THE ECONOMICS OF CONNECTING OF SMALL BUILDINGS TO GEOTHERMAL DISTRICT HEATING SYSTEMS

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ABSTRACT

Many of the communities co-located with geothermal resources are very small and as a result the buildings they contain tend to be small as well. Generally, small buildings (10,000 ft^2) use heating systems which are not hot water based. Since geothermal district heating systems deliver hot water, the costs associated with the conversion of small building heating systems to use hot water for heating is an issue of great influence in terms of the potential development of such systems. This paper examines the typical retrofit costs associated with conversion of small buildings and the level of savings necessary to attract the interest of owners. In general, the prospects for connection of such buildings based only on energy savings is not positive.

INTRODUCTION

Recently renewed interest has been expressed in district heating[1] as a potential application for low temperature geothermal fluids. To some extent this has been driven by a publication (Boyd, 1996) in which 271 communities were identified as being co-located with geothermal resources. Beyond that, the availability of a software tool (WSU, undated) which can be used for evaluating the economics of distribution systems for district heating, has made the process of feasibility study more convenient.

Evaluations of geothermal district heating (GDH) systems often focus heavily on the resource, central mechanical facilities and distribution piping. While it is true that these components do constitute the bulk of the capital costs for the system and without careful design of these components a system cannot brought to fruition, it is equally true that a system cannot be successfully developed without customers. In the world of simulation, virtual customers can be expected to connect to any system the modeler creates. Real customers however require a reasonable economic incentive to connect. In the small building size range typically found at most of the co-located sites, the economics associated with connecting to a geothermal district heating system may include some substantial economic hurdles for building owners.

1. The term "district energy" is often used in describing these systems. It is a useful term for marketing purposes and to describe systems in which both heating and cooling (and electricity in some cases) are delivered to the customer. Low temperature geothermal resources are capable of supporting only district heating and this is the term that will be used in this paper.

In many cases, the heat rate required to provide the potential customer with favorable economics may be far lower than what the system operator can afford to offer. This has been the case with some existing geothermal district heating systems. Few of these systems have achieved full subscribership (in 10 to 15 years of operation) and some are operating at less than 50% capacity with potential customers located adjacent to existing distribution lines unconnected to the system. In order to attract customers, geothermal district systems serving a small building customer base must offer rates substantially lower than competing heating fuels or other incentives to create the necessary customer economics. A feasibility study which fails to address the customer economics issues cannot provide an accurate picture of the prospects of the system.

THE ADVANTAGES OF LARGE BUILDING CUSTOMERS

In some cases, there has been the tendency to assume that rate structures used in large conventionally fueled district systems (typically located in large cities serving large (>50,000 ft^2 buildings)) would also be effective in small geothermal district systems. In the larger systems, rates are often in excess of the energy cost that would be incurred in generating the heat with a boiler in the customer's building. District systems can employ these high rates due to other savings large building owners receive when using district heating. One of the largest of these is the elimination of boiler operating personnel associated with large boilers. If the boiler room was staffed with only one individual per shift and 3 shifts per day, this savings alone would amount to between $100,000 and $200,000 per year. The average combined space and water heating energy consumption for a 200,000 ft^2 office building would amount to just 66,800 therms (EIA,1998). At a gas rate of $ 0.75 per therm this amounts to $50,100 per year - only 25 to 50% of the boiler operator costs. In addition to the personnel savings, large building owners may also realize insurance savings resulting from the elimination of the boiler operation on site. If the boiler is eliminated completely, additional floor space rent may be possible from rental of the boiler room area as well. Beyond the heating savings, many large district systems supply chilled water for space cooling in addition to the steam or hot water for heating. The savings from use of district chilled water normally dwarf those associated with heating service due to the greater cost of electricity compared to heating fuels. Together, these issues permit district systems serving large buildings to charge very high rates for their product.

The issue of retrofit costs is also a much smaller hurdle in large buildings due to their more common use of hot water based heating systems. Converting buildings of this type to using district supplied heating media is much less costly than small buildings since no retrofit of terminal equipment (the individual units which actually deliver heat to the space such as furnaces, unit heaters, heat pumps etc) is required.

SMALL TOWNS, SMALL BUILDINGS

In the context of the 271 sites, it is useful to consider the size of the population centers associated with them and the type of buildings which are likely to be encountered there. Though they have come to be referred to as "cities"(Bloomquist and Lund, 2000), the original reference more correctly refers to them as communities. Cities is a term that implies a certain level of population and infrastructure and in the case of the 271 locations identified in Boyd, 1996 this term is probably not an accurate characterization. Of the 271 sites, 43% have a population of less than 500 and 71% are less than 5000. Of the 45 with the highest populations, 10 already have geothermal district systems installed and 13 others have other forms of geothermal development in place - indicating that they are aware of geothermal development but have chosen to pursue applications other than district heating. It seems reasonable to conclude that geothermal district heating development associated with the 271 collocated sites will likely occur in small to very small towns.

Given the size of these communities, most prospective customers for any district heating systems that might be developed there would certainly be in the small size range since few towns in the 5000+/- population size range have many buildings (if any) larger than 10,000 ft^2. As a result, the costs of converting small buildings to hot water heating and the relationship between these costs and the savings to be had from connecting to a district system is a pivotal issue in the context of the development of GDH systems.

HEATING SYSTEMS USED IN SMALL-TO-MODERATE SIZE BUILDINGS

In existing buildings, the magnitude of the retrofit costs incurred by the customer to convert his heating system to use the hot water supplied by the district system is heavily influenced by the type of heating equipment in place. As mentioned above, systems already based on hot water are the simplest to connect since in most cases, no modification is necessary to the individual terminal units (the equipment actually supplying heat to the space). Unfortunately, most small buildings do not use hot water based heating systems. Figure 1 provides a summary of heating system types for small and moderate sized buildings. It is apparent from the figure that in the small building category, approximately 85% of the floor space in these buildings is heated by other than hot water based systems. In fact, the percentage may be higher than this assuming that some of the boiler systems would be older steam systems rather than hot water. The situation in moderate sized buildings (10,000 ft^2 to 200,000 ft^2) is somewhat better in that some 43% of the total floor area in these buildings is served by a boiler system.

As a result, it is clear that in the small building category, the majority of the buildings use other than hot water heating systems. For systems of this type, conversion to hot water heating involves at a minimum: installation of hot water coils at all terminal units, hot water supply and return piping, sheet metal modifications to existing duct work to accommodate the installations of the coils, new controls and associated fittings and components. Details of this equipment and costs are provided in the retrofit section of this paper.

RETROFIT OF SMALL BUILDING HEATING SYSTEMS

Retrofit of existing non hot water based heating equipment to use hot water heat involves substantial modifications. The extent of the retrofit modifications is dependant upon the type of equipment.

Given the type of equipment installed in these buildings (figure1), converting terminal equipment falls into two categories - applications where a coil must be installed in the distribution duct work (existing furnaces, packaged equipment, heat pumps) and applications where a hot water unit heater must be installed to replace existing fossil fired or electric unit heaters. Interestingly, in these small buildings the cost of the retrofit is more a function of the number of individual units which must be retrofit than it is of the total heating capacity required. This arises from the fact that the only component directly tied to the heating output is the coil or unit heater and the cost of this component constitutes only about 5 to 15% of the total retrofit costs. Beyond that doubling the capacity of a coil or unit heater only involves an incremental cost of about 40%.

Figure 2 provides a diagram of a simple, one coil retrofit of a building that might be served by a gas furnace or rooftop packaged unit. This retrofit design approach assumes that an isolation heat exchanger is not required at the customer building. The use of the customer heat exchanger would substantially increase (approx 33%) the cost of the retrofit since it would require the addition of a circulating pump, expansion tank, domestic water cross-connect (for pressurization), additional controls etc. The "open"type customer connection shown here minimizes retrofit cost and is an arrangement used by several operating GDH systems.

Table 1 provides a breakdown of the retrofit costs for the system. Depending upon the design of the district system, a circulating pump may be required to provide flow through the customers system and/or a meter may be required for measuring the customers consumption. These costs are shown separately.

Table 1
Retrofit Costs for Small GDH Customer

Outside lines, main tap, valve box	1800
wall cut, 11/2" bldg pipe, fittings	1550
coil, 3/4" pipe, controls sheet metal	2040
10% contingency	540
Total (single heating unit - ducted)	5930
Total (single unit heater)	6280
add for booster pump if necessary	660
add for Btu meter if necessary	1130
add for ea additional coil	3080
add for ea additional unit heater	3160
add for building heat exchanger if req'd	2020
add for domestic hot water retrofit (100kBtu/hr)	1660

Costs for each additional coil or unit heater are indicated as well. The basic piping used for the building in this case would accommodate up to a 500,000 Btu/hr load at a 40ºF Δt. Additional costs for the coils and unit heaters are based on a capacity of 100,000 Btu/hr per unit.

Using these figures, an automotive repair shop with 3 unit heaters would have a retrofit cost of $6280 + 2(3160) = $12600 to retrofit the heating system for the use of a hot water heating medium. If a booster pump and energy meter were also required, this total would be $14390.

A small office with two roof top heat pumps would incur a retrofit cost of $5930 + 3080 = $9013.

CUSTOMER SAVINGS

For the small building customer, decisions concerning connection to a district system are influenced by both retrofit costs and savings which accrue to the owner from connection to the system. In these smaller buildings (10,000 ft^2 and less), the additional non-energy savings discussed in the large building section of this paper are unavailable. The small heating equipment does not require operating personnel, space required for the equipment is of little or no consequence to the owner and insurance is unaffected since most customer agreements require that the building owner have a standby system available. As a result, the only savings to be had from the connection to the district system are those arising from reduced heating costs assuming the absence of any other incentives.

The savings the building owner receives from connecting to a district system is determined by the difference between the districts rate for the heat, the owner's existing cost of heating. For fossil fuel fired heating systems, there is a savings to the owner even if the district prices it's heat at the same as that of the competing fuel. This arises from the fact that fossil fired heating equipment has an efficiency associated with it. Depending upon the age and quality of the unit, between 5 and 35% of the heating value in the fuel is lost up the flue. Beyond the savings associated with the ineffici-ency of the conventional heating equipment, there is an additional savings associated with whatever difference may exist between the district rate and the conventional fuel rate (in equivalent dollars per million Btu). Most current geothermal district heating systems use rates which are lower than the most commonly used competing fuels--some as little as 70% of natural gas. Table 2 presents some example costs for heat based on current (March 2001) utility rates in Klamath Falls OR.

Table 2
Comparative Rates for GDH and Competing Fuels

Fuel	Cost of heat ($/1,000,000 Btu)
Natural gas @0.75 $/therm, 75% eff.	10.00
Natural gas @0.75 $/therm, 93% eff	8.07
Fuel oil @ 1.55 $/gal, 70% eff	15.82
Propane @ 1.40 $/gal, 75% eff	20.74
Heat Pump @ .065 $/kWh, 2.0 COP	9.52
Electric resistance @ .065 $/kWh	19.04
GDH @ 100% of Nat Gas (70%eff)	7.50
GDH @ 90% of Nat Gas (70% eff)	6.75
GDH @ 80% of Nat Gas (70% eff)	6.00
GDH @ 70% of Nat Gas (70% eff)	5.25

The table uses natural gas as the basis and this is common in areas where this fuel is available. Obviously, in areas where it is not, comparisons would be made to the most commonly used fuel. It is apparent that even at a GDH rate of 100% of that of natural gas, the potential GDH customer still enjoys a 25% savings due to the inefficiency of his older natural gas heating system. Of course the total savings a customer would achieve would be a function of the difference in rates and the total energy consumption of his building on an annual basis.

Heating energy consumption varies by building use, construction, climate, hours of operation and other variables. The US Energy Information Administration publishes averages values for building energy consumption. Table 3 summarizes these values for a variety of different commercial building types. The values appear in units of Btu/ft^2 yr, commonly referred to as the Energy Utilization Index or EUI.

Table 3
Commercial Building Heating Energy Consumption (Btu/ft2 yr)
(EIA,1998)

Building Type	Space Heating	Water Heating
Office	24.3	8.7
Mercantile/Service	30.6	5.1
Lodging	22.7	51.4
Public Assembly	53.6	17.5
Food Service	30.9	27.5
Warehouse	15.7	2.0
Food Sales	27.5	9.1
Public Safety	27.8	23.4

A check of the smaller buildings connected to the Klamath Falls GDH system agrees well with this data, indicating a range of 25,000 to 65,000 Btu/ft^2 yr for heating energy.

The question remains however, can sufficient savings be generated based on the existing heating costs and typical commercial building energy usage to create sufficient motivation for small business owners to connect to a GDH system .

To evaluate this issue figures 3 through 5 were developed. Figure 3 evaluates the economics of the smallest customers - 1000 ft^2 building typical of a small storefront in a downtown area. For this customer, it has been assumed that only a single unit will require retrofit (such as a single furnace, heat pump, unit heater, roof top unit etc). Two different building energy use rates are considered - 30,000 Btu/ft^2 yr and 60,000 Btu/ft^2 yr. This range of EUI's encompasses all of the small building types in the EIA data and also reflects the range of values found in the Klamath Falls building stock. A total of 8 curves appear in the figure. The solid line curves reflect the lower building EUI of 30,000 Btu/ft^2 yr and the dotted lines the higher (60,000) value. In each case the four curves represent customer savings using GDH of 25%, 32.5%, 60% and52.5% compared to the existing annual costs with conventional heat. Retrofit cost used to make the payback calculations appearing in this figure were based on the data in Table 1 . It was assumed that no circulating pump, energy meter, building heat exchanger or domestic hot water retrofit was required and a rounded off value of $6000 was used as reasonably representative of either the coil or unit heater type retrofit for a single heating unit. This represents a very conservative assumption with respect to the costs a building owner may encounter as the addition of the components assumed to be unnecessary would nearly double the retrofit cost.

Payback requirements necessary to trigger action on energy measures have been characterized by others (Spain, 2000; ComEd, 2000; Univ of Michigan, 2001; Rafferty, 1996) as being less than 5 years (less than 3 years in most cases). Using the 5 year figure, it appears that in the smallest building size as depicted in Figure 3, there are no circumstances under which it could be expected that owners would find connection to a GDH system attractive.

Figure 4 provides similar information for a building of 5000 ft^2 assuming two existing heating units would have to retrofit. Again table 1 values are used as the basis for retrofit cost and a rounded off value of $9000 (basic 1 unit retrofit of $6000 plus an additional unit at $3000) was used. This case is slightly more positive as far as the prospects for connection are concerned but only in those cases where high building energy use exists combined with the prospect of a GDH rate that results in greater than 50% savings for gas users or a minimum 25% savings for propane and electric resistance users.

Figure 5 provides information for buildings of 10,000 ft^2 floor area. Due to the much larger building and total energy use and the lower retrofit costs per square foot (4 units assumed to require retrofit @ $15,000), the customer economics are the most favorable of the building sizes considered here. For buildings at the low end of energy use (30,000 Btu/ft^2 yr) the economics of connecting to a GDH system appear only to be favorable in situations where the highest cost fuels are currently used (electric resistance and propane) and where the district rate results in a 50% or more cost savings. For buildings of a higher energy use index, the 5 year payback criteria could be met by gas users if the GDH system offered rates of approximately 50% that of natural gas.

CONCLUSIONS

Of the 271 population centers co-located with low temperature geothermal resources, over 70% have populations of less than 5000 people. Towns of this size typically do not have a substantial number of buildings in the large size range - the size range in which the economics of connecting to GDH system is often positive. As a result, if new GDH systems are to be developed in these small towns, a substantial portion of the potential customer buildings will be in the small size range.

Buildings in this size range, because they do not typically use hot water based heating systems, require fairly substantial retrofit work to their existing heating systems to accommodate the hot water heating medium. The costs associated with this retrofit work are such that, in buildings of less than 10,000 sq ft of floor area, the economics of retrofit of the buildings may not provide sufficient incentive to the owner to connect to the GDH system in many cases.

In the smallest buildings (<5000 ft^2), only in cases where the prospective GDH system is capable of offering heating costs which are substantially lower (40% to 50% lower) and where the building has high energy use and where the owner is using a high cost fuel (electric resistance or propane) can there be a reasonable expectation of connection. For those owners using higher cost fuels (propane and electric resistance) and having high energy use buildings, the prospects for favorable economics are present in buildings greater than 5000 ft^2. It is likely however that conversion to a more efficient or lower cost fuel heating system could be more attractive than connection to a district system in many cases. The prospects for competing with natural gas appear unfavorable in all cases. Clearly, other incentives (beyond energy cost savings) are required for the connection of small buildings to district systems.

These conclusions were based upon designs which resulted in minimum retrofit cost to the customer and the most optimistic assumptions as to what would constitute an attractive payback. In situations where the design would require a customer heat exchanger, a booster pump, an energy meter, domestic hot water retrofit (Table 1) or payback period requirements are shorter than 5 years, prospects for connection of small buildings will be less favorable than discussed in this paper.

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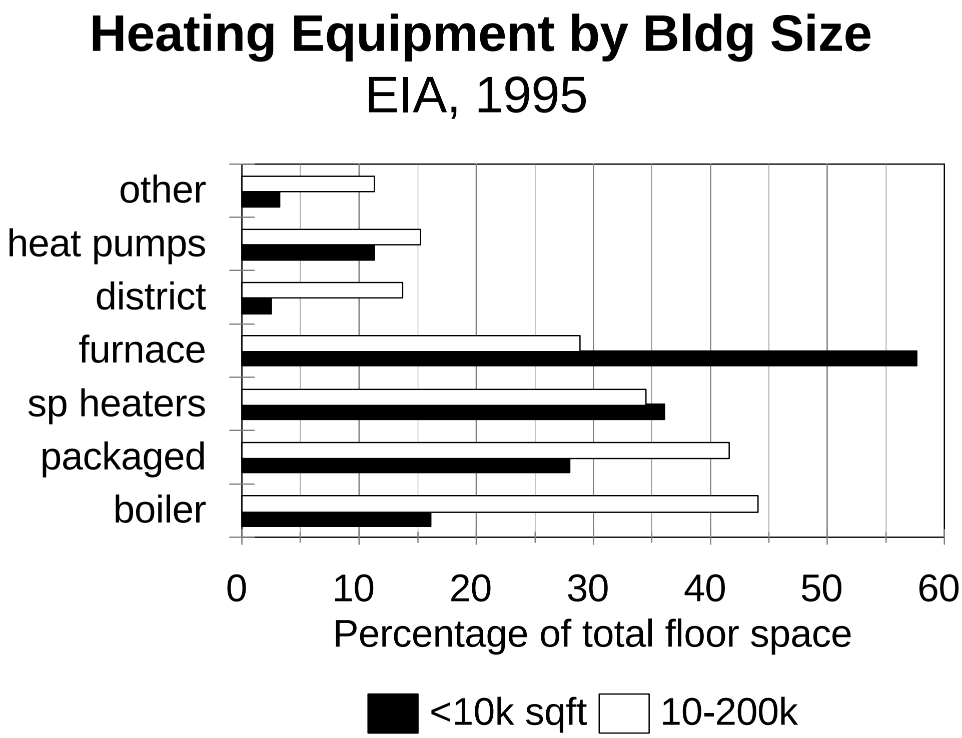
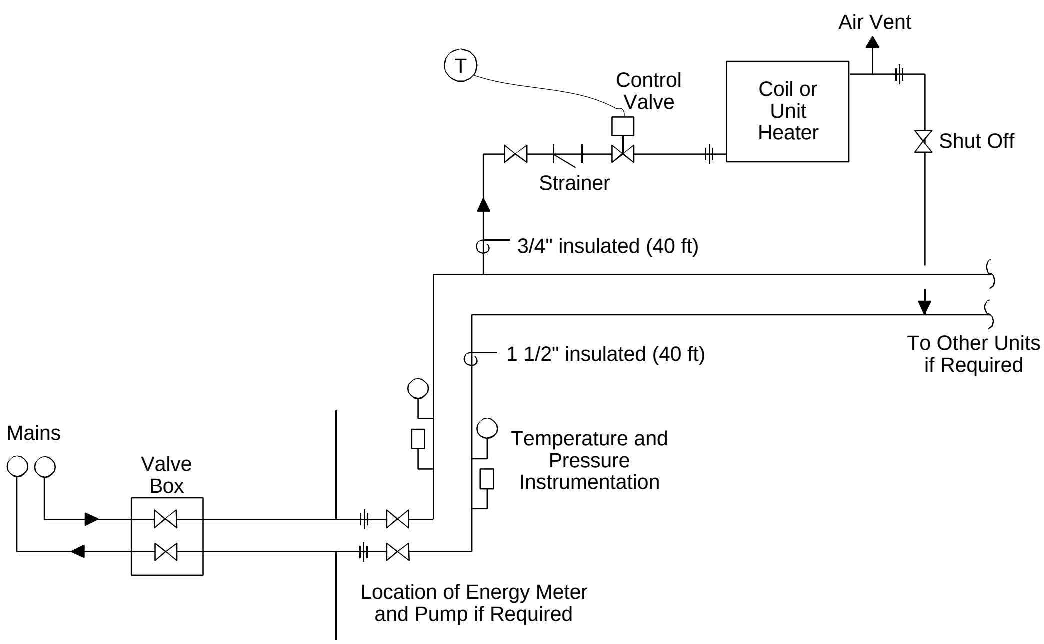


Figure 1.



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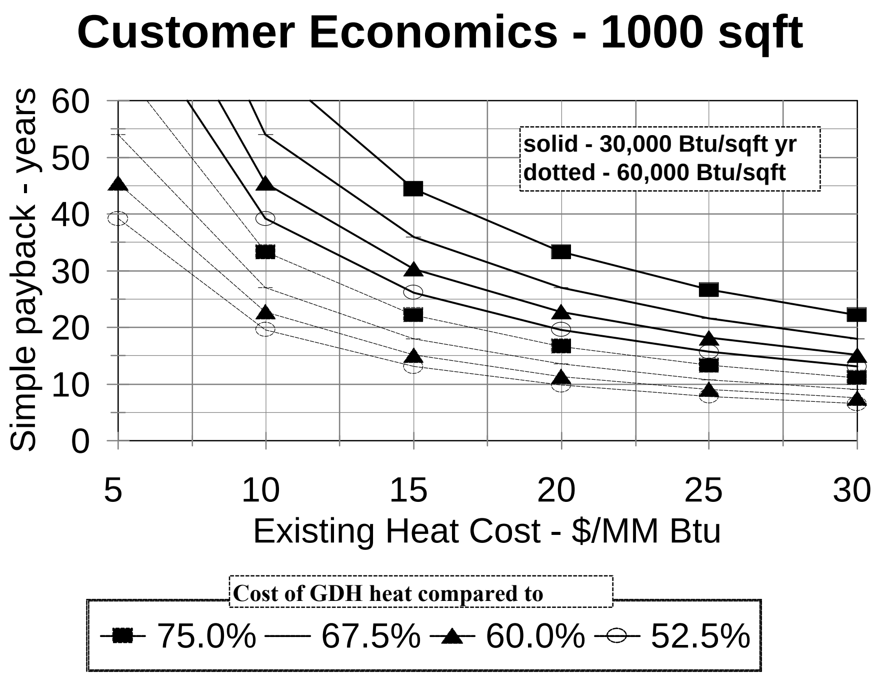
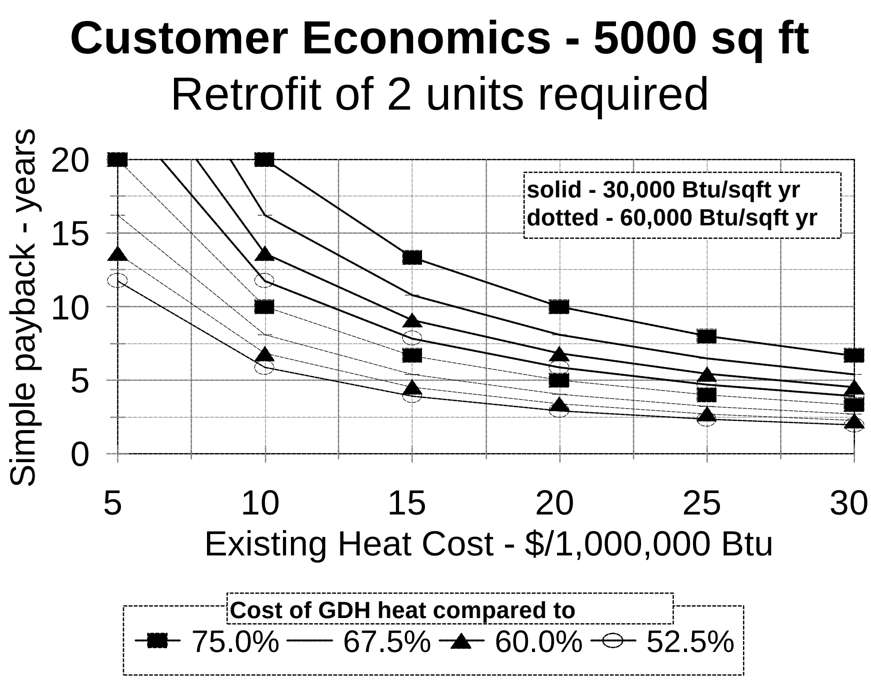


Figure 3.



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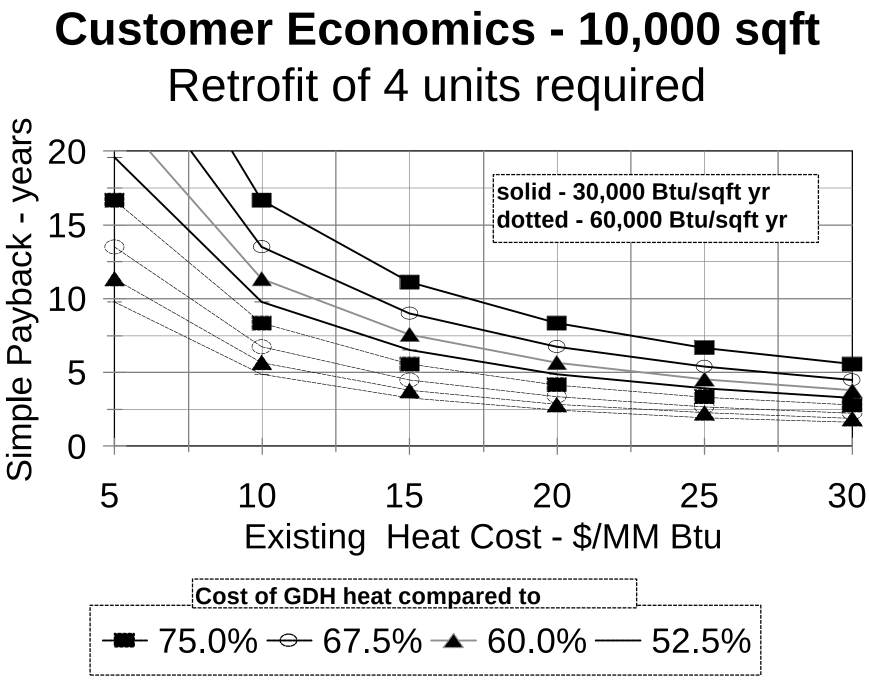
Customer Economics - 10,000 sqft
Retrofit of 4 units required
Simple Payback - years
20
15
10
5
0
5
10
15
20
25
30
Existing Heat Cost - $/MM Btu
solid - 30,000 Btu/sqft yr
dotted - 60,000 Btu/sqft yr
Cost of GDH heat compared to
75.0%
67.5%
60.0%
52.5%

Figure 5.