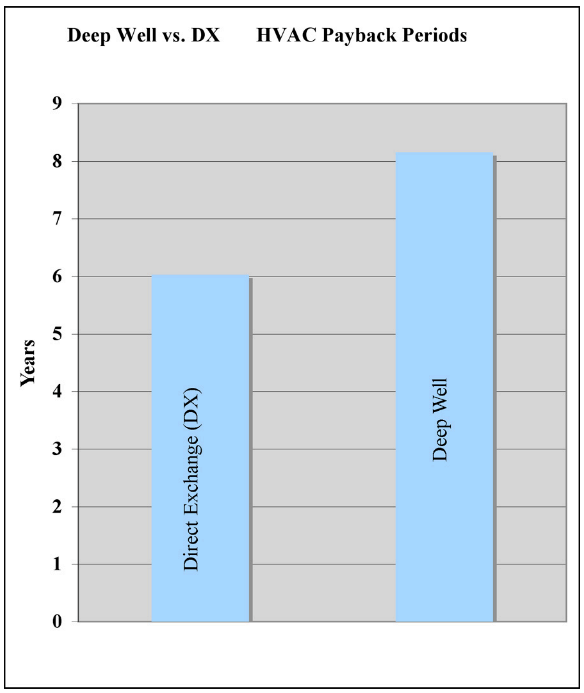


Figure 19. Effect of Rate Increase Assumption on Payback.

Deep Well vs. Direct Exchange

As mentioned in the ***Introduction***, there are two options available for the geothermal field at the Jackson Library site – Direct Exchange (DX) and Deep Well. The Deep Well option would have to be employed where contractors are (1) unfamiliar with bore-hole drilling or (2) do not have access to bore-hole drilling equipment. (If ***ECS TerraClime Geo*** were awarded the contract, DX would be installed as neither of these two conditions apply.) The deep well system has the disadvantages of greater capital cost due to higher drilling and grouting costs and the need for a secondary loop pumping system. Also, the deep well incurs a small increment in operating cost due to the pump power consumption. At this time, based on on-going analysis of the performance of these two types of systems, there appears to be no significant thermal efficiency advantage of the DX system, although no firm conclusion on this point has been reached.

The increased costs (using Year 2009 pricing) of the Deep Well installation (Fig. 20) results in a lengthening of the payback period of about 2 years and a decrease in the 20-Year savings of about $12k. A DX field is recommended.



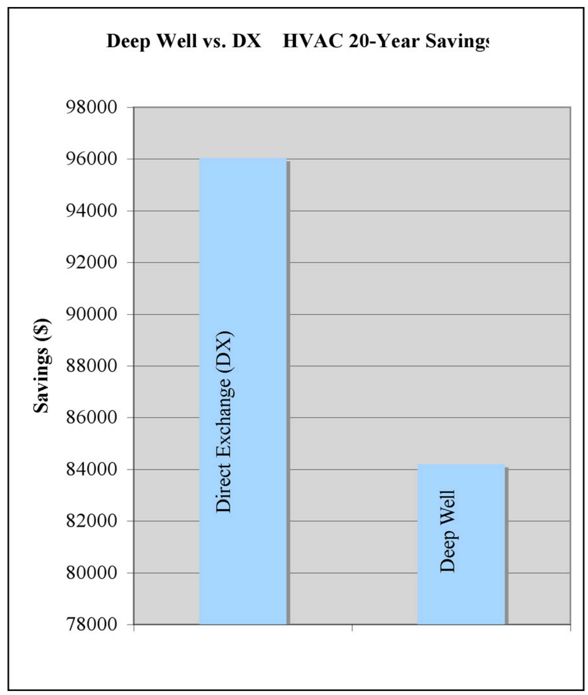


Figure 20. Direct Exchange Compared with Deep Well Construction

Effect of Heating Load Requirement

As discussed in ***Assumptions – Seasonal Heating Requirement***, the total heating requirement of a building can be characterized by a Heating Energy Index (HEI). The smaller this value, the smaller the heating requirement. The smaller the requirement, the less attractive will be the geothermal system. This is illustrated in Fig. 21 where is shown the effect on payback period (using Year 2009 assumptions) of a range of HEI from a low value 4.7 to a value of 15, characteristic of the average residential unit built over during the past half-century.

The value of 7, characteristic of modern tight construction, has been employed as the baseline in this analysis. This corresponds to the total seasonal heating load of 160MMBtu-- as noted in the figures --the load calculated based on the load calculations carried out in Year 2009.

Again, the value of 4.7 was derived from the energy audit computation contained in the 2/16/09 report submitted by Design Day Mechanicals to the JPL Building Committee. In Year 2010 that energy audit was repeated using the latest information on building construction and internal building heat loads. The result of that recalculation is that the HEI is 4.5 – incrementally better than the Year 2009 result. One would anticipate that the degradation in the payback period with reduced HEI, Fig. 21, would thus be extended using the Year 2010 HEI of 4.5. But that is not the case due primarily to the revised energy cost projections – the payback period using the full set of Year 2010 assumptions is still on the order of 7 years as shown in Fig. 14.

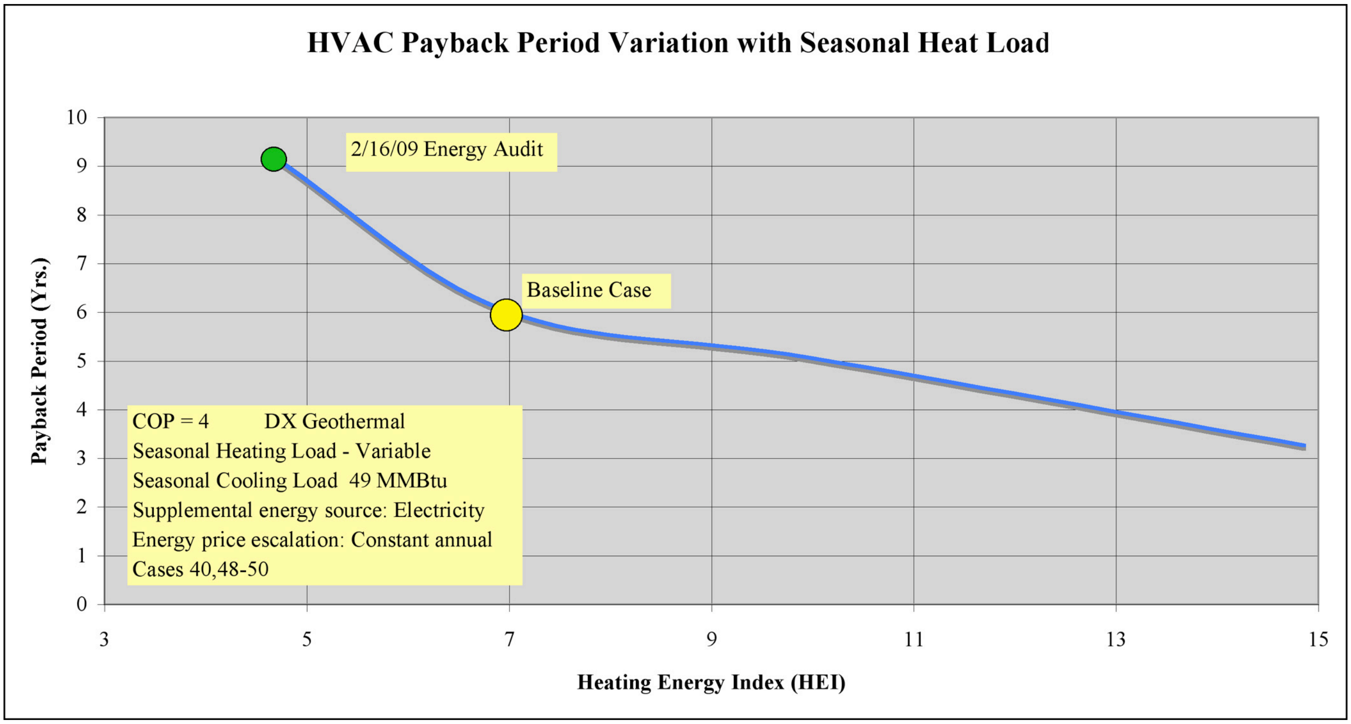


Figure 21. Heating Requirement Effect on Payback Period.

The second parameter used to characterize the payback is the 20-year cost savings (Fig. 22). Here the difference between the low value of 4.7 and the assumed baseline value is shown to be dramatic – almost $70k. Again, this effect is mitigated when using the full set of Year 2010 assumptions – see Fig. 14.

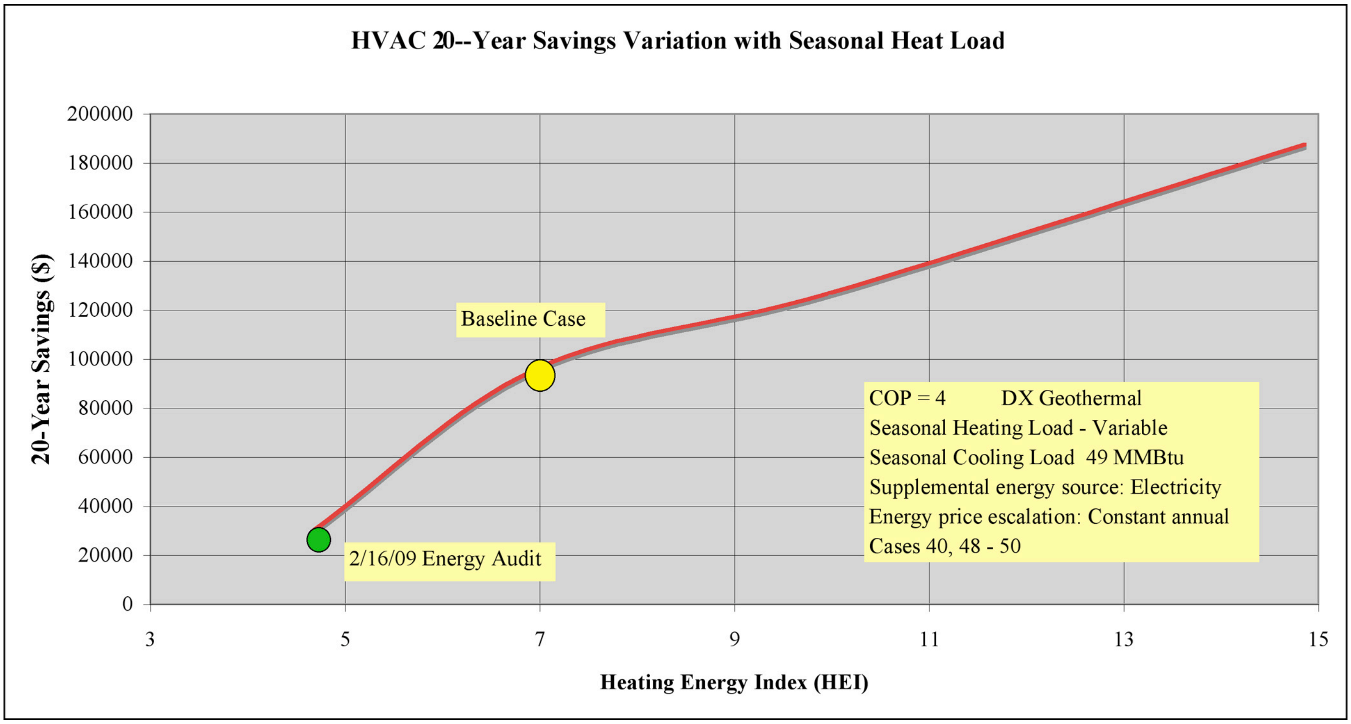


Figure 22. Heating Requirement Effect on 20-Year Savings

Conclusions

Using the Year 2010 specifications, a 5-ton geothermal HVAC system using either a full propane back-up/supplement can satisfy the Jackson Public Library heating and cooling requirements.

A DX geothermal field is recommended due to its lower drilling costs.

The initial capital outlay for a DX Geothermal HVAC system exceeds that of a propane-heating-system/conventional-air-conditioning-system by a modest amount (only $22.5k) which contrasts with reported estimates of GSHP installations at other venues.

A geothermal HVAC system is more economical than a conventional HVAC system. Payback is achieved in 7.1 years and the 20-year cost savings are almost $77k.

The recommended system is illustrated in the Summary Figure, given at the beginning of this report.

Along with the long-term cost savings come the benefits of contributing to the energy-independence movement, of participating in the 'green energy' revolution, and of knowing that you are independent of the actions of speculators and outside interests that are driving the petroleum markets.

The overall conclusion is that a geothermal HVAC system makes eminent sense for the Jackson Public Library. This conclusion is contrary to the mythology that currently exists regarding geothermal installations in the North Country and is the reason that ***ECS TerraClime Geo*** has examined this installation to the degree reflected in this report.

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REVISION NOTES

Rev. 2 10/26/09

1. Efficiencies of competing oil and propane systems were specified as: propane 92%; oil 86%. Prior editions assumed 100% efficiencies.
2. Current energy prices updated – see *Assumptions* for current values.
3. Costs for a deep-well installation (as opposed to DX) were updated based on quotes recently received by ECS TerraClime Geo.

Rev. 3 10/31/09

This revision reports the results for the complete HVAC system as opposed to for the heating system alone.

Rev. 4 11/1/09

This revision reports results based on heat loads estimated using a building footprint of 2960 sq. ft. (Prior estimates used 3880 which is, in fact, the total floor area, not the footprint.

Rev. 5 11/2/09

Results summarized and included in the lead section of the report. Miscellaneous editing of text and figures.

Rev. 6 2/04/10

Numerous assumptions and specifications based on information gathered in the 11/1/09 – 2/04/10 have been incorporated in the analysis.

Rev. 7 2/04/10

Capital cost of the DX system were increased from $33k to $35k in accordance with TerraClime's cost proposal of 2/5/2010. Adjustments were made to the Year 2010 DOE energy projects based on a review of the DOE data. An appendix showing photographs of the building progress is included.

APPENDIX
Photographs of the Construction of the Jackson Public Library

June 2008 The 150-year old Trickey Barn, a National Historic Landmark, stood on grounds in the center of town, next to the Jackson Grammar School. Federally-mandated regulations required the School Board to erect in this location a new building that serves several school functions. As a result, the Trickey Barn had to be dismantled with the thought it would be soon re-erected at a suitable site.

July 2008. Dismantlement begins. All the posts, beams, roof trusses, etc. are numbered for ease in reconstruction. The roofing, siding, windows, doors, all having been exposed to the elements, were discarded. The saved materials were stored in trailers.

In *October 2008*, the Friends of the Jackson Library and the Jackson Historical Society joined forces to generate a plan whereby the Trickey Barn structure would be preserved within a structure which would house the new Jackson Public Library. The existing 100-year old Jackson library had long become obsolete – a new library had been a goal of the Friends for several years. The above example of this form of preservation was erected recently in Gilmanton, NH. It was enthusiastically agreed by all that this course would be pursued in Jackson.

August 2009. Site preparation begins on the *Gray's Inn* tract in Jackson center – next to the town office building. Architectural plans were being continually upgraded to reflect the thinking of the Library Building Committee. The thought of utilizing a highly efficient ground source heat pump to provide the HVAC function had been expressed. Representatives from *TerraClime Geo* met with the Committee and briefed the participants on the latest developments in this field. After many additional meetings and briefings, the Committee committed the project to this approach – if funding of the capital cost for the geothermal machinery could be raised.

November 11, 2009 A combined tree-topping ceremony and Veterans Day celebration was held as the re-erection of the Trickey Barn structure neared completion. Over 150 townspeople attended the ceremony and took the opportunity to tour the interior of the building as it stood at that time. Events such as this were held numerous times for the purposes of generating interest which would lead to contributions. At this time, approximately $800k of the estimated $1.2M had been raised.

January 24, 2010. The library has been fully enclosed and windows installed. The area shown to the left of the barn is where the DX geothermal field will be located, assuming funding for the GSHP is secured. Work is progressing on the building insulation with the intent of making the structure as energy efficient as modern construction techniques permit.