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HOUSE HEATING WITH GEOTHERMAL ENERGY

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ABSTRACT

Geothermal energy is a clean energy source and its utilization can improve the quality of life of the cities' inhabitants considerably. Tons of harmful chemical compounds that would otherwise be emitted into the air will be spared, and with the proposed system, the official heating season will not be used. Proposed geothermal heating systems are built up in such a way that consumers can choose their comfort level themselves, and in addition, hot tap water heating production are proposed as a part of these geothermal heating systems.

To make a successful utilization of the geothermal resource, common management with re-injection is planned and by such approach the utilization is responsible and harmonized with nature.

A description is given of the main changes that are required on house heating systems when the heat source comes from geothermal energy. The main issue when putting up geothermal heating systems is to achieve large temperature utilization at the first stage with low return temperature. The return temperature plays a minor role in heating systems that uses coal as a fuel and therefore the design of these systems is not suitable for geothermal fluid unless changed substantially.

1. INTRODUCTION

The utilization of geothermal energy is a demanding task in today's societies. Geothermal energy is in most cases a clean and renewable energy resource, which can help decrease pollution significantly. If used in a proper way, it can also be a sustainable source of energy. The utilization of sustainable energy resources has become more and more important, both from an environmental point of view, as well as from an economical point of view. If reports of a global energy crisis are accurate, development of geothermal energy is without doubt feasible solely from a point of view of being a scarcely used energy resource.

A few pre-requisites are necessary, to make the transition to geothermal utilization in a sustainable and successful way. For instance, in the case of a geothermal district heating systems, the sustainable use of geothermal resources is highly dependent on the design of the system and the efficiency of the energy use by the end users, among with of course of re-injection of the geothermal fluid.

House heating systems in geothermal district heating are one of the most critical components when using a geothermal heat source. If geothermal heat is used incorrectly in house heating systems, for instance in unmodified house heating systems that were previously used for coal heating, the geothermal water from the reservoir will be overexploited. Inappropriate house heating system design will result in high flows, which require larger pipes, larger boilers and more production wells and re-injection wells than in properly designed house heating systems for geothermal energy.

Utilizing heat from coal does not necessarily involve the use of sophisticated pressure control, but the opposite is true when utilizing a geothermal heat source. By using correct pressure control equipment the flow through radiators is slowed down to lose heat at the designated locations, inside buildings and heated rooms.

2. GEOTHERMAL ENERGY – CLEAN ENERGY

Geothermal energy is a renewable source of energy which can contribute to improving the living standard of people in a sustainable way. One of the best examples in this field is the city of Reykjavík which used to be covered with clouds of smoke due to the burning of fossil fuels and where geothermal district heating was implemented around 1930. Today, the inhabitants of Reykjavík enjoy an environmentally friendly and competitive energy resource.

The reduction of air pollution due to geothermal production of heat for space heating and for heating of domestic hot water is one of the main advantages of a geothermal district heating system. Values in Table 1 are set forth as estimates of real pollution quantities for typical space heating systems using different source of heating. The values for coal boilers largely depend on coal and boiler quality, burning temperatures etc., and may differ quite a bit, especially in NO_x and SO_2.

TABLE 1: Methods of heating, comparison of typical emission values per produced kWh heat. (jansson, 1986; Bolland,2002; US Department of Energy, 2008; Interstate Natural Gas Association of America, 2008)

Peak load power	**Type of fuel**	**Resulting CO_2 emission (kg/kWh)**	**Resulting NO_x emission (g/kWh)**	**Resulting SO_2 emission (g/kWh)**
Coal boilers	coal	0.35	1.5	0.5*
Elec. heat pump	coal	0.20	0.4	0.1*
Nat. gas boilers	gas	0.25	0.03	< 0.01
Electric boilers	coal	0.85	2.6	0.8*

*Varies greatly with different sulphur content in unburned coals.

In addition, traces of mercury, Hg, are contained in coal and released upon burning. The amount of mercury in natural gas is around 0.2% of the amount in coal, having a capability to reduce the emissions of mercury considerably.

Assuming the above mentioned emission values, resulting emissions for three situations are calculated and shown in Table 2. These situations are 1) 100% coal boiler, 2) 50% coal boiler, 50% natural gas boiler and 3) geothermal and natural gas boiler. The service area is assumed as 10,000 m^2 of typical new houses in North-east China. Estimated energy demand is 96 kWh/m^2 per year for heating and 29kWh/m^2 per year for domestic hot water heating, total of 125 kWh/m^2 per year

TABLE 2: Annual polluting emissions for three cases of 10,000m^2, according to values in table 1.

Power source	**Resulting CO_2 emissions (tons)**	**Resulting NO_x emissions (tons)**	**Resulting SO_2 emissions (kilos)**
1) 100% Coal boiler	437	1.9	625
2) 50% Coal, 50% Natural gas.	344	0.9	313
3) 80% Geothermal, 20% Nat. gas peak boiler	50	0.007	0.1

According to the numbers, the CO_2 amounts are reduced with almost 90%, and other pollutants nearly disappear.

At least one source from the USA (Energy information Administration, 2008) indicates that when providing grants to reduce pollution, grants for reduced NOx, SO_2 and Hg may be 0-8 fold compared to the grants for reduced CO_2 per ton. The actual matter may differ significantly from these values, and are of course dependent on any grant acceptance.

The implementation of a geothermal district heating system would contribute to achieve a significant reduction of local and global air pollution and therefore to reduce health hazards for the population of case, the cities improving their quality of life.

3. HOUSE HEATING SYSTEMS, PRESENT ARRANGEMENT USING COAL

In most cities in China and many places in the world a single piping system has been used to connect the district heating system to in-house radiator systems. The main principle is that water is led up to the highest floor and the radiators are connected in series so that the return water from a high level radiator is led to the next floor supply below. A throttle valve is sometimes installed parallel to the radiator to ensure that the water runs through the radiators on each floor. The result is that the supply water to radiators situated on lower levels will be colder than the supply water to radiators higher up in the building. This means that radiators on the lower levels must be installed larger than the radiators higher up. The overall temperature drop can be measured from top to bottom of each building. A common temperature drop is from 90°C to 70°C during periods of maximum heat load for an average apartment building, see present system in Figure 1.

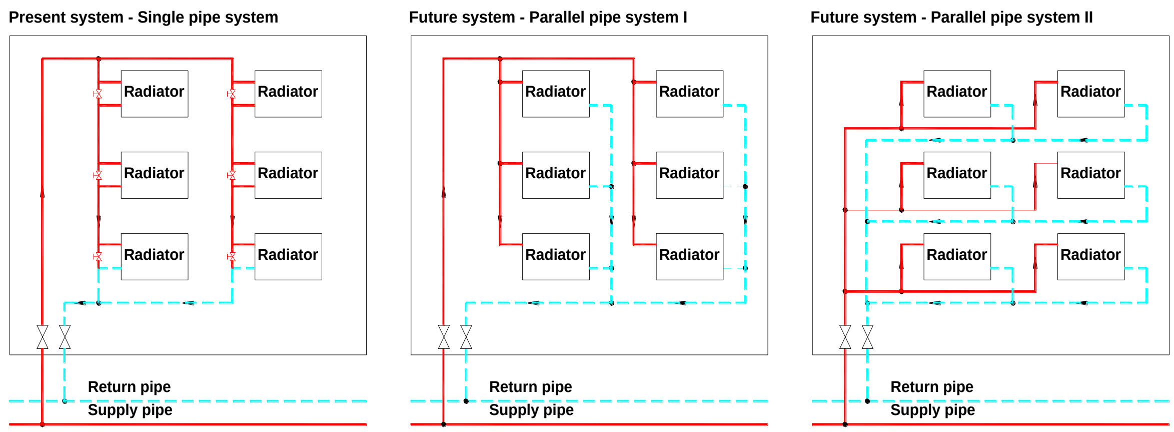

FIGURE 1: Typical pipe arrangement system in coal heated buildings

The advantage of a series loop arrangement is that the installation of the heating system is easy and therefore the installation cost is low. The disadvantage is the complex design of the heating units. This is caused by the fact that the average water temperature lowers progressively from the first unit connected to the last causing the heat output to fall. This calls for adjustments of each unit in the circuit. In addition, if the water flow is controlled, comfort cannot be maintained in separate spaces.

This system is not suited to low temperature usage, mainly because radiators on the lower floors have to be quite large since the water running through them has already cooled considerably. Therefore a parallel system is recommended. In this type of system a similar temperature drop is experienced in every radiator in the building.

To be able to use low temperature fluid, i.e. 70°C the overall size of a radiator must be large. Radiators installed to use 70°C supply water with a 35°C return temperature will be about 60% larger than 90-70°C.

Due to the large temperature difference between the supply and return water, the flow rate is 50% lower at maximum load; it is possible to reduce the size of the distribution network and in-house piping system.

New buildings should be equipped with modern parallel radiator connections of suitable size, enough to deliver 50-60 W/m^2 for 70°C supply water and 35°C return water and maintaining a room temperature of at least 18°C.

4. FIRST IMPROVEMENT – EASE THE WORK OF RADIATORS AND HEATING EQUIPMENT

The sizes of radiators currently installed in many existing buildings heated with coal might be of suitable size despite the difference between the temperature of supply water proposed for geothermal heating and currently encountered. This is due to the current practice of covering the extremely hot (90°C) radiators behind a wood panel to prevent accidental burns. The wooden panel partially insulates the radiator, thus calling for a larger size than if the radiators were not screened behind the panel. Using 70°C hot water will not result in skin burning and so the panels can be removed.

Each radiator's performance and capability to deliver heat to each room depends on the conditions around it. When installations are such that free air-flow around the radiator is hindered, such as built-in walls, the installations will deteriorate the heating performance of radiators.

The effect of built-in radiators is poor for at least three reasons:

1) Heat is not well dissipated to the room as air flow is hindered.
2) The outer walls (with one surface indoor and the other outdoor) facing inside the radiator chamber will be heated extensively by radiation and by the accumulation of hot air. The outer wall will be locally hotter in these areas, making the building energy losses through the outer wall easier at these locations than otherwise. One way to prevent an increase in energy losses would be to insulate the outer wall at these locations more than on other areas, but this is scarcely the practice and will unlikely become a popular architectural issue.
3) The built in radiator will have very hot air around it. This has the effect that it will be harder to cool the heating water down in the radiator. In technical terms, $\Delta T = T_{supply} - T_{return}$ will remain lower than otherwise.

In other words, these installations hinder natural air flow around the radiator and worsen the conditions to get uniform heating in each room. In addition these installations will increase the loss of energy from each building through outer walls. These facts are not dependent on the heat source; these problems originate from general design practices in the field of building services (Figure 2 and 3).

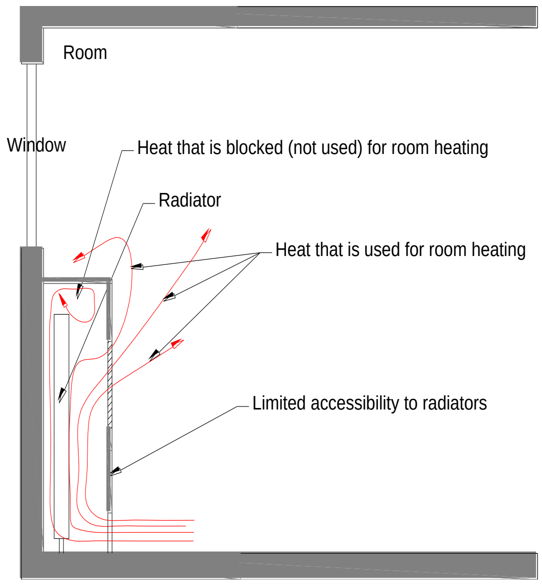

FIGURE 2: When objects hinder the way of free air-flow, heating equipment cannot deliver heat to the room at full capacity. (Pictures from (Reykjavik Energy, 2008)).

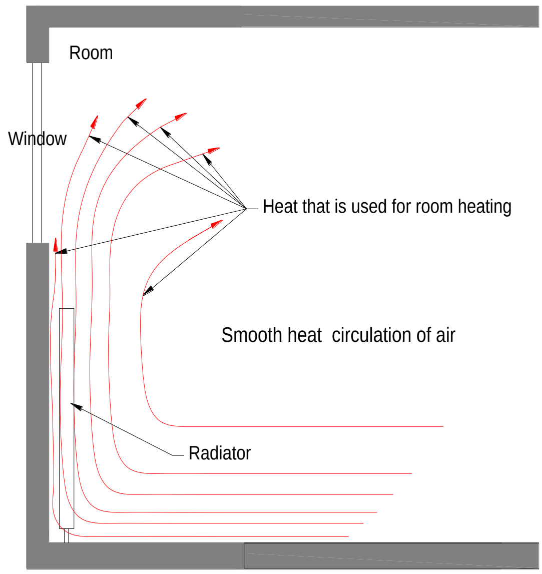

FIGURE 3: Free flow is optimum for heating conditions and results in a more uniform temperature distribution in each room. (Pictures from (Reykjavik Energy, 2008))

The best situation is to have free flow around each radiator. In that case air will circulate freely in each room, heated air is not directed into walls and heating will be uniform. This case is shown in Figure 3. Note that loose objects can also hinder heating, such as curtains, etc.

Thus, a recommended first step in modifying heating systems towards geothermal heating systems is to <u>remove all unnecessary obstacles from radiators</u>. In fact, this recommendation is valid for all heating systems, regardless of the driving heat.

5. GENERAL GUIDELINES IN GEOTHERMAL HEATING SYSTEM DESIGN

The guidelines in geothermal heating are as follows:

1. Utilize the temperature of the geothermal water as much as possible, or economically feasible in one step.
2. Keep the systems simple.
3. These two lead to the rule: Get as high ΔT as possible in the first step.
4. When renewal of water occurs slowly in the reservoir: 100% Re-injection is always the future goal.

The proposed geothermal systems in north east China are 75°C/35°C/-10°C/18°C (supply temp / return temp / outdoor temp / indoor temp). Note that to achieve these goals the current systems can be used in their current condition to a large extent.

Parallel pipeline house heating systems requires both a supply and return pipe that are connected with each radiator. By doing so, each radiator is connected directly with the source and the sizing of the radiator is a simple function of the room size (heating area size), irrespective of the level of installation. Main pipes can either go horizontally or vertically to apartments as is showed in Figure 4. Main pipes are often in smaller dimensions than in current gravitational systems. Note that all radiators are installed in parallel; all are connected with the hottest heat source.

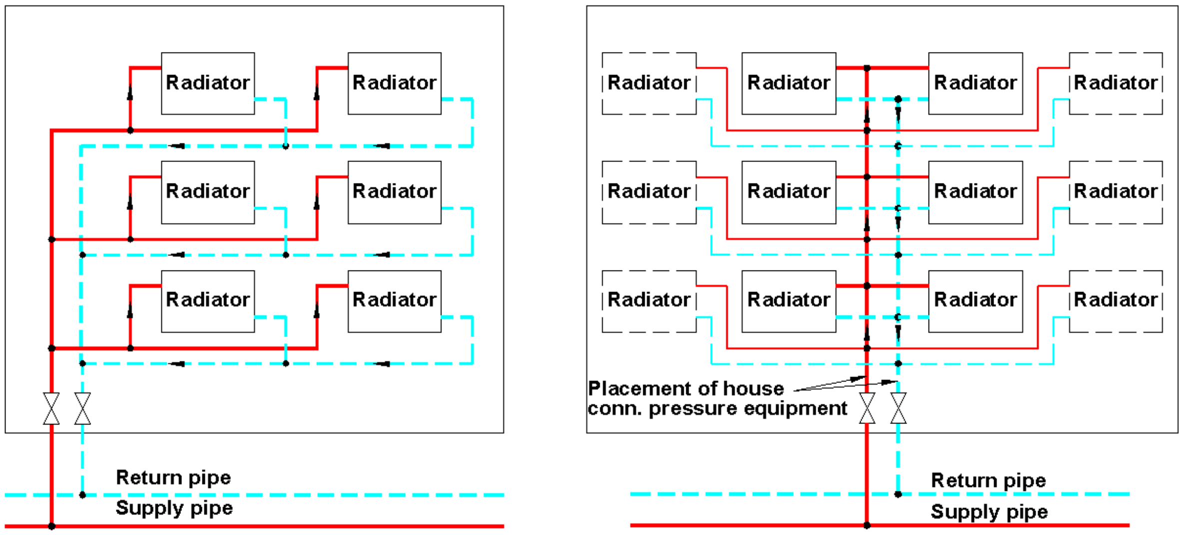

FIGURE 4: Piping networks in properly installed geothermal house heating systems. All regulating valves are skipped on purpose.

Differential pressure control valves need to be installed, i.e. in the basement, and from there, the heating is controlled with thermostatic valves. It is possible to connect either each radiator with a thermostatic valve, or the whole branch of radiators, which are connected with the main pipe. There are pros and cons with either solution. In larger buildings additional pressure difference controlling valves are needed.

When a whole branch of radiators (one main pipe) are connected with one thermostat, the placement of that thermostat is very critical as it controls the flow for the whole branch. In addition, all radiators on the same branch have to be of the same size, as the heating is quantified according to the situation where the thermostat is located. Another risk with a common thermostat for a whole branch is that the conditions around the thermostat are colder than usual (i.e. opened window or room located in the shadow when the other rooms are on the sunny side of the building) and in such cases energy will be wasted as heat is not required in all rooms. NB: it is also important to make sure that no cooling system can be used at the same time as the heating system in a room equipped with radiators.

When each radiator is connected with a thermostatic valve, which tunes according to the room temperature, the comfort level will be maximal. This however is a little bit more expensive solution, as the starting cost of all thermostats is higher.

It is recommended that hot tap water is heated at the same place, i.e. in the basement. By doing so, a specific hot tap water pipeline will be unnecessary in the distribution network, but the size of the cold distribution pipe may need to be enlarged by one size.

Figure 5 shows how the control mechanism is put up in a typical basement. Note that a common hot tap water heater is via a heat exchanger that heats cold water for the whole building. It is not desirable to use district heating hot water directly as this water has been softened and de-aerated for closed loop circulation.

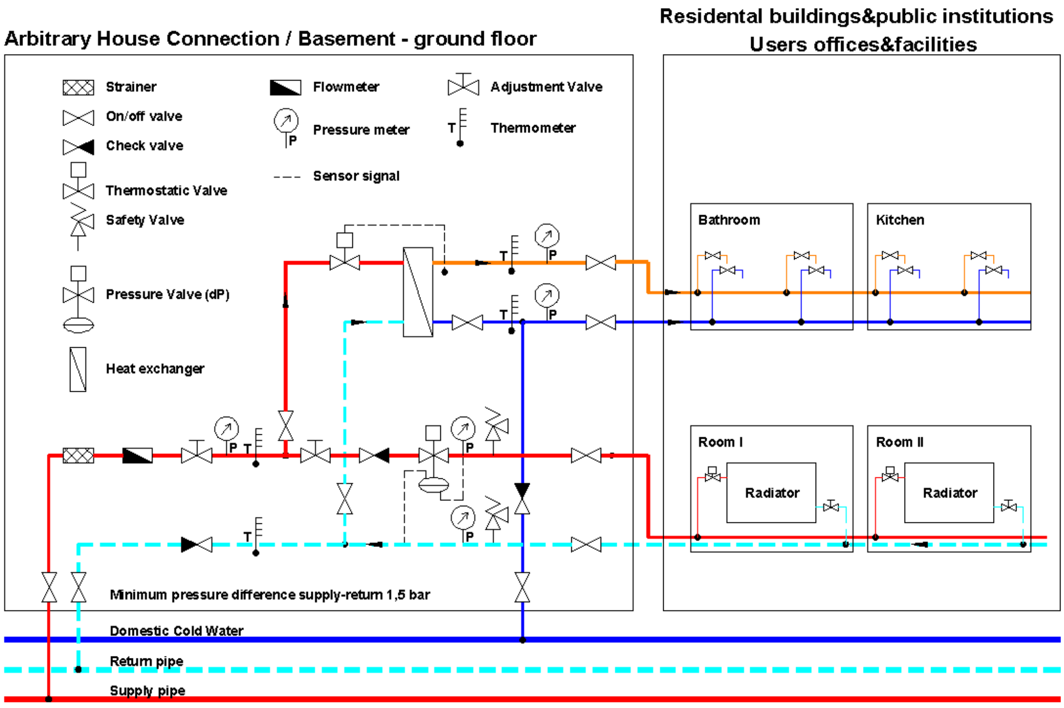

FIGURE 5: The geothermal district heating control equipment for a stairway or a whole building.

It is noted that in Figure 5, each radiator has one thermostat. Also, the placement of flow meters is not necessarily correct with respect to metering and charging for energy.

Floor heating systems are becoming more popular then radiators in new buildings. Typical floor heating system has 30 to 40°C supply temperature and return temperature is 25 to 35°C. This type of space heating system can utilize the geothermal water to a lower temperature and therefore more effectively and should be promoted where geothermal heating is used.

6. METERING METHODS

The consumer in China today is most often charged for energy used for heating based on square meters of housing per year and has nothing to do with energy consumed. This charging method does not encourage energy saving or promote controlling the quantity of heat used. It does not either encourage any house improvements such as added insulation, double glassing or keeping windows shut in cold periods.

By choosing a suitable charging method with respect to the energy source, one can establish an incentive for users to follow an applicable using pattern. The consumer has to have the choice to save energy for instance by adding insulation or selecting the indoor temperature.

A metering method is a combination of three types of fees. These are as follows:

1. Initial connection fee
2. Annual or monthly fee
3. Variable fee based on metering or usage of energy

There are several ways to implement variable fees or to set up some restriction of usage:

	Method	Variables used
1)	Square meter	m^2 heated space (most often used in China)
2)	Flow meter	Volume flow (most often used in Iceland)
3)	Maximum flow	None (flow restrictors built in line)
4)	Energy meter	Supply and return temperatures, mass flow
5)	Energy meter with fixed or calculated return temperature.	Volume flow, supply temperature.

When using square meters, the heating area is the main basis for heating. This metering method does not take into account any of the variables of importance with respect to energy savings, i.e. T_{in},T_{out}, mass flow or used heat (Q). The results when applying this method could be as follows:

Positive:

- A simple way of metering which does not require any flow measuring or flow restriction equipment.

Negative:

- As no measures are performed, supervision and monitoring can be poor. The system even encourages users to announce incorrect heating area.
- As no information is provided on heating systems, their quality can be very poor.
- The method does not penalize excessive use of heat.
- The method does not support energy savings.
- When heating utility is providing heat to a network of houses, the user with the poorest heating system will complain until his apartment/facility is given enough heat. Other users will have an over supply of heat and open windows for cooling at these times.

Mitigation:

- Any mitigation method to compensate for the negative impact of this metering method is rather unrealistic, as the parameter used is heated area.

This method is seldom recommended as it does not encourage energy savings and the consumer does not have any control of the energy consumed.

When using flow meters as a metering basis, the consumer is charged for his use of water according to the volume of water used. This metering method is commonly used in Iceland and is presented in Figure 6. In Figure 6, a sealed regulating valve is used to limit the maximum flow into the system. The role of the sealed regulating valve is to prevent unbounded flow into the system. It can be regarded as safety equipment, for instance, in case of accidental leaks. Figure6 shows the metering environment itself.

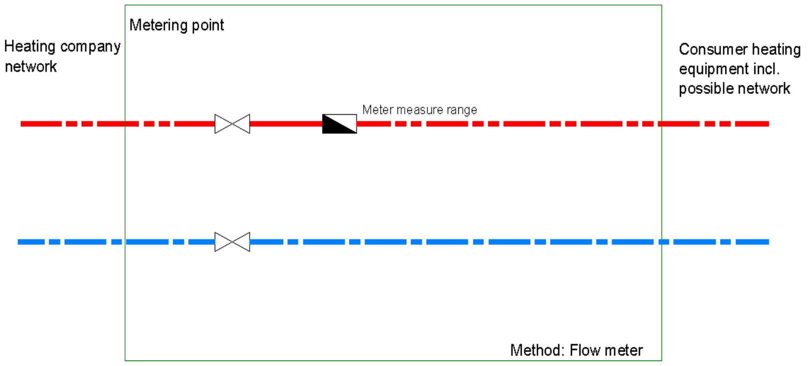

FIGURE 6: Measurement environment of flow meter charging.

The method itself does not require a measure on T_{in} or T_{out} although such measurements are often performed on behalf of the user. The results of this metering method on the user could be the following:

Positive:

A rather simple way of metering that requires only flow measuring equipment.
The method encourages high temperature drop and low flow.
And hence, it does encourage a good energy utilization of the geothermal resource.

Negative:

The method does not take into account the temperature of supply water, which can affect the behaviour of the radiator system This can be an issue as colder incoming water makes heating more difficult.

Several other methods exist but flow meter is probably the simplest and the most economical way of metering. On the other hand, square meter price on apartment and cubic meter price for the hot water is often combined in such a way that 20 to 30% of the price is according to square meter and 70 to 80% is according to used energy. This has turned out to be the most reasonable way of charging energy.

Usage of an energy meter solely is not recommended for geothermal utilization since it does not encourage a large temperature drop.

7. IMPROVING INDOOR CLIMATE AND QUALITY OF LIFE

Many areas in north and north-eastern China, such as Beijing, Tianjin, Xian etc. experience extreme temperatures as low as -10°C in winter (and even as low as -20°C) and as high as 40°C in summer, see typical temperature distribution over the year for both Beijing and Reykjavík in Figure 7. Housing conditions such as cold indoor temperatures can result in adverse effects on human health. The minimum ideal comfort temperature for dwelling-houses is 18°C during winter, many western countries requiring 20°C as a standard.

Heating is usually required to sustain a temperature of 18°C indoors when outdoor temperatures fall under 15°C. Outdoor temperatures in many places in China fall below 15°C during 6 months of the year. The current district heating system provides hot water for space heating only 4 months a year, which means that the indoor temperature does not reach the ideal 18°C for about 2 months a year, in the fall and in the spring when the outdoor temperature is between 7°C and 15°C.

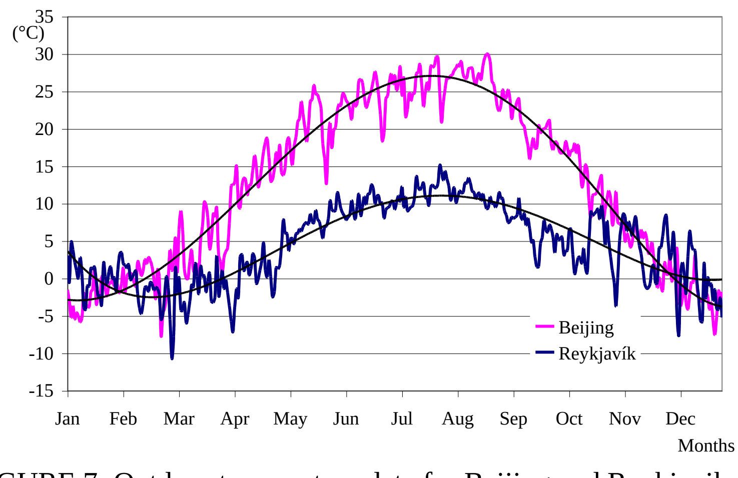

FIGURE 7: Outdoor temperature data for Beijing and Reykjavik, 1991

When using geothermal resources, heating can be used whenever needed. This increases the quality of the heating service provided, and lengthens the current heating period from 2 months to 6 months in total. The increase in service is given in Figure 8, with typical energy needs and sources of supply over a time span of one year.

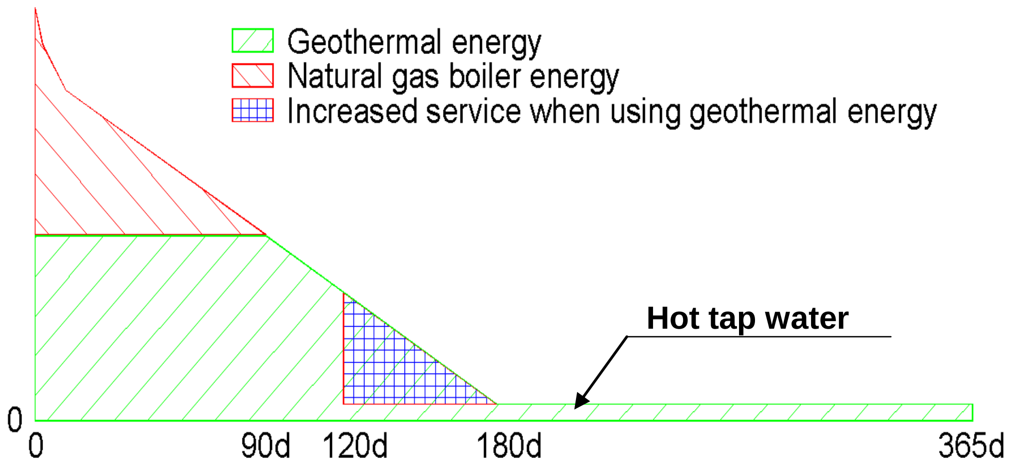

FIGURE 8: Typical heat load curve for north-east, China, including energy source coverage according to conceptual design.

The implementation of a geothermal district heating system requires a new way of thinking with regards to house heating systems. Old house heating systems need to be modified and new heating systems need to include a few components and pipes that are not used in current coal house heating systems as discussed here before.

Usually, the domestic hot water heating for bathing and other uses are included in the geothermal heating systems and used all year around. The hot tap water system is generally added as a subsystem in the heating system of houses and it uses the same district network as the heating system. It does not require any specific hot tap water network pipes in the distribution system. This saves the now often used electricity and gas used for heating up the hot tap water for individual apartments.

8. CONCLUSIONS AND RECOMMENDATIONS

By utilizing the geothermal resources in various cities in China and Asia and substituting heating systems based on the burning of fossil fuels with geothermal energy the quality of life of the people can be improved. Utilizing geothermal energy will reduce air pollution and provide healthy indoor conditions. It will furthermore contribute to minimizing the impact of human activities on the environment by managing natural resources in a sustainable way and by reducing the emission of gases contributing to climate change and to local air pollution. The development of geothermal district heating can thus increase the heating services and create better air for inhabitants, and enhance the economical development of each area.

To achieve the goal of creating a successful and modern heating system, house heating systems need to be modified to suit a geothermal heat source. This can be difficult to carry out on site, especially when upgrading current coal based house heating systems. A reason for potential problems is that the metering systems used and heating responsibility have been the responsibility of the heating company solely.

The first step in increasing heat efficiency is to overlook each heat element with respect to its capability to deliver heat. Any built in covers or other media that hinder free flow of air are very undesirable. Besides, the original purpose of hindering people from burning themselves is usually inappropriate as the temperature of geothermal water is lower than in the original design.

The main goals of geothermal heating systems are to utilize the temperature of the geothermal water to the greatest extend or to what is economically feasible in one step and to keep the systems simple. This can be effectively done with differential pressure control and variable flow through heat elements, controlled with thermostats.

House heating systems in geothermal district heating systems are one of the most critical components when using a geothermal heat source. If geothermal heat is used in unsuitable house heating systems, the utilization of the energy source will be poor and the resource will not be used responsibly.

Considered in its widest implications, the use of a geothermal production system in place of a traditional coal fired boiler will be highly positive at the local and global level. The geothermal implementation has to be carried out responsibly in all ways. The geothermal resource has to be carefully measured and monitored. When these conditions are met, cities using geothermal energy as an energy source for space heating can become the model cities for clean energy.

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