STAFF ISSUE PAPER

ASSESSMENT OF THE POTENTIAL FOR THE DIRECT APPLICATION OF RENEWABLE RESOURCES

89-39

NORTHWEST POWER PLANNING COUNCIL
October 16, 1989

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October 16, 1989

To Interested Parties:

The Council is circulating the attached issue paper, "Assessment of the Potential for the Direct Application of Renewable Resources" (publication #89-39), for public review and comment.

This paper is part of the Council's effort to develop a new Northwest Power Plan in 1990. It investigates the potential to reduce the region's need for central power generation and transmission where consumers employ renewable resources directly--solar, hydro, wind, geothermal and biomass--for some of their power.

Common sources of direct application include passive solar space heating, solar water heating, geothermal space heating and wind-power pumping. These sources produce energy that consumers can use directly, rather than receiving it over transmission lines.

Past Council power plans have not included direct application of renewables in the Northwest's 20-year portfolio of resources. The comment and discussion this paper fosters will help the Council determine if it will play a part in the 1990 power plan.

The Council seeks public comment on the issues raised in and related to this paper. Deadline for comment on this paper is 5 p.m., Monday, November 13, 1989. Oral testimony will be taken at the Council's meeting November 8-9, 1989, in Helena, Montana. To help us record and circulate your comments quickly and accurately, please identify them by issue paper title or publication number.

COMMENT PERIOD ON THIS
ISSUE PAPER HAS BEEN EXTENDED
TO 12/15/89.

Sincerely,

Dulcy Mahar, Director
Public Involvement Division

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Issue Paper 89-39

ASSESSMENT OF THE POTENTIAL FOR THE DIRECT APPLICATION OF RENEWABLE RESOURCES

INTRODUCTION

This issue paper is intended to take a general look at the direct application of renewable resources. The focus of the paper is to provide background information on what is currently known about these resources. The Council is interested in comments to supplement the information discussed in this paper. Perhaps more importantly, the Council is looking for recommendations on how to treat these resources in the next power plan. The Council is faced with at least two important questions related to this issue. First, should the Council attempt to develop detailed supply curves for these resources? Second, should programs be developed to encourage the acquisition of these resources?

In answering these two questions, other issues must first be addressed. For example; does the site specific nature of these resources rule out a comprehensive estimate of supply curves; should the Council develop completely separate supply curves for these resources or should they be integrated with the conservation supply curves; if detailed supply curves are not developed, should the Council still try and quantify the resource size and cost effectiveness? Obviously these are only some of the issues to be addressed in answering the primary questions before the Council. In development of this issue paper the Council is hoping to stimulate discussion that will lead to creative and effective solutions to these questions.

The Council is actively seeking comment on the issues raised in and related to this paper. Deadline for comment is 5 p.m. Monday, November 13, 1989. Oral testimony will be taken at the Council's November 8-9, 1989 meeting in Helena, Montana. It would help us record and circulate your comments quickly and accurately if you would mark your comments with either the issue paper title or publication number.

OVERVIEW

The direct application of renewable resources is generally defined as the use of a renewable resource such as solar, hydro, wind, geothermal and biomass for the direct reduction of electrical energy use by a consumer. While there have been previous staff analysis of these resources they have not been explicitly treated in previous power plans. Given the renewed emphasis on evaluating the environmental consequences of resource development, these relatively benign

resources merit further analysis. This paper will provide the basis for treatment of direct application of renewable resources in the 1990 Power Plan.

Most of these resources tend to be site specific and typically require large collection areas to capture a significant amount of energy. Because of high fixed installation costs, they also tend to be most cost effective with higher usage. These characteristics generally prevent widespread regional application and limit the size of any particular resource. Early programs designed to encourage these resources focussed on individual end use applications. However, given the unique characteristics of these resources, it is likely that future programs will treat these resources as one option among several conservation measures applied to a given end use or sector.

Several of the direct application of renewable resources appear cost effective today or are close enough to justify further analysis. Examples include solar domestic water heating, passive solar heating east of the cascades, geothermal heating systems and daylighting in commercial buildings. This paper will examine these uses of direct application of renewable resources as well as others in detail and will provide recommendations for treatment in the 1990 Power Plan.

BACKGROUND

Definition in the Act. The Regional Act provides for a definition for resources that includes conservation and direct application of renewable resources as follows:

Section 3(19)(B) "Resource means- actual or planned load reduction resulting from direct application of a renewable energy resource by a consumer or from a conservation measure."

Section 3(16): "Renewable Resource means a resource which utilizes solar, wind, hydro, geothermal, biomass, or similar sources of energy and which either is used for electric power generation or will reduce the electric power requirements of a consumer, including direct application."

Conservation Credit. A preliminary reading of the Act indicates that these resources are distinct from conservation resources and are not necessarily covered by the 10% cost effectiveness credit in the act for conservation resources. However, because they reduce electric loads at the end use and are generally environmentally benign, they look very similar to conservation resources from the power system's perspective.

Previous Analysis. Although there have been several staff assessments of direct application of renewable resources for previous power plans, there has been no explicit treatment within the plans themselves. Most of these analysis focussed on specific technologies or sectors and were not broad treatments of the subject.

Several analysis were conducted by Battelle Pacific Northwest Laboratories under contract to the Council for the 1983 power plan. These studies included analysis of passive solar space heat, commercial sector applications including daylighting, space and water heating, and potential use of geothermal district heating. These studies took a rough cut at the cost and size of the resources

available given the current technology. However, they were used primarily as background material and not included directly in the plan.

Specific analysis of solar water heating has been performed by staff as late as January of 1989. This work supplemented the water heating supply curves and did not include a methodology to treat resources with the specific characteristics of direct application of renewables.

Although somewhat dated, much of this previous work is still valid and has been referenced in this paper.

CHARACTERISTICS OF DIRECT APPLICATION OF RENEWABLE RESOURCES

There are several characteristics of direct application of renewable resources that make them very different from conservation or generation resources. A brief overview of these will provide background for the sector specific applications detailed later. Direct application of renewable resources can generally be characterized as having the following traits:

Site Specific. Generally, these resources tend to be very site specific. For example, in Klamath Falls, Oregon there are large areas of the city with intermediate and high temperature geothermal resources directly available for use in space and water heating. However, in the outlying rural areas there is generally not direct access to the same high temperature resources and it would be cost prohibitive to pipe the geothermally heated water from the city to the rural areas. In other words, cost effectiveness is generally dependent upon the proximity of the resource to the end use.

Dilute. Direct application of renewable resources also tend to be fairly dilute; i.e., they require a fairly large amount of hardware to produce a significant amount of energy. For example, a solar hot water heater requires 40-60 ft² of collector to provide around 2,000 kWh of savings. A ground coupled heat pump requires several hundred feet of pipe to exchange heat with the earth and provide 9,000 to 10,000 kWh of savings. Exceptions to this rule are high and intermediate temperature geothermal resources and biomass. However, the site specific nature of these two resources make their use much more limited than their more dilute counterparts.

Increasing Cost Effectiveness with Higher Usage. Previous experience indicates that due to the high fixed costs of installation, the costs per unit of energy displaced tend to drop as the amount of energy available for displacement increases. For example, solar hot water heaters of any size require a certain amount of hardware that is almost invariable with the collector size. Because of this there are generally only certain size systems available. In the summer months, these systems are capable of producing more hot water than a household with two people would ever use. However, during the same months a five person household might well use all of the solar system output as well as some electricity to meet their hot water needs. Because the solar system costs the same in both cases but produces more usable energy for the latter it will inevitably be more cost effective for the five person family than the two person family.

Seasonal. Direct application of renewable resources tend to be seasonal in nature which impacts their cost effectiveness to the system. An example would be a wind powered pumping station that was used primarily during the summer. Because it is providing savings during off-peak for the power system the value of the resource to the region is less than if it were used primarily during the fall and winter when system power needs are high and the hydro output is low. In some cases this may result in resources that meet the economic feasibility criteria for the end user but not be cost effective to the region. Other resources may have seasonal variations that better match the load. Some wind resources have higher potential energy output during the fall and winter due to seasonal wind patterns. Exceptions to this generalization are intermediate and high temperature geothermal and biomass which tend to have a steady energy output year round.

Environmentally Benign. Last but not least, direct application of renewable resources are generally considered to be environmentally benign. There are exceptions to this, primarily biomass in the form of combustion of wood products for industrial process and residential space heat. Geothermal resources that directly use ground water wells that do not reinject the water into the same aquifer would also be an exception to the generalization of environmentally benign.

SECTOR USES OF DIRECT APPLICATION OF RENEWABLE RESOURCES

Although some applications such as solar water heat are fairly well developed, other applications involve technology which is still in evolution. In addition, even the well developed applications may continue to see changes in costs as refinements in the technology and economies of scale come into play. For these reasons, it is important to look at both current applications and future applications and technologies as well.

In order to look at both current and future applications, it is easiest to look at each sector and break the applications into three different categories. The first category can best be described as those resources that either are or are close to being cost effective today. The second category consists of those applications where the technology is fairly advanced but are not cost effective to the region. In the final category are those applications that are promising new technologies but that are not well enough developed to even estimate cost effectiveness. Only the first category, those resources where cost effectiveness is already fairly established, will receive detailed analysis in this paper.

RESIDENTIAL SECTOR

Direct application of renewable resources are probably most prevalent and the most technologically advanced within the residential sector. During the 1970s and early 1980s a great deal of federal money was spent investigating residential applications. The federal energy tax credits encouraged a the development of a fairly large number of manufacturing and installation businesses. Unfortunately, when the tax credits disappeared so did most of the infrastructure. Because of this collapse there is very little data on direct applications of renewable resources installed since 1985. For the same reason, the general technologies associated with these resources have not changed dramatically either. Because most of the programs operated during the tax credit era were aimed at specific end uses, most

of the information available in this sector is also focussed onto a specific end use. Where good information exists, analysis of this sector will look at potential applications in each end use in the following sections.

1. Water Heating.

This is probably the most developed of all the direct application of renewable resources applications. Direct application of renewable resources can be used to supply hot water for domestic uses such as cooking, bathing and laundry as well as for "discretionary" uses such as pool and spa heating. Applications of solar, geothermal and biomass are possible for providing energy for this end-use.

Solar. Solar hot water systems have been used for this application since the mid 1970's and are considered to be a fairly well developed technology. These systems have gone through a series of evolutions revolving spurred first by the creation of the federal energy tax credits and later by their disappearance. Initially a cottage industry focussing on "do-it-yourself" systems, introduction of the tax credits created an industry that produced fairly complex and expensive systems. Later as the end of the tax credits approached a new generation of passive systems began to appear that promised lower costs and fewer operation and maintenance problems. After the tax credits disappeared the solar hot water industry virtually collapsed leaving a small core of viable businesses. Since the collapse, the industry has become very competitive and the systems have been refined to minimize initial costs as well as O & M costs.

The state of Oregon has continued its own tax credit program from 1978 through the present. Data¹ from the Oregon program shows the history of the average system price through the last ten years in Figure 1. The primary point of interest is that average system cost has dropped in the last four years to the current level of roughly \$2,000. In addition to dropping prices, the technology in the market has changed; the market is currently being dominated by passive systems with minimal O&M costs. The output of these systems are also fairly high. The average system applying for the Oregon tax credit was estimated to be saving approximately 2,600 kWh per year per residence.

Figure 1
Oregon Tax Credit Program
Solar Hot Water System Costs

Unlike many of the other end uses, solar hot water has been the focus of several monitoring efforts over the last ten years. While most of these studies are quite dated there have been several fairly recent regional studies. Unfortunately, even these represent technologies that are representative of the tax credit era systems. A summary of the results from these studies is presented in Table 1.

**Table 1. Studies of Solar Hot Water Heater Output
and Savings Fractions**

<u>Study¹</u>	<u>Date</u>	<u>Sample Size</u>	<u>Mean kWh/yr</u>	<u>Savings % Load</u>	<u>System Locations</u>
ODOE	1981		1900	36%	Oregon, All Climates
PGE	1985	32	2252	41%	Portland, OR
Washington WP	1982		2668	46%	Eastern WA, North ID
Idaho Power	1982		2632	52%	Idaho
California PUC	1982		2246	48%	Warm Climates
Robison	1987	337	2226	42%	All Climates
Battelle ²	1986	473	910-1723	36%-69%	Coastal-Interior
BPA Pilot	1987	70	2863	48%	All Climates

1. All study comparison data taken from reference 2 with the following exceptions: Battelle study was taken from reference 3; BPA Pilot study was taken from reference 4.
2. The Battelle study was not direct monitored savings but used a statistical comparison of total electrical consumption of solar systems with ELAC and RSPD homes as a control groups.

From Table 1 there is indication that for the older technology, solar systems can produce roughly 2,000 to 2,400 kWh/yr with a savings fraction of roughly 40% to 45%. This is not dramatically different from the latest tax credit data from Oregon.

Given this information on performance, it is reasonable to attempt a cost effectiveness calculation based on the most current cost and savings data from the Oregon tax credit program¹. This data was combined with assumptions about O&M and system lifetime that should be representative of the current technology to compute a regional levelized cost assuming regional utility financing. Table 2 lists the assumptions for this calculation.

Using the inputs in Table 2, the typical system has a regional nominal levelized cost of 96.8 mills/kWh (1989\$). However, because solar is a seasonal resource, an additional adjustment would be needed to reflect the true value of the resource to the region. Using a simplified method developed by Council staff to adjust for seasonality would add approximately 5 mills/kWh to the stand alone cost. In addition, if the lifetime of the system were only 20 years, the levelized cost would increase by roughly 10%. The O&M costs add approximately 7 mills/kwh using the assumptions in Table 2. while this may in fact be overly pessimistic for passive systems, it appears to be a reasonable number from Robison² and Dent⁴.

**Table 2. Estimate of Solar Hot Water System
Cost Effectiveness Using Oregon Tax Credit Data**

Inputs: Avg ODOE Installed Cost: \$1942
 Avg ODOE Solar Savings: 2,584 kWh/yr
 System Life: 30 Years
 Annual O&M: 10\$/yr
 Financing: Debt/Equity Ratio
 - Private Utilities: 50/50
 - Public Utilities: 100/0
 Finance Rate (Debt/Equity)
 - Private Utilities: 11/3%/12.9%
 - Public Utilities: 9.2%
 Inflation Rate: 5.0%
 Discount Rate: 8.15% (Nominal)

The levelized cost using the average Oregon tax credit data is probably representative of large water heating loads. However, regionally the average household does not have as large a heating load as indicated by the tax credit information. The current regional forecast assumes only 2.4 persons per household and a usage of 3,219 kWh/yr for hot water. A full analysis of the cost effectiveness should look at a range of usage depending on the number of persons in the household. Robison² developed a simple equation to compute usage based on household size. A simple cost effectiveness analysis was performed using Robison's water consumption algorithm, a fixed system cost approximating the ODOE costs (this assumes that there is a minimum unit size roughly equal to the current ODOE system size), a fixed savings fraction and the same financing assumptions used in Table 2. Table 3 details the input assumptions and provides the results of this analysis.

Table 3. Estimate of SDHW Cost Effectiveness by Household Size

Input Assumptions: Installed Cost: \$2,000
 Annual O&M Costs: \$10
 Net Solar Savings: %42
 Usage (Gals/day): 22.7 + 13.6*# Persons
 Hot Water Temp Rise: 70F
 Standby Losses: 2 kWh/day

Household Size	Usage Gals/Day	Savings kWh	Nominal Levelized Cost mills/kWh
2	50	1611	160
3	64	1976	130
4	77	2316	111
5	91	2681	96

Table three indicates that solar DHW is probably cost effective to the region primarily in large households. Unfortunately, at the time this paper was being prepared, there was insufficient data to determine how many of the regions households fall into the 4+ person category. However, if we assume 10% of the roughly 2 1/2 million households with electric water heating had 4 to 5 persons

and were eligible for solar systems (e.g. adequate solar access, etc.) the resource would be in the range of 50 to 75 MWa in the year 2010. However, it is not likely to be practical to run a program aimed specifically at large households that is independent from other programs. It is probably more efficient to include it as part of a general water heating program that includes conservation measures such as tank wraps and flow restriction devices.

For new households, solar water heat will likely have to compete against heat pump water heaters using either waste heat from ventilation or air conditioning systems. These integrated appliances fall under the conservation measure category and would be analyzed as such. These types of systems hold a great deal of potential for cost reduction because of their multipurpose capability. Success of these devices in the new market may substantially reduce the market share eligible for solar domestic water heating.

Pool and spa heating for residential buildings provide another opportunity for cost effective installation of solar water heating equipment. Data from the ODOE tax credit program¹ indicates that solar water heating systems for pools are available for use today and appear to be quite cost effective. Using the average system cost from the ODOE tax credit program of \$2,100 and average savings of 9,545 kWh and the same financing assumptions used for domestic water heat, solar pool heat has a levelized costs of 28.2 mills/kWh. While it appears to be quite cost effective, there is insufficient data to estimate the regional size of this resource.

Geothermal. Where available, high temperature geothermal could be used for heating domestic hot water directly. Unfortunately, the amount of high temperature resource available is quite limited. Lower temperature resources using heat pumps to develop acceptable hot water temperatures is a more likely possibility. These systems would likely be installed as part of a combined space/water heating system due to the relatively low incremental costs of the water heating system compared to the stand alone system cost.

Data from the ODOE tax credit program¹ indicate that the add-on cost of including water heating from a ground coupled heat pump system is approximately \$1,500. Assuming that these systems could achieve roughly the same level of savings as solar water heating systems (and probably more) this would provide a nominal levelized cost of roughly 85 mills/kWh. The cost is probably lower for systems installed at the same time as the space heating system.

Biomass. Another potential direct application of renewable resources water heating system involves burning wood to heat domestic hot water. Where wood is being used for space heat, a relatively simple installation of a water heating loop to the wood stove or fireplace can provide substantial water heating savings. These systems can be installed relatively inexpensively (less than \$500) and provide savings that tend to match the system load well. They also provide a good backup to solar systems. Dent⁴ monitored several of these combined solar/wood systems that provided nearly 80% of the water heating load year round. Due to the potential environmental problems associated with wood burning it is unlikely that it would be practical to encourage use of these heaters on a widespread basis.

2. Space Heat.

Like water heat, the use of direct application of renewable resources for space heating is also a fairly well developed technology. Applications in this end use include active and passive solar, direct or heat pump assisted geothermal, and biomass in the form of wood heat.

Solar. Probably the most common and available application of direct application of renewable resources in this sector is solar space heating. There are two main types of solar space heating; active and passive. Active solar system use air or fluids circulated by fans or pumps through separate solar collector panels and storage components to collect, store and circulate heat to the house. Passive solar space heating uses the building itself as the collector and storage system relying on natural heat transfer mechanisms to distribute the heat to the house. Active solar heating was demonstrated across the country in various projects during the late 1970s and early 1980s but was generally found to be very expensive and have high operation and maintenance costs. Passive systems were developed later, primarily during the early 1980s and are the only solar space heating system still being pursued in any substantive way.

Passive solar designs range from modest "sun-tempered" designs to designs attempting to heat almost entirely with solar. A typical northwest home built to insulation levels of the Model Conservation Standards (MCS) will save an additional 10% by orienting 50% of the total glazing on the house to the south. This "sun-tempering" can be achieved at essentially no additional cost. On a typical MCS building this amounts to roughly 500 kWh/yr.

More extensive passive solar systems typically involve one of several strategies that add south facing glazing area as well as thermal mass to collect and store additional solar energy. These "passive solar" systems are generally categorized as one of three types: direct gain, indirect gain or isolated gain.

Direct gain houses are characterized by large areas of south facing glass. Solar energy passing through the glazing is stored directly in the floors and walls of the building and later released during the night. This is probably the most typical and most effective passive solar design used in the Northwest.

Indirect gain houses use a special thermal storage component to collect the solar energy before it enters the main part of the house. This thermal storage component collects energy all day but because of the large mass involved only begins to transmit that energy to the house toward the end of the day and during the night time. These systems often use thick masonry walls or tubes of water directly behind large, south facing glazing areas. These systems have not been used extensively in the northwest and are not generally considered to be poor performers in the typical northwest climate.

Isolated gain houses use a separate building or room to collect and store the solar energy and then use natural or forced convection to distribute heat from the building to the main part of the house. The most common example of this type of system is the attached greenhouse. These systems are often retrofittable and add living space to the house. Unfortunately, in the northwest climate they often provide little heat gain to the existing building. The most effective use of this

strategy is where the collection area is integrated as an enclosed "atrium" in part of the house design.

Although not as extensive as in water heating there have been several monitored studies of passive solar buildings. By far the most comprehensive was the Class B monitoring project performed by the Solar Energy research Institute. This project used detailed monitoring equipment to determine the solar contribution to the house. Approximately 25 of these buildings were constructed and monitored in the Northwest under BPA's Passive Solar Homebuilder's Project. Savings of 20% to 40% were measured. Unfortunately, this project was completed over five years ago and does not necessarily represent the current state of the technology.

The only recent cost data that was available at the time this paper was being written was once again the Oregon tax credit program which has continued to provide tax credits for passive solar space heating systems. In 1988, the average savings computed by Oregon for the systems was 2464 kWh at a cost of \$7,700. Assuming a life of the system of 50 years and the same regional financing assumptions used in previous calculations this represents a regional nominal levelized cost of roughly 370 mills/kWh (1989\$). These costs and savings probably represent the attached greenhouse type of system more than the a direct gain design which may be more cost effective.

Another example of costs would be to take the same house used in the sun tempered example and add 100 ft² of south facing glass and 576 ft² of 4" concrete slab for storage. In Seattle, these changes will save roughly 20% of the space heating need. Assuming that the glass is replacing R-19 wall and that the concrete is finished with tile, the total cost of the system would run approximately \$2,000. Assuming that the system saved 1100 kWh (assuming the house was built to Model Conservation Standards Levels), the nominal levelized cost would be 210 mills/kWh. The same house in Boise, Idaho would save roughly 30% or 1,900 kWh at a regional cost of 120 mills/kWh.

From these simple examples it is clear that passive solar is most likely to be cost effective east of the cascades. However, passive solar space heating requires adequate access to the sun to be effective. Implementation of solar access ordinances or solar easements are necessary to assure the long term value of the resource.

Geothermal. Probably the other main application of direct application of renewable resources for space heating is the use of geothermal energy. Geothermal resources for direct use can generally be categorized as high temperature (greater than 150 °F), intermediate temperature (100 to 150 °F), and low temperature (less than 100 °F). High temperature geothermal resources are very site specific and have limited applicability. Most of these resources that are near the surface have already been developed. The remaining options for using high temperature geothermal directly lie in undeveloped deep sources that could be used as part of a district heating system.

A Battelle Pacific Northwest Laboratories⁵ study for the 1983 power plan examined the costs of district heating systems using an intermediate temperature (100-150°F) resource. After looking at 78 cities with populations of 10,000 or more, the analysis came up with 11 that looked feasible for implementation of a geothermal district heating system. Table 4 lists the cities and the estimated cost

of energy delivered to the house. These costs do not include any incremental costs for the individual heating systems.

Table 4. Potential Geothermal District Heating Sites

<u>City</u>	<u>Estimated Usable Energy MWa</u>	<u>Estimated Cost of Energy¹</u>	
		<u>Urban mills/kWh</u>	<u>Suburban mills/kWh</u>
Boise, ID	130	71	NA
Caldwell, ID	16	75	NA
Nampa, ID	32	75	NA
Rexburg, ID	16	64	NA
Twin Falls, ID	32	72	NA
Butte, MT	32	56	NA
Altamont, OR	24	54	72
Klamath Falls, OR	24	42	61
The Dalles, OR	16	86	NA
Bellingham, WA	56	76	NA
Mount Vernon, WA	16	86	NA

1. Escalated from 1980 to 1988 Dollars by a multiplier of 1.45.

Looking at Table 4, suggest that there may be several sites where geothermal district heating may be cost effective. However, there are many significant institutional barriers to implementation of such systems. There may be serious environmental objections. Current environmental challenges to exploratory drilling near Crater Lake, Oregon is an example of the potential challenges to development of these resources.

There are also serious problems finding developers with the capital to establish the plant for the district heating system. Given that in retrofit situations the installation of the system would require major disruption of existing facilities the developer would require close cooperation from the municipal system it would serve. Finally, there is competition with other fuels. A strong argument can be made that other utility companies, notably natural gas suppliers, could provide the same end product, space heat, at a lower cost and with less disruption of streets, etc.

A more likely use of geothermal energy may be in the form of ground source heat pumps. These machines work just like air source heat pumps only they exchange heat with the ground. The stable ground temperature generally provides the potential for higher and less varying coefficients of performance. There are generally three types of ground source systems.

The first type, generally classified as open loop systems uses water from a well as the heat source. After use in the heat pump the water is either reinjected into the well or disposed of into a pond or river. Where there are low temperature geothermal resources that are still warmer than the typical ground temperatures these systems can have extraordinary coefficients of performance.

The second type of system is generally designated as a closed loop system. These system exchange heat with a fluid circulated through a series of pipes that

are buried in the ground either horizontally in a grid or vertically in a well. These are the most common systems available and are most flexible in their installation requirements.

The third type of system is a form of closed loop system. Instead of exchanging heat with a water based fluid in the ground loop these systems circulate the compressor refrigerant directly into the ground loop. These systems are categorized as direct expansion systems. While providing good heat transfer with the ground coil, these systems have the disadvantage of requiring large quantities of refrigerant with a larger surface area for potential leaks to develop. However, a number of these systems have been installed in Oregon with good results.

There have been very few regional monitoring projects to confirm the performance of ground coupled heat pump systems. However, because the compressors used in these systems are operating under fairly stable conditions, the primary uncertainties lie in the performance of the ground loop itself. In a study in of one home located in Helena, Montana, Jackson⁶ reported an overall system coefficient of performance of 2.3 compared to a predicted COP of 2.5. This study seemed to indicate that the tools used to estimate the performance of the ground loop were adequate for insuring reasonable performance. Assuming that the ground loop sizing models are indeed correct, typical performance west of the cascades should result in COP's close to 3.

There is also very little information on the cost of these systems. The Oregon tax credit program listed 80 ground coupled heat pump systems installed in 1988 with an average system cost of \$8,000. Because of the high installation cost, these systems are generally installed as a retrofit measure on large homes with relatively poor insulation characteristics. Table 5 provides an estimate of cost effectiveness for a ground coupled system assuming an unweatherized building, a fully weatherized building and a building built to the MCS and financing assumptions consistent with those used previously in this paper.

Table 5. Ground Coupled Heat Pump Cost Effectiveness

Input Assumptions:	House Size:	3,000 & 2,000 ft ²
	System Cost:	\$8,000
	Compressor Cost:	\$1,000
	System Life:	20 years
	Annual O&M Costs:	\$50/yr
	Annual COP:	3.0

<u>Case</u>	<u>Base Use kWh/ft²</u>	<u>Total Space Heat kWh</u>	<u>Savings kWh</u>	<u>Nominal Levelized Cost mills/kWh</u>
3,000 ft ²				
Unweatherized	8.0	24,000	16,000	71
Weatherized	5.0	15,000	10,000	114
MCS	3.0	9,000	6,000	189
2,000 ft ²				
Unweatherized	8.0	16,000	10,667	106
Weatherized	5.0	10,000	6,667	170
MCS	3.0	6,000	4,000	284

From Table 5, it appears that the ground coupled heat pump is primarily cost effective for large homes or those for which weatherization is either not possible or is limited. It is important to note that these costs do not include the distribution systems. If these systems were to be compared to a zonal electric house, the costs of distribution system would have to be added in.

An offsetting potential benefit of these systems is the potential to provide hot water as well as space heat. More of these combined systems are beginning to go in according the Oregon tax credit information. The systems should easily be capable of providing 40% to 50% savings for water heating for a relatively low incremental cost. Preliminary data from the Oregon program suggests that the add-on costs is around \$1,500 but may be less with better integrated systems.

These systems also provide cooling which is a desirable amenity in parts of the Northwest. However, the cooling performance of these machines is roughly equivalent to a standard air source heat pump and may provide only marginal additional cooling savings. Again, the savings potential for cooling increases with load. Areas with a large amount of cooling may see substantial savings from cooling to add to the savings on space and water heat.

Biomass. In addition to solar and geothermal, biomass currently provides a substantial direct application of renewable resources application for space heating primarily in the form of wood heat. This includes wood heating as it is currently performed today using wood stoves and ranges to future use of specialized fuel from lumber industry waste products. Pellet stoves, a very efficient stove using pre-processed wood pellets for fuel is one example of future uses of this resource.

Unfortunately, wood burning in conventional equipment has severe environmental consequences and stands out from other direct application of renewable resources as being undesirable for that reason. Newer technology such as pellet stoves and regular stoves with catalytic converters may be "clean" enough to be considered. There also questions about the sustainability of wood when it is cut directly for space heat as opposed to using a residue from the wood products industries. A common rule of thumb is that a 5 acre wood lot is necessary to provide a sustainable wood supply for a typical home. If this is true there are some obvious upper limits to the ultimate penetration of wood heat if it is indeed to be considered renewable.

The current planning process accounts for wood use as a reduction in space heat that already exists. Given the environmental problems associated with wood use, it seems doubtful that any programs encouraging wood burning are likely to be considered in the future. However, continued monitoring of the technology is important as future changes in the emissions output and use of industry waste products become more prevalent.

COMMERCIAL SECTOR

The commercial sector has several possibilities for direct application of renewable resources applications ranging from hot water systems for restaurants to daylighting in large office buildings. Unfortunately, there is not a good set of recent data on commercial direct application of renewable resources applications unlike the residential sector. As in residential, direct application of renewable resources in commercial is very site specific. The primary applications are: 1)water heating; 2)space heating and cooling; and 3)daylighting.

Water Heating

Commercial water heating applications include all of the same residential uses in large apartments and dormitories as well as for laundries, car washes, and restaurants. The use of solar water heating can in general be more cost effective than in residential due to the lower ratio of fixed installation costs to incremental collector costs. However, there remain several large barriers in the commercial sector to solar water heating. These include the high price of the area required for the collector arrays, reliability concerns, and aesthetic and architectural considerations.

There is also a large major competing technology in large commercial buildings. For large commercial buildings, the cooling load is often much larger than the heating load. Given that conventional cooling equipment rejects large amounts of waste heat, heat recovery systems used to supply water heating are a major competing technology.

Geothermal resources are also potentially available for water heating although the resources available are again site specific. Low temperature and ground coupled heat pump systems have a wider potential application.

Space Heating and Cooling

Both solar and geothermal provide opportunities for space heating in commercial buildings. Because of the large plant costs of developing a geothermal resource, the commercial building provides a large opportunity where a resource is available. As in residential, the largest potential probably resides in low temperature applications that may use a heat pump to increase the temperature to a usable level. There is a geothermal heat pump driven system in Portland, Oregon that supplies heat to a large building downtown.

Solar space heating in commercial buildings is fairly limited and is generally given second priority to rejecting solar heat for cooling reduction. However, passive solar heating in schools and other smaller commercial facilities with a high heating load can benefit from the same technology as residential. Again, because the balance of system costs for larger applications tend to be smaller, commercial