Heat Pump Technology - potential impact on Juneau economically and on climate action goals.

Heat pumps use electricity to convert heat from a heat source to make heat and are substantially more efficient than baseboard or resistance type electrical heating and combustion (oil, propane, wood, pellets) sources of heating. In fact heat pumps are the most efficient forms of heating technology developed to date. The reason that they are so efficient is that they produce more thermal energy than the electricity that is needed to operate and move the thermal energy.

Heat pumps are also good for the global and local environment. Full deployment and application of Heat Pump technology operated on a global scale with renewable energy could reduce global greenhouse gas emissions by eight percent.[1] This eight percent reduction in greenhouse gas emissions is the equivalent of taking 52 million vehicles off the road globally. As a result of their ecological and economic benefits, heat pump applications are gaining importance around the world.

Heat Pumps and Greenhouse Gas Emissions

Heat Pumps operated on a renewable energy source like hydropower are not only the most energy efficient heating systems, but they are also the best source of heating for the environment because they are the only heat source that emits ZERO emissions when the electricity used in them is renewable. Heat pumping technologies are widely used for upgrading low-temperature free heat from renewable sources, such as air, water, ground and waste heat, to useful temperatures. In producing heat, they are called heat pumps, and they effectively compete with fossil fuel-fired furnaces and boilers, pellet heating systems and with direct electric heating. Heat pump technologies are being widely used in many places in the world where renewable energy sources are mated with the heat pump technology to mitigate societal carbon emissions. According to the International Energy Agency, Heat Pump Centre of which the United States is a contributing member, widespread deployment of heat pump technologies could reduce world carbon emissions by 1.8 billion metric tons of CO_2.

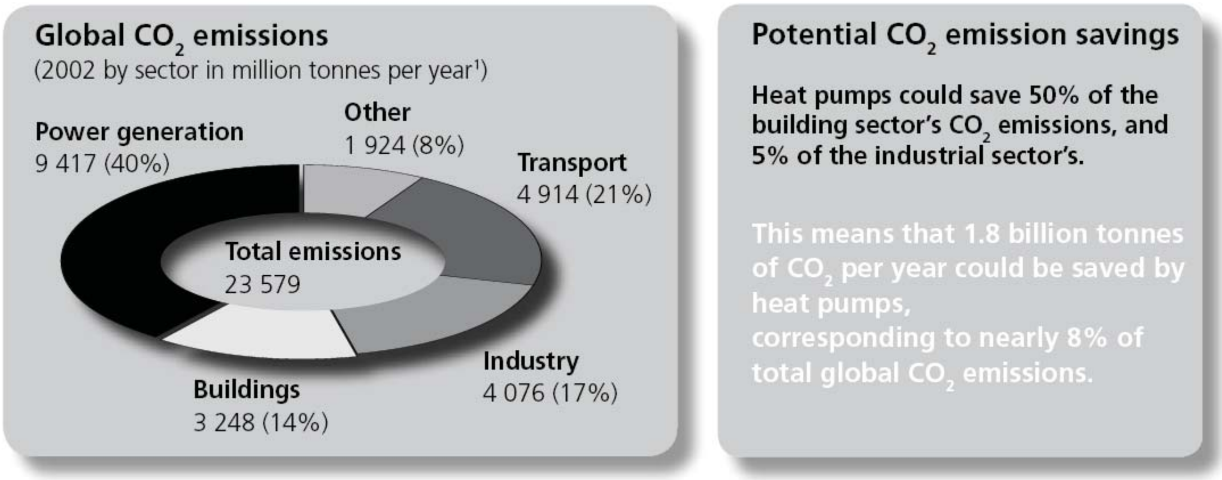
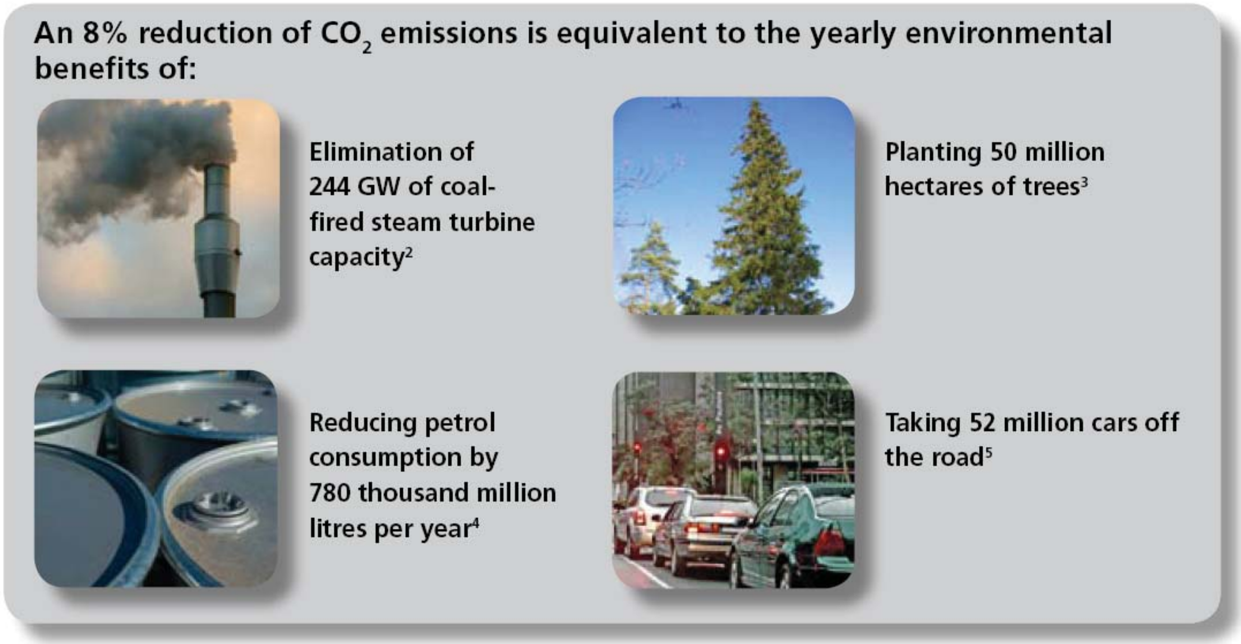


Figure 1 Global CO_2 emissions and potential CO_2 savings with heat pumps

[1] http://www-v2.sp.se/hpc/publ/HPCOrder/viewdocument.aspx?RapportId=451



1) World Energy Outlook 2004, The International Energy Agency
2) Assumptions: specific emissions 890 kg CO_2/MWh_{el}, operating time 8 400 h/year
3) 36 tonnes CO_2 per hectare trees and year abated, according to Myers, N., and T. J. Goreau. 1991. Tropical forests and the greenhouse effect: A management response. *Climatic Change*, 19: 215-26.
4) Use of 1 litre of petrol creates 2.3 kg CO_2, according to http://www.epa.gov/otaq/climate/420f05001.htm
5) Assumptions: 15 000 km per year, 0.8 litre petrol used/10 km, use of 1 litre petrol creates 2.3 kg CO_2

Figure 2. Equivalent values of an 8% global reduction in CO_2.

Below is a table that compares types of heating systems to their specific output of CO_2 emissions.

Type	Heat Demand (kWh)	Efficiency (%)	Input Energy (kWh)	Specific CO2 emissions (kg CO2/kWh)	Annual CO2 emissions (kg)
Oil-fired boiler	15 000	80	18 750	0.274	5 138
Gas-fired boiler	15 000	95	15 790	0.202	3 189
Electric boiler,	15 000	95	15 790	0.472	7 454
non renewable source					
Electric heat pump,	15 000	300	5 000	*0*	*0*
electricity from renewables					
Source Heat Pump Centre Boras, Sweden					

Table 1. Comparison of Annual CO_2 emissions from different heating systems

Heat Sources for Heat Pumps

Source IEA Heat Pump Centre - SP Technical Research Institute of Sweden www.heatpumpcentre.org

The technical and economic performance of a heat pump is closely related to the characteristics of the heat source. An ideal heat source for heat pumps in buildings is a heat source with a high and stable temperature during the heating season, is abundantly available, is not corrosive or polluted, has favorable thermophysical properties, and its utilization requires low investment and operational costs. In most cases, however, the availability of the heat source is the key factor determining its use. Table 2 below presents commonly used heat sources and their heat source range. Heat pump technologies, when properly engineered, have proven successful with Alaska temperatures.

Ambient and exhaust air, soil and ground water are practical heat sources for small heat pump systems, while sea/lake/river water, rock (geothermal) and waste water are used for large heat pump systems. Recently, Alaska has led in seawater heat pump applications at the Seward Sea Life facility and the Juneau NOAA Ted Stevens Marine Research Institute.

Heat Source Capacity Range Table				
Heat Source		**Commonly Used Heat Sources**		
Heat Source	**Temperature Range (°C)**		**Temperature Range (°F)**	
Ambient Air	-10	25	14	77
Exhaust Air	15	25	59	77
Ground Water	4	10	39.2	50
Lake Water	0	10	32	50
River Water	0	10	32	50
Sea Water	3	8	36.5	46.4
Rock	0	5	32	41
Ground	0	10	32	50
Waste water and effluent	>10	>10	50	50

Table 2 Commonly used Heat Pump heat sources and Temperature Range (source: www.heatpumpcentre.org)

Types of Heat Pumps that would economically and environmentally benefit Juneau, Alaska

Seawater Heat Pump (SWHP)

Seawater heat pumps are water-to-water systems that operate by using electric compressors in combination with the physical properties of an evaporating and condensing fluid known as a refrigerant. The refrigerant used in the heat pumps in the Alaska SeaLife Center project is known as R-134a. HFC-134A replaced an older refrigerant, CFC-12 when CFCs were largely banned from use in 1987. HFC-134A does not damage the ozone layer like its CFC predecessors.

This project also used a dual high efficiency rotary screw compressors on a single water-to-water heat pump that is an emerging technology; this feature is what allows the temperature lifting of heat from as low as 37°F up to the target building heat temperature of 120°F. A stainless steel and titanium coated plate-and-frame heat exchanger is also required to prevent corrosion during the process of removing heat from the raw seawater flow in advance of the heat pump.
(Source Alaska Center for Energy and Power)
http://energy-alaska.wikidot.com/seawater-heat-pump-demonstration-project#toc3

Heat Pumps at the Seward Sea Life Center
Photo by Lang Van Dommelen

In Juneau, the NOAA Ted Stevens Marine Research Institute located at Lena Point installed a seawater heat pump energy system in 2011. The facility, with other features, is 100% green. Green can also mean saving green. The seawater energy recovery system will replace 60,000 gallons of heating oil annually, saving taxpayers an estimated $130,000 a year. The system is expected to recoup the half-million dollars invested in it in about five years. The new, year-round seawater heat recovery system produces enough energy to heat 60 houses. It could be used as an energy recovery model throughout the U.S. In fact, analysis is currently underway to see if a similar technology could be used to heat NOAA’s Kodiak facility. Jim Rehfeldt of Alaska Energy Engineering, LLC of Juneau designed the project.

Michael Penn-Juneau Empire Photo

Photo Credit: NOAA - One of two heat pumps that extract 4 degrees of heat from 38-degree seawater and use that energy to heat the 66,000-square foot Ted Stevens Marine Research Institute in Juneau, Alaska.

Coefficient of Performance of a Seawater Heat Pump

The Coefficient of Performance (COP) for a heat pump is the ratio of total heat output to electricity input. For this seawater heat pump project, a minimum COP value of 3.0 can be maintained and will lead to viable economic returns. This COP is maintained because there is enough heat stored in the thermal mass of Southeast Alaska sea water through the winter heating season to keep seawater temperatures well above freezing. This heat can be captured as renewable energy using the emerging technology heat pumps now available. The seawater heat pump process and associated COP is illustrated below:

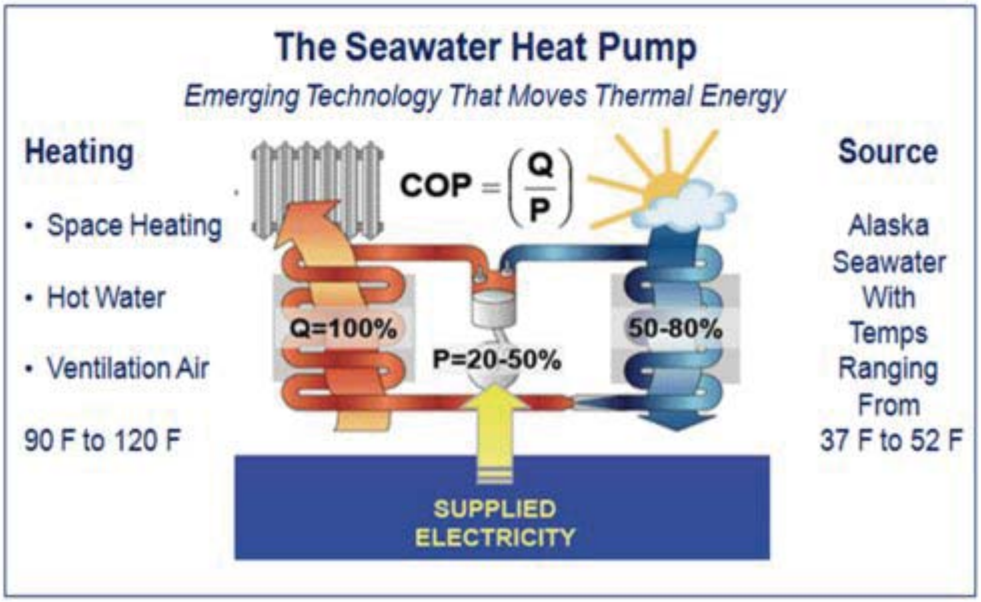


Figure 3. Seawater Heat Pump Overview

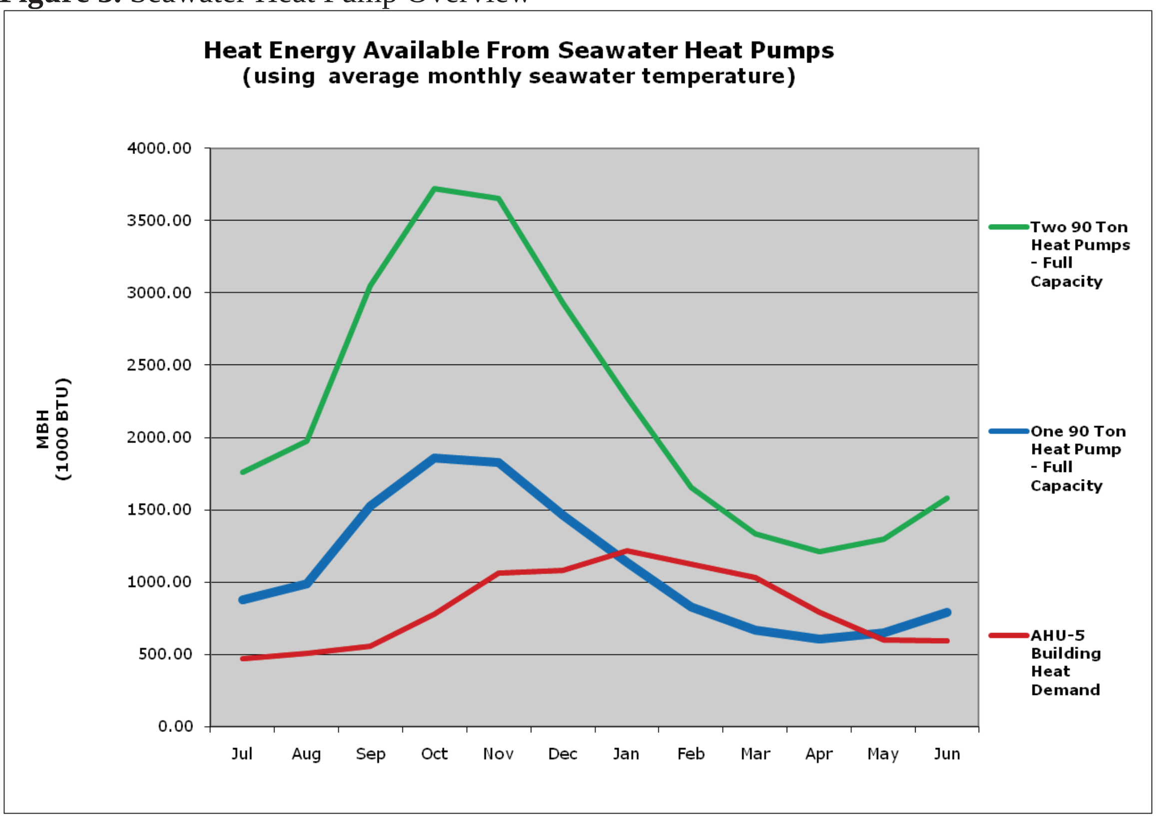


Figure 4. Seward Sea Life Heat Energy Available from Seawater Heat Pumps

Air Source Heat Pumps (ASHP)

Air-source heat pumps (ASHPs) are attractive for moderate climates because they do not require ground coupling, substantially reducing capital costs and infrastructure complexities when compared with ground source heat pumps. Recent technological advances may challenge the assumption that ASHP systems are not appropriate for cold climates, especially for locations like Southeast Alaska that have relatively mild temperatures for building heating load. From the outside, air source heat pumps look like air conditioning units.

Air-source heat pumps draw heat from the outside air during the heating season and reject heat outside during the summer cooling season. There are two types of air-source heat pumps. The most common is the air-to-air heat pump. It extracts heat from the air and then transfers heat to either the inside or outside of your home depending on the season.

The other type is the air-to-water heat pump, which is used in homes with hydronic heat distribution systems. During the heating season, the heat pump takes heat from the outside air and then transfers it to the water in the hydronic distribution system. If cooling is provided during the summer, the process is reversed: the heat pump extracts heat from the water in the home's distribution system and "pumps" it outside to cool the house. These systems are rare, and many don't provide cooling; therefore, most information focuses on air-to-air systems.

More recently, ductless mini-split air source heat pumps have been successfully introduced to the Canadian market and are extensively deployed in neighboring British Columbia. They are ideal for retrofit in homes with hydronic or electric resistance baseboard heating. They are wall-mounted, free-air delivery units that can be installed in individual rooms of a house. Up to eight separate indoor wall-mounted units can be served by one outdoor section.

Air-source heat pumps can be add-on, all-electric or bivalent. Add-on heat pumps are designed to be used with another source of supplementary heat, such as an oil, gas or electric furnace. All-electric air-source heat pumps come equipped with their own supplementary heating system in the form of electric-resistance heaters. Bivalent heat pumps are a special type, developed in Canada, that use a gas or propane fired burner to increase the temperature of the air entering the outdoor coil. This allows these units to operate at lower outdoor temperatures.

Air-source heat pumps have also been used in some home ventilation systems to recover heat from outgoing stale air and transfer it to incoming fresh air or to domestic hot water.

Source: Natural Resources Canada www.ncran.gc.ca

In 2011, the State of Minnesota commissioned a study to determine the Air Source Heat Pump Efficiency Gains from Low Ambient Temperature Operation Using Supplemental Electric Heating.

The field results from this study demonstrated that it is feasible to utilize an ASHP for residential heating at temperatures below 30°F, and that in the temperature range between 0° and 30°, a significant portion of the heating energy is supplied by the ASHP and the overall system efficiency is improved over using resistance heat alone. From an electric heating standpoint, a hybrid system of electric resistance heat and ASHP is an efficient heating solution for climates like Minnesota that are usually colder than Juneau.

ASHPs, typically operating in combination with supplemental electric resistance heating, are a viable and economical means to improve electric heating efficiency. Independent research shows ASHPs will maintain a coefficient of performance (COP) well above 1, and often between 2 to 3, in cold-climate conditions (as compared to a COP of 1 for electric resistance heat). In essence, this means that for every unit of energy consumed the unit produces two to three times more units of thermal energy.

In Minnesota, converting from less efficient electric systems to heat pump-only or hybrid electric systems offers significant opportunity for energy savings. Billing data analysis of individual homes highlights examples of electrically-heating homes that have realized as much as 40% electricity consumption reductions through the adoption of hybrid ASHP systems.

Overall, customers are highly satisfied with their system's performance. Surveyed customers provide an average rating of 4.3 on a 5-point scale (1 = 'Poor', 5 = 'Excellent') across all dimensions of their hybrid system performance.

A large majority of customers adopting hybrid ASHPs are found to be converting from other heating fuel sources.

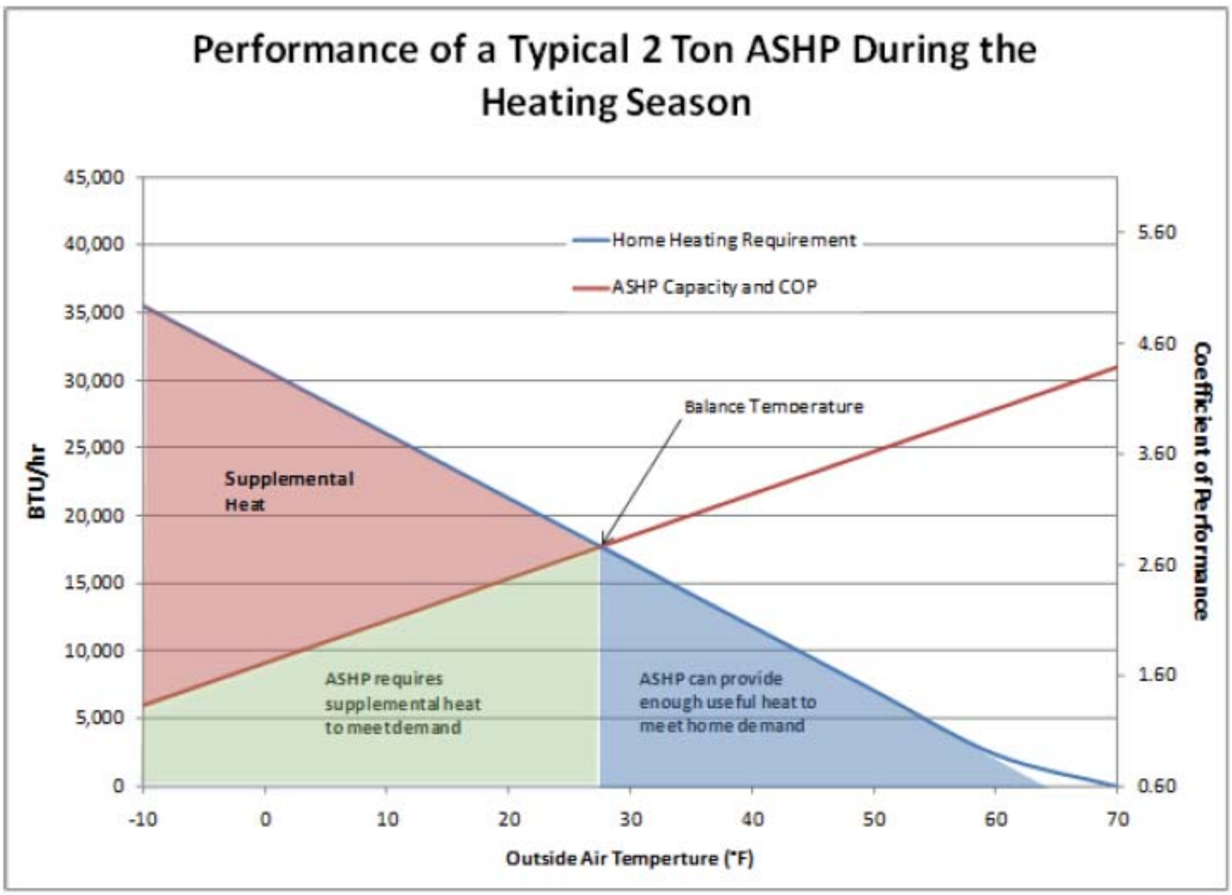


Figure 5. Performance of a typical Air Source Heat Pump during heating season (Source-State of Minnesota)
http://mn.gov/commerce/energy/images/CIP-AirSource-Pump-Report.pdf

In addition, the Canadian Government continues to conduct cold climate air source heat pump research and provide valuable references and resources at Natural Resources Canada: http://www.nrcan.gc.ca/energy/science/programs-funding/2066

Ductless type air source heat pump

Duct type air source heat pump

Air Source Heat Pumps in Southeast Alaska

(Source: Cold Climate Housing Research Center http://makinghouseswork.cchrc.org/?p=2534

Southeast Alaska is a promising candidate for ASHP heating appliances because it has a milder climate than the rest of the state and access to affordable hydroelectric power. Because ASHPs take some heat from the outdoor air and require less electricity than electric baseboards, they have the potential to reduce heating costs for homeowners who previously heated with electric appliances.

However, there is still uncertainty about the performance of ASHPs in cold climates, and about the barriers to their adoption in Alaska. The Cold Climate Housing Research Center (CCHRC) located in Alaska is planning to explore the opportunity of using ASHPs in Southeast Alaska in a new project: Southeast Alaska ASHP Technology Assessment. The CCHRC plans to conduct a literature review, interview installers, distributers, and ASHP owners, create an inventory of existing ASHPs in Alaska, and model their economic and heating impact. Results of some of the CCHRC investigation and analysis should be available on the CCRHC website in 2013. http://www.cchrc.org

When selecting an air source heat pump, look for the highest Heating Seasonal Performance Factor (HSPF) rating. The higher the HSPF rating of a unit, the more energy efficient the unit is. HSPF is a ratio of BTU heat output over the heating season to watt-hours of electricity used. These ratings are listed with the manufacture and can be verified by the US Green Star Energy Program.

Ground Source Heat Pumps (GSHP)

Ground-source heat pumps (GSHPs) are well-established systems that can economically heat and cool buildings in most locations, including Juneau. GSHP's are in use throughout the United States and several have been installed in Juneau. GSHPs take advantage of moderate soil temperatures available year-round a short distance underground.

Although many parts of the country experience seasonal temperature extremes -- from scorching heat in the summer to sub-zero cold in the winter—a few feet below the earth's surface the ground remains at a relatively constant temperature. Ground temperatures in Juneau range from 35°F to 60°F.

There is some pubic data on ground temperatures on various locations in Juneau. This data is displayed in the table below:

Ground Temperature Thermal Probes at location and depth shown. Juneau temperatures are shown in degrees F. Data collected December 13, 2002. *These are the beginning temperature readings for the Winter 2002-2003*

	Depth (inches)	Tee Harbor Lynn Canal Fire Dept.	Lower Mendenhall Valley Teslin St.	Mid Mendenhall Valley Portage Blvd.	Thread Needle St.	Lemon Creek Water Utility	Eighth Street Juneau	North Douglas	Crow Hill Douglas
1	12	57.3	35.84	41.47	41.3	42.89	43.17	43.47	43.77
2	24	50	35.75	40.84	41.4	42.54	43.32	43.71	43.71
3	48	56.3	35.77	39.95	40.84	42.06	42.5	43	43.33
4	60	60.1	35.77	41.38	42.31	43.81	44.05	44.21	44.27

Table 3. Juneau Ground Temperatures in December
Source CBJ Water Utility http://www.juneau.lib.ak.us/waterftp/temperature.htm

Like a cave, this ground temperature is warmer than the air above it during the winter and cooler than the air in the summer. The GHP takes advantage of this by exchanging heat with the earth through a ground heat exchanger.

As with any heat pump, geothermal and water-source heat pumps are able to heat, cool, and, if so equipped, supply the house with hot water. Some models of geothermal systems are available with two-speed compressors and variable fans for more comfort and energy savings.

GSHP system life is estimated at 25 years for the inside components and 50+ years for the ground loop. There are approximately 50,000 geothermal heat pumps installed in the United States each year[2].

Heat Pumps at the Juneau International Airport

[2] http://energy.gov/energysaver/articles/geothermal-heat-pumps

Drilling to establish the vertical ground loops at the Juneau Valley Dimond Park Aquatic Center

Michael Penn/Juneau Empire
Drilling for the new Alaska State Library, Archives and Museum building's geothermal heating system

Types of Geothermal Heat Pump Systems
(Source from US Dept of Energy)
There are four basic types of ground loop systems. Three of these – horizontal, vertical, and pond/lake – are closed-loop systems. The fourth type of system is the open-loop option. Which one of these is best depends on the climate, soil conditions, available land, and local installation costs at the site. All of these approaches can be used for residential and commercial building applications.

Closed-Loop Systems

Most closed-loop geothermal heat pumps circulate an antifreeze solution through a closed loop – usually made of plastic tubing – that is buried in the ground or submerged in water. A heat exchanger transfers heat between the refrigerant in the heat pump and the antifreeze solution in the closed loop. The loop can be in a horizontal, vertical, or pond/lake configuration.

One variant of this approach, called direct exchange, does not use a heat exchanger and instead pumps the refrigerant through copper tubing that is buried in the ground in a horizontal or vertical configuration. Direct exchange systems require a larger compressor and work best in moist soils (sometimes requiring additional irrigation to keep the soil moist), but you should avoid installing in soils corrosive to the copper tubing. Because these systems circulate refrigerant through the ground this could cause environmental problems is some locations.

Horizontal

This type of installation is generally most cost-effective for residential installations, particularly for new construction where sufficient land is available. It requires trenches at least four feet deep. The most common layouts either use two pipes, one buried at six feet, and the other at four feet, or two pipes placed side-by-side at five feet in the ground in a two-foot wide trench. The Slinky™ method of looping pipe allows more piping in a shorter trench, which cuts down on installation costs and makes horizontal installation possible in areas it would not be with conventional horizontal applications.

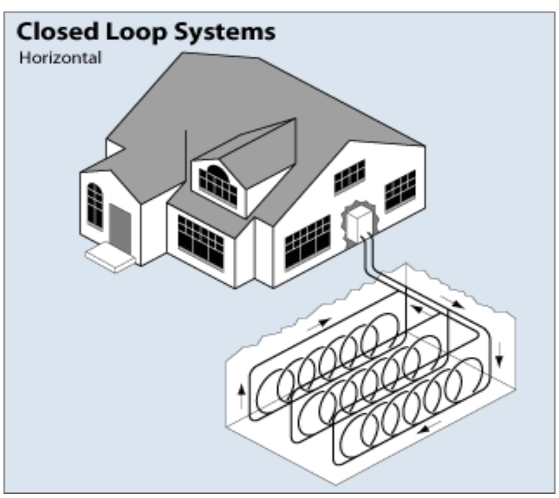


Figure 6. Closed Loop Horizontal System

Vertical

Large commercial buildings and schools often use vertical systems because the land area required for horizontal loops would be prohibitive and they minimize the disturbance to existing landscaping. Vertical loops are also used where the soil is too shallow for trenching. For a vertical system, holes (approximately four inches in diameter) are drilled about 20 feet apart and 100 to 400 feet deep. Into these holes go two pipes that are connected at the bottom with a U-bend to form a loop. The vertical loops are connected with horizontal pipe (i.e., manifold), placed in trenches, and connected to the heat pump in the building.

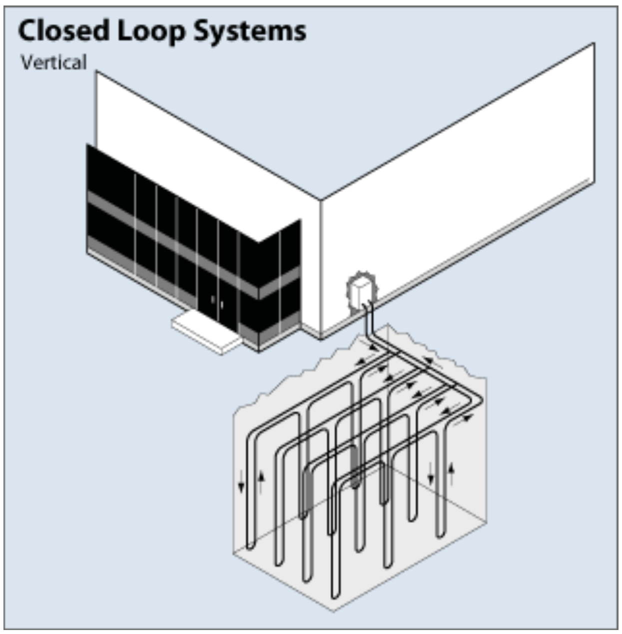


Figure 7. Closed Loop Vertical System

Pond/Lake

If the site has an adequate water body, this may be the lowest cost option among GSHP options. A supply line pipe is run underground from the building to the water and coiled into circles at least eight feet under the surface to prevent freezing. The coils should only be placed in a water source that meets minimum volume, depth, and quality criteria.

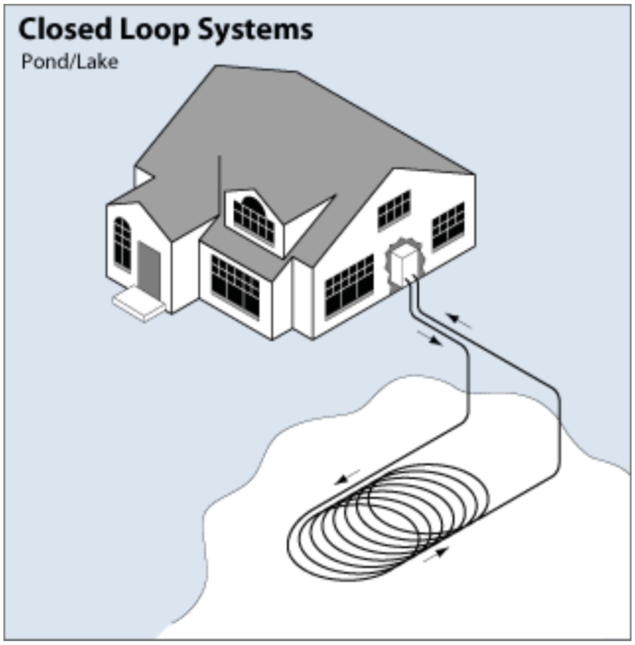


Figure 8. Closed Look Lake/Pond System

Open-Loop System

This type of system uses well or surface body water as the heat exchange fluid that circulates directly through the GHP system. Once it has circulated through the system, the water returns to the ground through the well, a recharge well, or surface discharge. This option is obviously practical only where there is an adequate supply of relatively clean water.

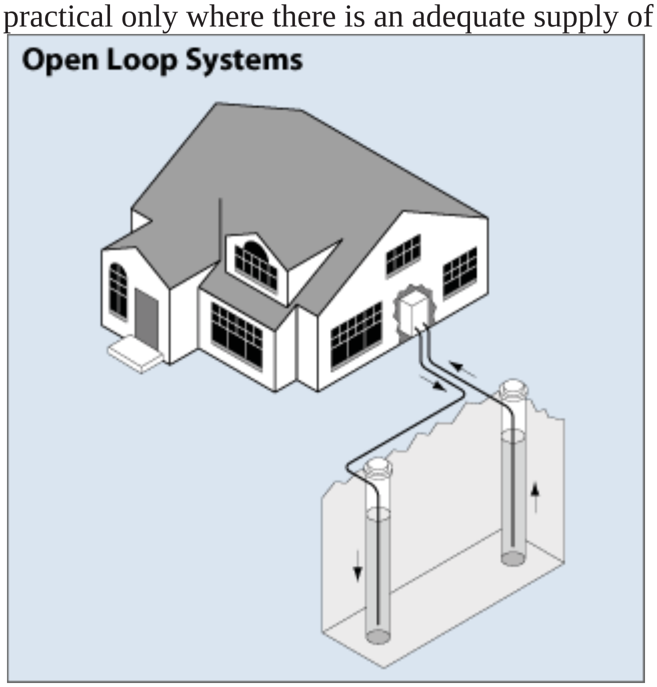


Figure 9. Open Loop System

Hybrid Systems

Hybrid systems using several different geothermal resources, or a combination of a geothermal resource with outdoor air (i.e., a cooling tower), are another technology option. Hybrid approaches are particularly effective where cooling needs are significantly larger than heating needs. Where local geology permits, the "standing column well" is another option. In this variation of an open-loop system, one or more deep vertical wells are drilled. Water is drawn from the bottom of a standing column and returned to the top. During periods of peak heating and cooling, the system can bleed a portion of the return water rather than reinjecting it all, causing water inflow to the column from the surrounding aquifer. The bleed cycle cools the column during heat rejection, heats it during heat extraction, and reduces the required bore depth.

For a video from the US Department of Energy explaining Ground Source Heat Pumps: http://energy.gov/articles/technology-breakthrough-geothermal

Heat Pump District heating and cooling systems (DHC) examples from around the world

In many countries, heat pumps are successfully applied in district heating systems or in combined district heating and cooling systems. Typical heat sources and heat sinks for the systems are sea water, ground water, rock or sewage. The largest district heating heat pump in the world utilizing untreated sewage as a heat source is a 28 MW R134a two stage system installed in 2006 in the district heating grid of Viken Fjernvarme AS in Oslo, Norway. Compared to direct electric heating systems based on the mean European (UCPTE) electricity mix, this heat pump cuts CO2 emissions by 50 000 tonnes annually.

Sewage water heat pump system in Norway. 2006

District Heating Energy from the Sea

Bodo, Norway Air Base, above the Arctic Circle, operates on a centralized heating Seawater hybrid heat pump system.

Bodø, Norway Air Base, above the Arctic Circle has had a sea water based heat pump central heating system since 1992. The district heating plant consists of two heat pumps of 2 MW (1,896 Btu/sec), one electric boiler and two oil-fired boilers at 3.8 MW (3,600 Btu/sec). The central heating plant is located close to the beach, approximately 200 m (656 ft) away. Seawater is drawn from a depth of 170 m (558 ft); where the temperature is constantly 7°C (44.6°F) throughout the year. The seawater drains into a 7-m deep basin (19.7-ft); where, two submerged pumps are located. Their total capacity is 180 m3/hr (47,600 gal/hr). The System uses NH3 Ammonia where it is heated with seawater and boils in the evaporator at 4 bar (58 psi) and minus 0.7°C (33.3°F). The low-pressure compressor compresses the vapor to 14 bar (203 psi), 100°C (212°F). The hot vapor enters the inter-stage receiver. The high-pressure compressor compresses the vapor from 14 bar, 38.7°C (102°F) to 30.7 bar (445 psi), 108°C (226°F). The hot vapor enters the condenser; where, it is cooled to 74°C (165° F), and the condensation heat is transferred to the district heating system. The water in the district heating system enters the first aggregate (the "master"), which is always running, at 60°oC (140°F) and leaves at 64°C (147°F). It enters the second aggregate (the "slave"), which runs only if necessary, at 64°C and leaves at 68°C (154°F). The heat factor is 3.4 at the master and 3.2 at the slave.

The Norwegian Government estimated that it took 6 years in energy savings to pay for the system that was installed in 1992.

Another Norwegian District Heat Pump system began operation in Drammen Norway in 2011 as the Drammen District Heating System. To date, this is the world's largest district heat pump with a rating of 14.3 MW supplying the town of Drammen (population of 60,000) with district heat. The system, like other Norwegian heat pump systems, transfers heat with environmentally friendly Ammonia. In fact, the new ammonia-based industrial heat pump has a performance improvement estimated to be more than 15 percent higher than a heat pump using R-134A refrigerant. The district heating system is able to deliver heat at up to 95°C (203°F) and is able to extract heat from seawater below <5°C (41 °F). The system provides environment-friendly heating for more than 6,000 residents and companies in Drammen, Norway. The saltwater heat pump electricity is operated by abundant hydroelectric power.

For a video of the Drammen District Seawater Heat Pump:
http://www.youtube.com/watch?v=a6xMS_hBNKM

Recent CBJ Public Sentiment for Ground Source Heat Pump systems for public buildings.

The Juneau private and public sector has been migrating to geothermal heat pumps in order to save on energy costs for several years. Heat pumps consume less electricity than transitional resistance heat (plug in type heaters), but they consume electricity at a higher efficiency than most other currently available technologies. Juneau now has several buildings on geothermal heat pumps that include the Juneau International Airport, Alaska Electric Light and Power Office building, and the Dimond Aquatic Center.

In 2011, Proposition 3 on the CBJ municipal election ballot asked voters if they would be willing to bond for a geothermal heat pump system for the local Auke Bay School for $1.4 million dollars. The Auke Bay Geothermal heat pump bond measure passed affirmatively by a greater margin than any other ballot in the 2011 election cycle. The Yes votes numbered 4,432 to No votes numbering 1,585. A winning margin by 73.66% of the votes cast. While this ballot election is not a scientific poll of how Juneau citizens would vote today on converting additional public buildings to lower cost ground source heating sources, it does provide an indication of the acceptance of the citizens of Juneau to invest in more electrically efficient heating systems.

Ground source heat pumps have been rated up to 330% efficient. Local experience has been somewhat lower and could be 250% efficient (Source Robert Deering personal conversation with Jim Rehfeldt). What this means is that for every watt of electrical energy that goes into powering the heat pump, 2.5 watts of thermal energy are delivered to the building. Only heat pump technologies: seawater heat pumps, ground source heat pumps and air source heat pumps provide positive efficiencies where they produce more thermal energy than they consume. For more information to compare heat pump technology heating costs compared to traditional heating fossil fuel and wood pellet heating sources, please review the Juneau Fuel Cost Comparison Calculator on this website.

Heat Pump Technology

About heat pumps and detailed information on how they work.

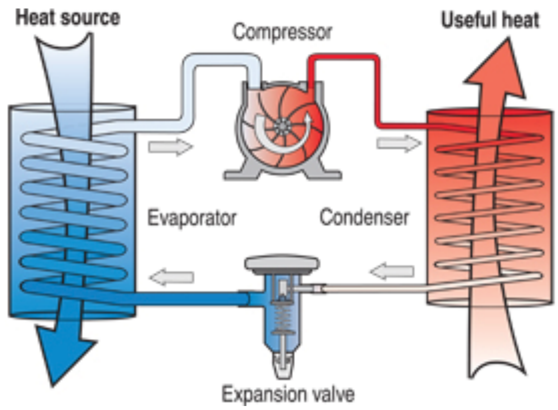


Figure 10. How Heat Pumps Work

Source IEA Heat Pump Centre - SP Technical Research Institute of Sweden www.heatpumpcentre.org

Heat flows naturally from a higher to a lower temperature. Heat pumps, however, are able to force the heat flow in the other direction, using a relatively small amount of high quality drive energy (electricity, fuel, or high-temperature waste heat). Thus heat pumps can transfer heat from natural heat sources in the surroundings, such as the air, ground or water, or from man-made heat sources such as industrial or domestic waste, to a building or an industrial application. Heat pumps can also be used for cooling. Heat is then transferred in the opposite direction, from the application that is cooled, to surroundings at a higher temperature. Sometimes the excess heat from cooling is used to meet a simultaneous heat demand.

In order to transport heat from a heat source to a heat sink, external energy is needed to drive the heat pump. Theoretically, the total heat delivered by the heat pump is equal to the heat extracted from the heat source, plus the amount of drive energy supplied. Electrically-driven heat pumps for heating buildings typically supply 100 kWh of heat with just 20-40 kWh of electricity. Many industrial heat pumps can achieve even higher performance, and supply the same amount of heat with only 3-10 kWh of electricity.

Because heat pumps consume less primary energy than conventional heating systems, they are an important technology for reducing gas emissions that harm the environment, such as carbon dioxide (CO_2), sulphur dioxide (SO_2) and nitrogen oxides (NOx). However, the overall environmental impact of electric heat pumps depends very much on how the electricity is produced. Heat pumps driven by electricity from, for instance, hydropower or renewable energy, reduce emissions more significantly than if the electricity is generated by coal, oil or gas-fired power plants.

The two main heat pump types-vapor compression or absorption cycle

Almost all heat pumps currently in operation are either based on a vapor compression, or on an absorption cycle. These two principles will be briefly discussed in the following two sections. Theoretically, heat pumping can be achieved by many more thermodynamic cycles and processes. These include Sterling and Vuilleumier cycles, single-phase cycles (e.g. with air, CO_2 or noble gases), solid-vapor sorption systems, hybrid systems (notably combining the vapor compression and absorption cycle) and electromagnetic and acoustic processes. Some of these are entering the market or have reached technical maturity, and could become significant in the future.

Vapor compression

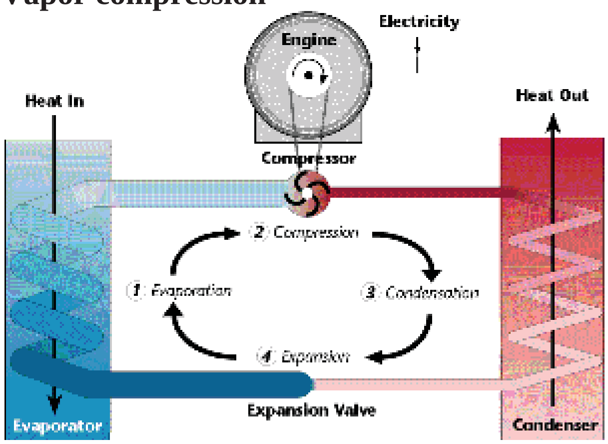


Figure 11: Closed cycle, electric motor-driven vapor compression heat pump

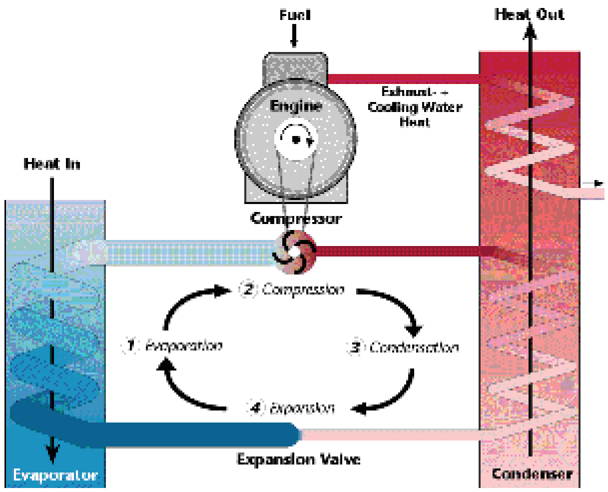


Figure 12: Closed cycle, engine-driven vapor compression heat pump

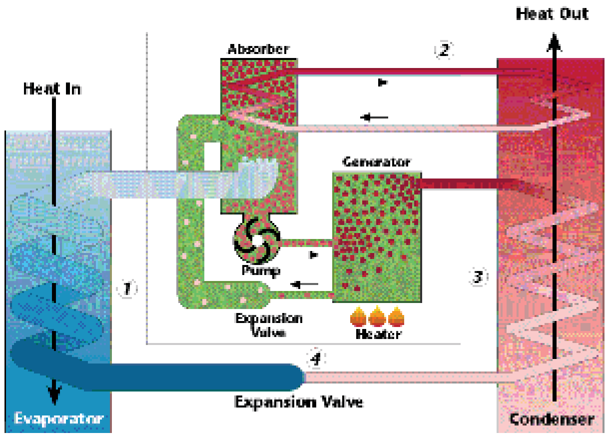


Figure 13: Absorption heat pump

The great majority of heat pumps work on the principle of the vapor compression cycle. The main components in such a heat pump system are the compressor, the expansion valve and two heat exchangers referred to as evaporator and condenser. The components are connected to form a closed circuit, as shown in Figure 11. A volatile liquid, known as the working fluid or refrigerant, circulates through the four components.

In the evaporator the temperature of the liquid working fluid is kept lower than the temperature of the heat source, causing heat to flow from the heat source to the liquid, and the working fluid evaporates. Vapor from the evaporator is compressed to a higher pressure and temperature. The hot vapor then enters the condenser, where it condenses and gives off useful heat. Finally, the high-pressure working fluid is expanded to the evaporator pressure and temperature in the expansion valve. The working fluid is returned to its original state and once again enters the evaporator. The compressor is usually driven by an electric motor and sometimes by a combustion engine.

- An electric motor drives the compressor (see Figure 11) with very low energy losses. The overall energy efficiency of the heat pump strongly depends on the efficiency by which the electricity is generated. Hydropower and other forms of renewable over the maximum efficiency of heat pumps. This is discussed in the section above on Heat pump performance.
- When the compressor is driven by a gas or diesel engine (see Figure 12), heat from the cooling water and exhaust gas is used in addition to the condenser heat.
- Industrial vapor compression type heat pumps often use the process fluid itself as working fluid in an open cycle. These heat pumps are generally referred to as mechanical vapor recompressors, or MVRs; refer to the section on Heat pumps in industry.

Absorption

Absorption heat pumps are thermally driven, which means that heat rather than mechanical energy is supplied to drive the cycle. Absorption heat pumps for space conditioning are often gas-fired, while industrial installations are usually driven by high-pressure steam or waste heat.

Absorption systems utilize the ability of liquids or salts to absorb the vapor of the working fluid. The most common working pairs for absorption systems are:

- water (working fluid) and lithium bromide (absorbent); and
- ammonia (working fluid) and water (absorbent).

In absorption systems, compression of the working fluid is achieved thermally in a solution circuit which consists of an absorber, a solution pump, a generator and an expansion valve as shown in Figure 13. Low-pressure vapor from the evaporator is absorbed in the absorbent. This process generates heat. The solution is pumped to high pressure and then enters the generator, where the working fluid is boiled off with an external heat supply at a high temperature. The working fluid (vapor) is condensed in the condenser while the absorbent is returned to the absorber via the expansion valve.

Heat is extracted from the heat source in the evaporator. Useful heat is given off at medium temperature in the condenser and in the absorber. In the generator high-temperature heat is supplied to run the process. A small amount of electricity may be needed to operate the solution pump.

Reference and For More Information on Heat Pumps and Heat Pump Technologies:

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