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# SPACE HEATING NEEDS IN ASIA

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## ABSTRACT

Data on demand for space heating in Asia is limited mainly because great parts of Asia use mixed fuels for heating, cooking and lighting purposes, and it is impossible to distinguish between the end uses for all fuel products.

Three major aspects indicate the heating needs for individual countries: the population, the total energy consumption, and the Gross Domestic Product. The controlling factor, however, is the climate, and maps of periodic mean surface isotherms can provide a valid image of the areal extend for heating needs, assuming a temperature limit for discomfort. The comfort threshold for space heating requirements is assumed to lie between an average outdoor temperature of 10°C and 15°C, depending on heating traditions and living standard of individual countries.

The climate in southern and eastern Asia is controlled by the South-West and North-East Monsoons. With its vast size and varied relief the winter temperatures in southern and eastern Asia fall below -15°C in the northernmost and mountainous areas and exceed 40°C in the southern most and dry deserts areas.

The staggering economic growth rate in Asia is increasing the energy needs tremendously. As the countries become richer the population is utilizing more energy, including energy for space heating, in their homes, offices and factories.

There are various factors determining whether it is economically viable to implement geothermal district heating to meet local space heating demands. Among these are: population density, heating demand according to climatic circumstances availability of resource. In southern and eastern Asia there is a good correlation between the availability of resources and areas with high space heating demand.

## 1. INTRODUCTION

Providing affordable warmth in a clean and sustainable way is a major challenge, especially, in low income countries, as are many of those in southern and eastern Asia. Inadequate warmth and moisture increases the likelihood of respiratory and cardiovascular diseases and in some cases threatens survival.
Geothermal water replaces major pollutants and $CO_2$ emission contributors (coal and oil) as heat sources. With the rising awareness of global warming geothermal energy is becoming increasingly popular. The world geothermal installed capacity for direct use in 2004 was 27,825 $MW_{th}$. This is a two-fold increase from year 2000 (Lund et al., 2005).

The numbers in Table 1 place China and India among the top five countries with greatest $CO_2$ emission (IEA, 2005a). In major cities in China people daily wear respiratory guards to avoid health problems due to the extensively polluted air. Geothermal in China won its impasse in the 1970s and is well received due to its effect on $CO_2$ emission reduction. According to Lund et al. (2005) China is now at the top of the world list in annual geothermal direct use and among the top five in geothermal direct use installed capacity.

In well developed and greatly populated cities/areas heating demand is superior and it is economically viable to build geothermal district heating systems if the resource is available. The more problematic situations arise in areas where the population is scarcer, as for example in Lhasa. Here people predominantly live in poorly insulated huts with no form for space heating, although heating is essentially needed throughout most of the year. The geothermal resources are present in Lhasa but the installation of geothermal district heating would demand setting up a modern distribution system.

TABLE 1: $CO_2$ emission from fuel combustion only (IEA, 2007a)

| Region/Country | $CO_2$ emissions (Mt of $CO_2$) |
|---|---|
| World | 27136* |
| OECD | 12910 |
| United States | 5816,96 |
| Peoples Republic of China | 5059,87 |
| Russia | 1543,76 |
| Japan | 1214,19 |
| India | 1147,46 |

*$CO_2$ emission from the world includes emission from international aviation and international marine bunkers.

Three major aspects indicate the heating needs for individual countries, being the population, the total energy consumption, and the GDP (Gross Domestic Product). The controlling factor, however, is the climate, giving an areal extend for heating needs. Population, energy consumption per capita and GDPs are presented in Table 2 for selected countries in Asia. The population gives a quantitative measure of households, and the energy consumption and GDP give measures of the economy and living standard.

TABLE 2: Population, total primary energy supply per capita and gross domestic product for selected countries in southern and eastern Asia (IEA, 2007a)

| Country | POP (million) | TPES/POP (toe/capita) | GDP (billion 2000$) |
|---|---|---|---|
| China | 1304.50 | 1.32 | 1889.93 |
| Democratic People´s Republic of Korea | 22.49 | 0.94 | 10.53 |
| India | 1094.58 | 0.49 | 644.10 |
| Iran | 68.25 | 2.38 | 132.62 |
| Japan | 127.76 | 4.15 | 4994.13 |
| Jordan | 5.47 | 1.30 | 11.42 |
| Mongolia | 2.79 | 0.92 | 1.24 |
| Nepal | 27.13 | 0.34 | 6.35 |
| Pakistan | 155.77 | 0.49 | 92.77 |
| Republic of Korea | 48.29 | 4.43 | 637.95 |

## 1.1 Climate

The climate in southern and eastern Asia is controlled by the South-West and North-East Monsoons, with seasonal winds blowing regularly from the same direction for several months of the year (World Book, 2008). With its vast size and varied relief the climate in southern and eastern Asia ranges from extremely cold in the mountainous regions to hot and dry in the deserts (Figure 1).

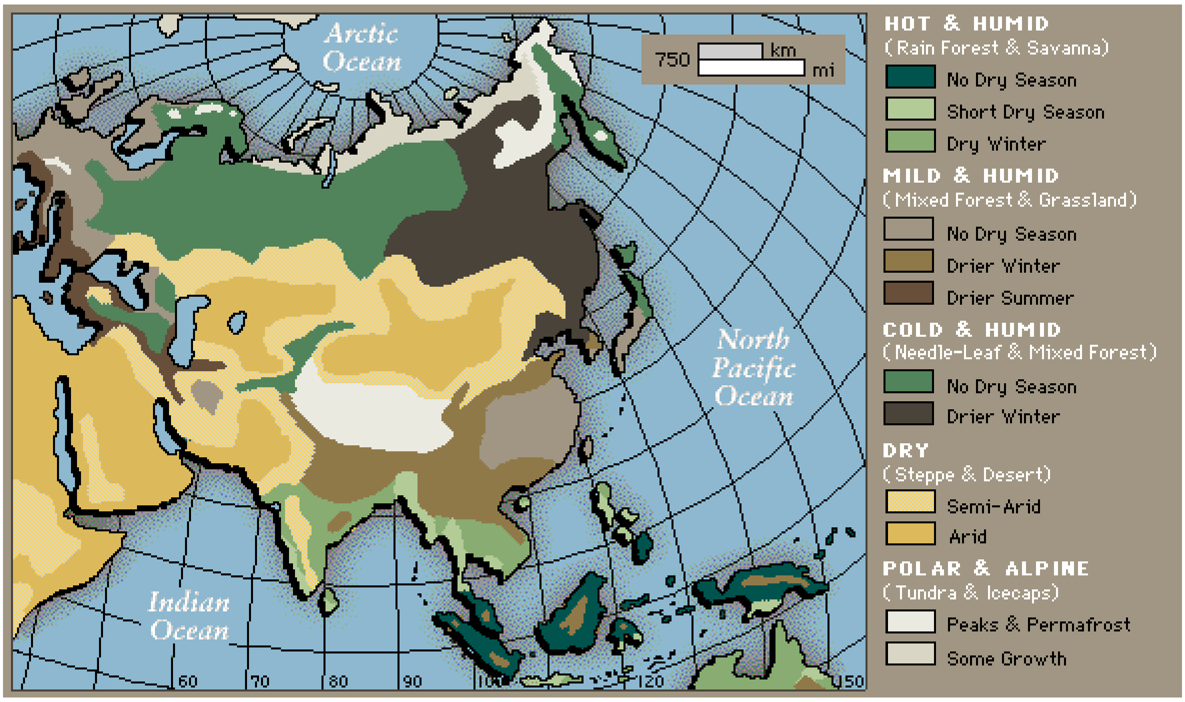


FIGURE 1: Climate map of Asia (Encarta, 2008).

When the sun is on fast retreat in September and the northern hemisphere winter sets in the temperature in central Asia is below 25°C and a high pressure evolves causing cold winds of the North-East Monsoon to sweep down the sides of the Himalaya Mountains towards the warmer Indian Ocean. On the way to the Indian Ocean the dry cold air picks up moisture from the Bay of Bengal and releases it over parts of southern India. The North East Monsoon affects southern and eastern Asia from November to early March, making these months the coldest (Wikipedia, 2008). The immense climatic variations created by the monsoons give rise to air-conditioning needs in the summer heating needs throughout the winter in large parts of southern and eastern Asia.

The South-West Monsoon comes about in the summer months from June to September when the Thar Desert in India heats up and causes a low pressure build up over the northern and the central Indian subcontinent. Hot moist air from the Indian Ocean is drawn towards the low pressure area and is forced to ascend when reaching the Himalaya Mountains. With the gain in altitude, the air temperature drops and condense is formed. Some areas receive up to 10,000 mm of rain.

### 1.2 Population

Approximately 3.6 billion or 60% of the world´s population reside in Asia. Seven of the ten most populated areas, China, India, Russia, Pakistan, Bangladesh and Japan, are located in Asia, four of these in southern and eastern Asia, being China, India, Pakistan and Japan (see Table 2). According to the IEA China, India and Pakistan are among five most populated countries in the world

Although the demographic boom of the 1990s is effectively over in East Asia and is rapidly winding down in Southeast Asia the population of this region has grown at a rate without historical precedence due to lowered mortality rates. The population in eastern, south-eastern and south-central Asia increased by an absolute value of 2.2 billion with an average increase of 1.8% from 1950-2000. Figure 2 shows the location of the most densely populated areas in southern and eastern Asia.

The United Nations Population Division´s medium variant projections from 1975-2025 predict that the populations of China and India will increase by 30% from 930 million to 1.4 billion and 50% from 620 million to 1.3 billion, respectively (Eberstadt, 2004). According to the 2007 IEA statistics these marks have nearly been reached (Table 2).

The vast population increase and the multiplication of households with families becoming smaller increase the demand for heating. Furthermore greater extends of densely populated areas make geothermal district heating more feasible.

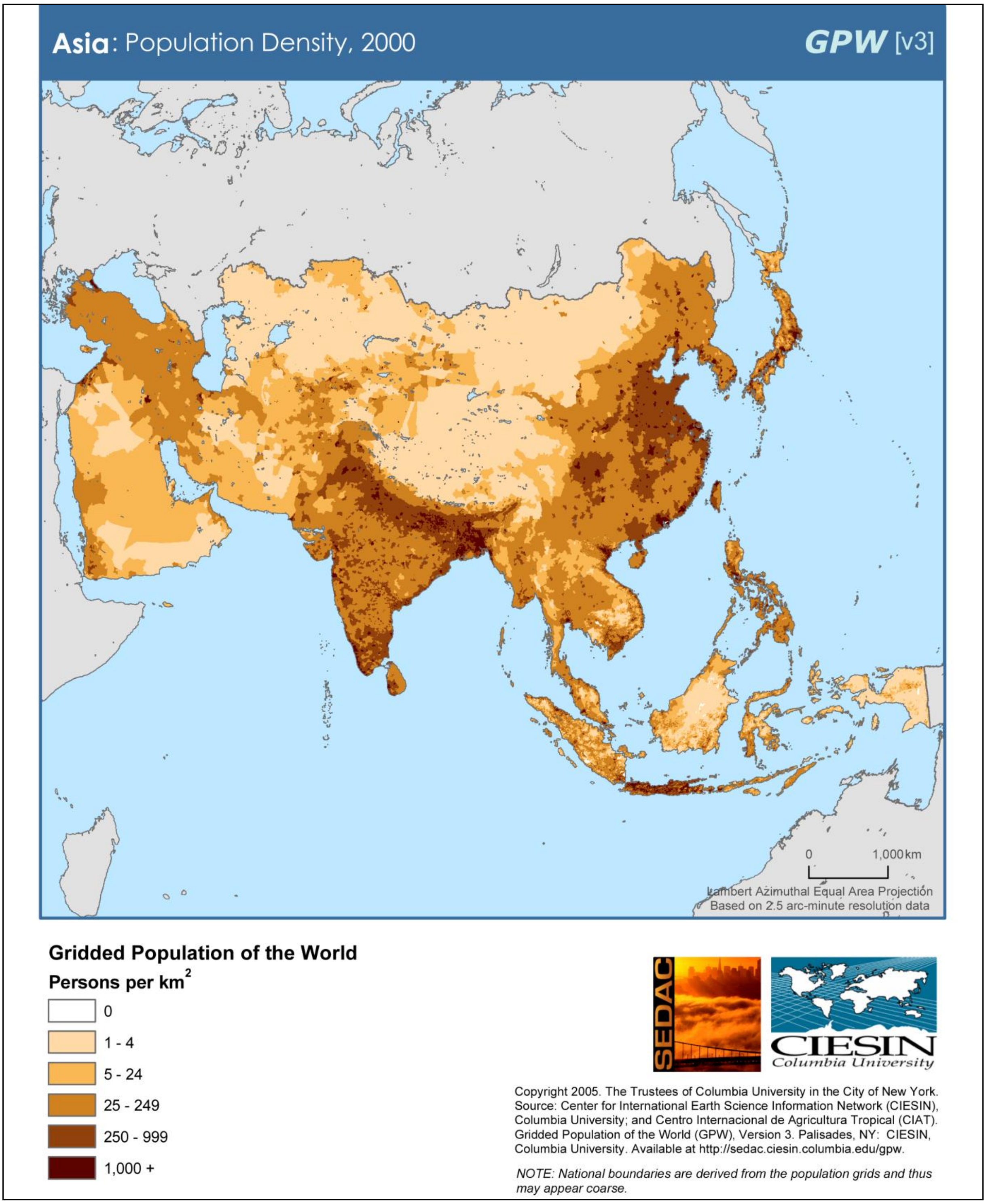


FIGURE 2: Population density in Asia in 2000 (CIESIN, 2005).

## 1.3 Economy and energy consumption

Countries in Asia, including China, India, Iran, are experiencing a tremendous industrial and economic growth. In China and India the growth reaches annual rates of more that 8%.

Asia as a whole has the third largest nominal Gross Domestic Product (GDP) of all continents, after North America and Europe. According to the IEA Japan has the largest GDP within Asia, followed by China, India and the Republic of Korea (Table 2). Historically Japan has the largest economy in Asia and in 1995 it almost equalled that for the USA. However, the Commonwealth Business Council-Asia forecasts that China will surpass Japan to have the largest nominal GDP in Asia within a decade, and that India will overtake Japan in nominal GDP by 2020 (Wikipedia, 2008).

In relation to the economic growth the energy demand is expected to grow at an average rate of 3.2 % per year to 2030 accounting for 65% of the increase in energy use for all non-OECD countries. In 2004 non-OECD Asia accounted for 48% of the energy consumption of the non-OECD total, and the projection to 2030 foresees a share of 56% (EIA, 2007). The forecast for energy consumption in different parts of the world is presented in Figure 3.

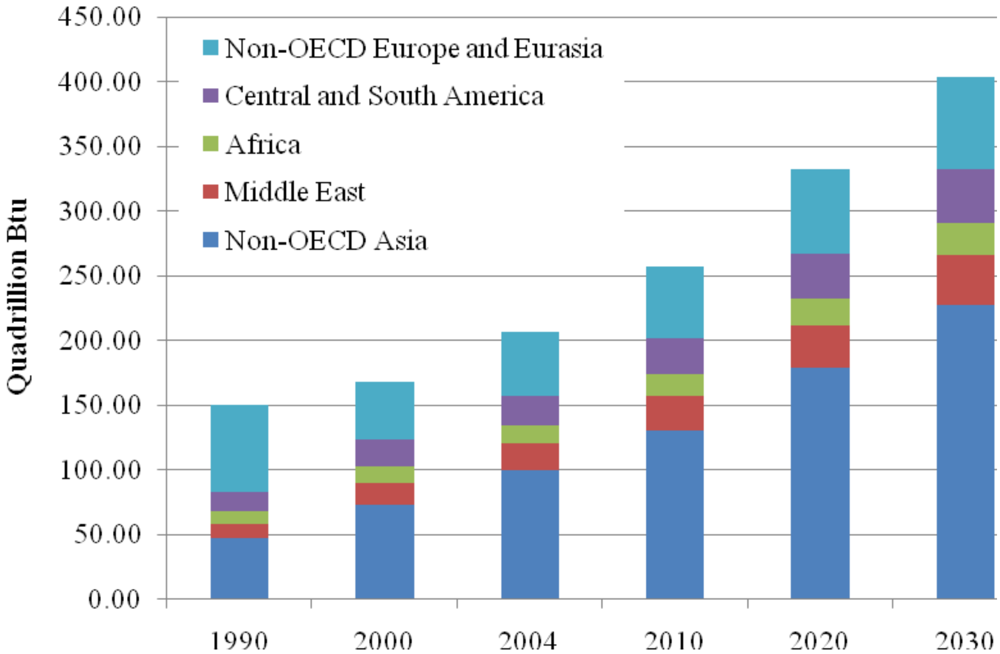


FIGURE 3: Energy use in Non-OECD regions with predictions to 2030 (modified from EIA, 2007). $1\text{Btu} = 1.0551\text{x}10^{-3}\text{TJ}$

The staggering growth rate in China and India has already increased the energy needs tremendously and the economic development keeps the demand for energy growing steadily (IEA, 2007b). As the countries become richer the population is utilizing more energy in their homes, offices and factories. Included in the total energy consumption is the amount of energy used for heating, and as development contributes to improvement of quality of life homes become bigger and the comfort threshold become higher, thus, the populations need for heating increases.

## 2. SPACE HEATING DEMAND

Data on demand for space heating in Asia is limited mainly because great parts of Asia, i.e. Iran, Mongolia and Tibet, use mixed fuels (gas, petrol, oil, fire wood, animal dung etc.) for heating, cooking and lighting purposes, and it is impossible to distinguish between the end uses for all fuel products. However, assessing what regions require heating within a certain period of the year can be done by studying maps of periodic mean surface isotherms, assuming a temperature limit for discomfort.

The isothermal maps presented here are based on international meteorological data from the National Oceanic & Atmospheric Administration/Earth System Research Laboratory website. The plots are based on data from 1980-2007 to avoid annual climate variations.

According to Erlingsson et al. (2008) the minimum comfort temperature for dwelling-houses is 18°C and heating is usually required to sustain a temperature of 18°C indoors when outdoor temperatures fall under 15°C. In China the outdoor temperatures, in many places, fall below 15°C during 6 months of the year but the district heating system provides space heating for only 4 months, during the official heating season

The comfort threshold for space heating requirements is assumed here, to lie between an average outdoor temperature of 10°C and 15°C depending on heating traditions and living standard (GDPs) of individual countries.

With regards to space heating supplied by district heating companies the construction of a district heating system must be feasible, and thus, the supply period should be of certain duration. Experience shows that the supply period should be no shorter than four months. Furthermore the duration of the North-East Monsoon in southern and eastern Asia is four months (Dec-March). Isothermal maps in the section are plotted according to these facts.

Figure 4 presents an isothermal map for the duration of the North-East Monsoon (Dec-March). The great temperature differences in southern and eastern Asia are evident, with average winter temperatures below -15°C in Northern China, parts of Mongolia and Tibet and above 25°C in southern India.

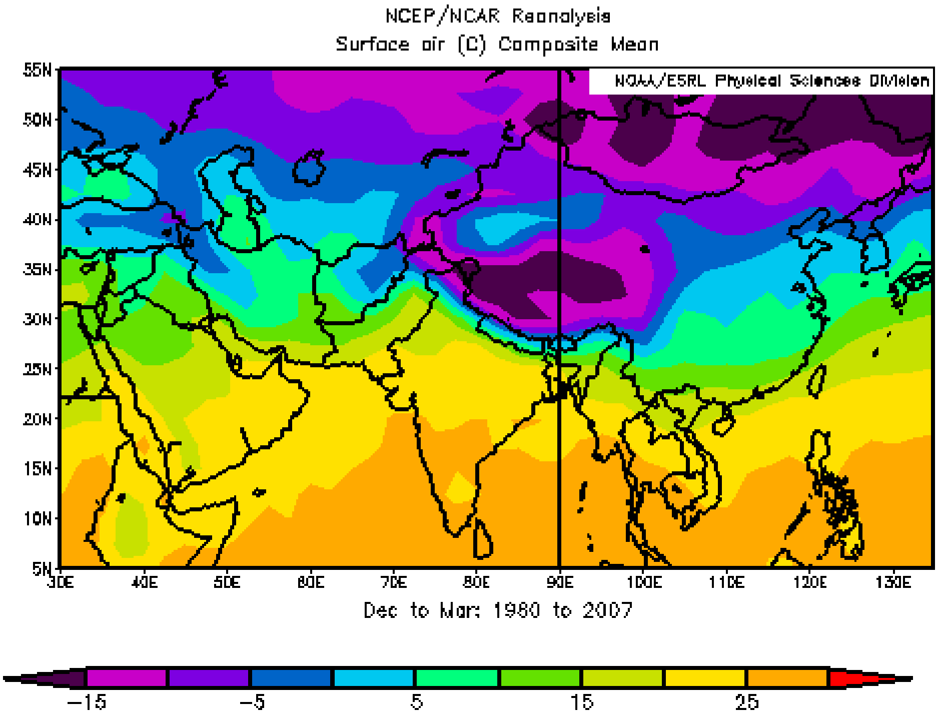


FIGURE 4: Isothermal map of average surface temperatures from December to March (1980-2007) in southern and eastern Asia (Image provided by the NOAA/ESRL Physical Science Division, Boulder Colorado from their website: http://www.cdc.noaa.gov/).

Figures 5 and 6 depict the monthly average isotherms for 15°C and 10°C respectively. The figures illustrate the extent of the winter season form November to March, excluding October from the winter months. In both figures December, January and February are the three coldest months and November and March alternate between regions, as being the fourth coldest month. Obviously, the area requiring space heating for more than four months of the year reaches more southerly latitudes for a threshold of 15°C than for 10°C.

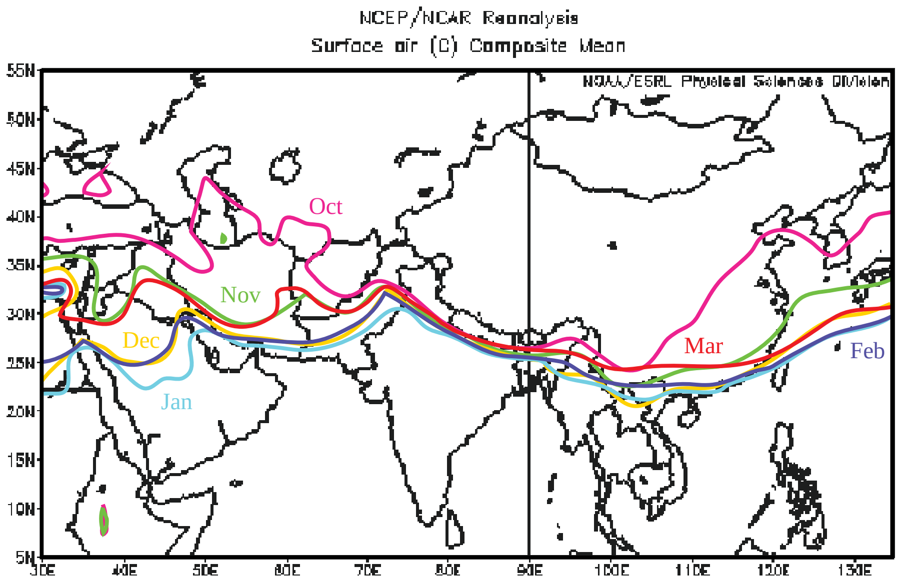


FIGURE 5: Monthly 15°C surface isotherms based on average data from 1980-2007 (Modified from images provided by the NOAA/ESRL Physical Science Division, Boulder Colorado from their website: http://www.cdc.noaa.gov/) .

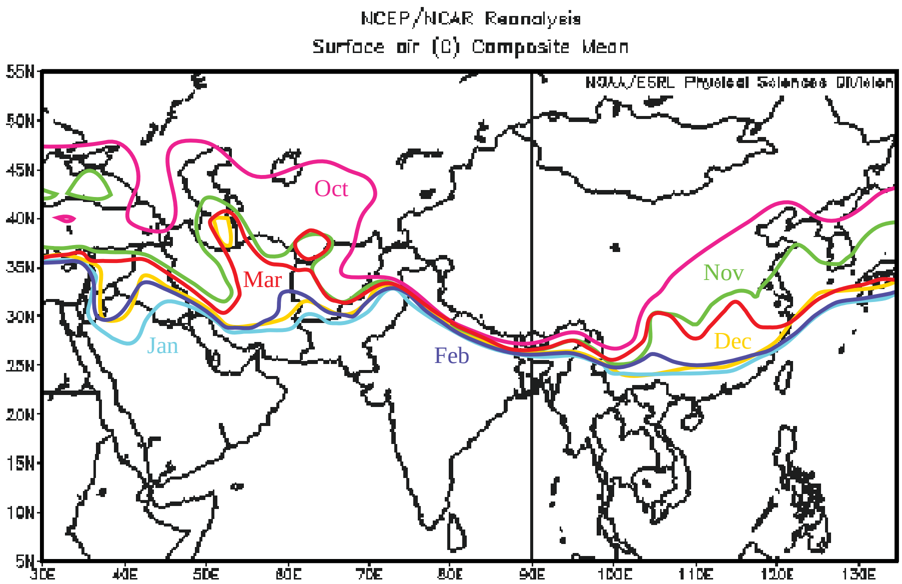


FIGURE 6: Monthly 10°C surface isotherms based on average data from 1980-2007 (Modified from images provided by the NOAA/ESRL Physical Science Division, Boulder Colorado from their website: http://www.cdc.noaa.gov/).

The 10°C and 15°C isotherms for the fourth coldest month (alternating between November and March) are plotted together in Figure 7 dividing southern and eastern Asia into three segments. The northern segment (blue) requiring heating for more than four months of the year, the southern segment (yellow) needing less than four months of heating a year and a boundary segment (grey) where heating is needed on a basis of heating tradition, living standard and availability of resource.

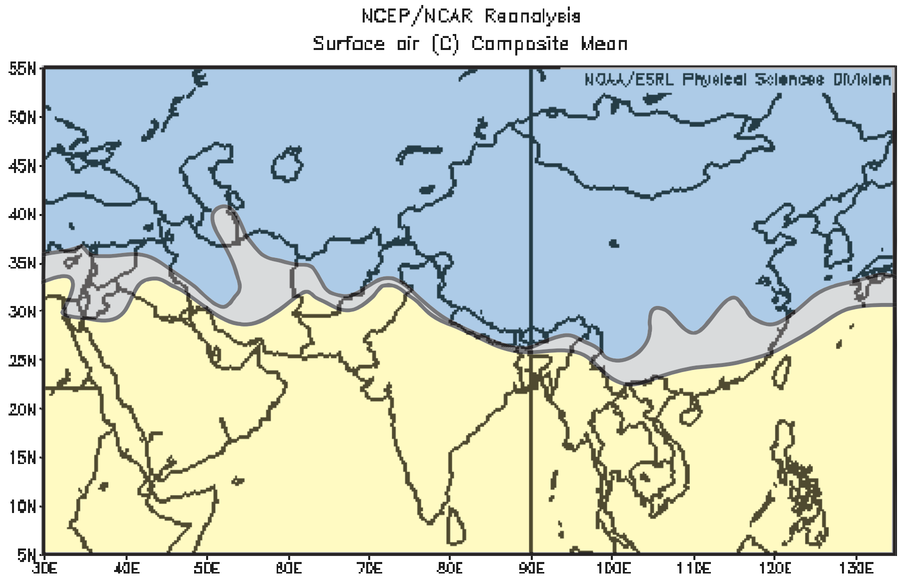


FIGURE 7: 10°C and 15°C surface isotherms based on average data from 1980-2007 for the fourth coldest month (alternating between November and March). The northern segment (blue) requiring heating for more than four months of the year, the southern segment (yellow) needing less than four months of heating a year and a boundary segment (grey) where heating is needed on a basis of heating tradition, living standard and availability of resource (Modified from images provided by the NOAA/ESRL Physical Science Division, Boulder Colorado from their website: http://www.cdc.noaa.gov/)

It is evident from Figure 7 that all of Mongolia, all of Korea, great parts of China, northern India and north-western Iran undoubtedly have a demand for space heating for more than four months a year. If the comfort level for space heating is assumed at 15°C the area is extended vastly for Iran and China and all of Jordan requires space heating.

## 3. GEOTHERMAL DIRECT USE IN SOUTHERN AND EASTERN ASIA

With the global energy crisis and the rising awareness of the influence of $CO_2$ emission on global warming, geothermal and other renewable and sustainable energy resources that are scarcely used today will almost certainly win their in pass on the space heating market.

Country updates from more than 75 countries were presented at the World Geothermal Congress in 2005. A resume of the direct use reported in the country updates from southern and eastern Asia is given below. Table 3 gives an overview of numbers for installed capacity and direct use for most countries in southern and eastern Asia utilising geothermal energy for direct use.

TABLE 3: Installed capacity, direct use and capacity factor for developing countries in southern and eastern Asia with some utilisation of geothermal resources. (Lund et al., 2005; Chandrasekharam and Chandrasekhar, 2005; Kononov and Povarov, 2005; Ranjit, 2005; Saudi and Swarieh, 2005; Zheng et al., 2005)

| **Country** | **Installed capacity ($MW_{th}$)** | **Direct use (TJ/yr)** |
|---|---|---|
| China | 3687 | 45,373.0 |
| India | 203 | 1,606.3 |
| Iran | 30.1 | 752.3 |
| Jordan | 153 | 1,540.0 |
| Kamchatka | 122 | 2701 |
| Mongolia | 6.8 | 213.2 |
| Nepal | 2.1 | 51.4 |
| Republic of Korea | 16.9 | 175.2 |

### 3.1 China

China has a long tradition for geothermal utilisation, especially with regards to recreational purposes, which makes direct use the main focus of attention in China, although there are many high temperature geothermal resources distributed in distant areas in Tibet and Taiwan. Zheng et al. (2005) reports a total installed capacity of 3687 $MW_{th}$ and a direct use of 45,373.0 TJ/yr. More than half of the geothermal resources are used in about 1,600 public hot spring bathing houses and swimming pools, and 430 spa facilities that have become increasingly popular among the Chinese consumers as a result of the rising living standard or what is locally called the “hot spring economy”.

Geothermal space heating including heating with GHPs also accounts for a large part of the geothermal resources. Locally replacing heating with conventional fuelled boilers geothermal space heating now covers an area of 12.7 million $m^2$, largely by district heating in densely populated cities i.e. Tianjin, Beijing and Xi’an.

Other uses of geothermal in China include agricultural greenhousing and fish breeding.

### 3.2 India

An installed capacity of 203 $MW_{th}$, and a direct use of 1,606.3 TJ/yr is reported by Chandrasekharam (2005), all of which is utilised for bathing and swimming only. In the near future a generating power plant will open in Puga Valley and the thermal discharge (87-93°C) is planned to supply heating for greenhouses and a local residential school. Direct utilisation is also planned for the food processing industry.

### 3.3 Iran

The installed capacity of 30.1 $MW_{th}$ is contained within Sabalan area, where an annual amount of 752.3 TJ is used at 12 bathing and swimming sites. The prospect for 2005 was to develop direct heating and improving on bathing and swimming facilities in Sarein and Meshkinshahr, located in the coldest regions in north-western Iran. Two other areas in northern and western Iran were considered for development in the agricultural, the aquacultural and the heating sectors. In addition, Saffarzadeh and Noorolahi (2005) suggest direct use for heating in greenhouses in central Iran and utilization of geothermal heat pumps in particularly in the southern regions of Iran that experience hot and humid summers.

### 3.4 Jordan

Geothermal utilisation in Jordan is limited to curative purposes in balneological facilities, although Saudi and Swarieh (2005) mention that thermal waters in the future can be used successfully to maintain constant temperatures in greenhouses and fish basins for better production yield. The total installed capacity is 153 $MW_{th}$ and the direct use accounts for 1,540.0 TJ/yr.

### 3.5 Kamchatka

Kononov and Povarov (2005) list the current total installed capacity of Kamchatka as 122 $MW_{th}$ exploited in greenhouses, balneological hospitals and swimming pools. A major project is planned with financial aid from theWorld Bank/GEF in the Elizovo region involving geothermal heat and power supply to 60 thousand inhabitants. Mutnovsky and Verhne-Mutnovsky GeoPP will provide 40$MW_e$ to run geothermal heat pumps for district heating in Elizovo. The project will include reconstruction of the main heating network; construction of a heat pump station, balneological swimming pools, greenhouses for vegetable, fruit and flower production, a hotel with sauna and a water park, as well as other industrial facilities. Geothermal resources are estimated to cover 92% of the total heat demand in Elizovo.

### 3.6 Korea

Song et al. (2005) reports a total installed capacity of 16.9 $MW_{th}$ divided into 13.5 $MW_{th}$ for bathing and swimming and 3.4 $MW_{th}$ for heating at 30 geothermal heat pump (GHP) sites. Together these account for 175.2 TJ7Yr. Governmental investments in geothermal has been increasing since 2002 and a district heating system is planned in the Pohang Basin in the southern part of the peninsula. Provided that the project is successful other district heating systems will follow in places of high geothermal potential. It is expected that the application of GHPs will continue to expand (Lund et al, 2005).

### 3.7 Mongolia

The geothermal resources in Mongolia are used for heating, bathing and medicine use. Eight National Sanatoriums are making use of thermal waters from shallow wells (Bingall et al., 2005). Despite a number of areas using thermal water for space heating, bathing and greenhouse heating only the Shargaljuut area has recorded capacity data (1.7 $MW_{th.}$) Lund et al. (2005) made an approximate calculation of 6.8 $MW_{th}$ and 213.2 TJ/yr based on flow rates from Bingall et al. (2005).

### 3.8 Nepal

A great part of Nepal is covered by the spectacular Himalaya Mountains. A majority of the 30 geothermal localities are located in mountainous regions and consequently geothermal direct use has not been feasible to date. Ranjit (2005) report an installed capacity 2.1 $MW_{th}$ with a direct use outcome of 51.4 TJ/yr used solely for bathing and swimming purposes. However, the government recognizes geothermal energy as one of the alternate sources of energy for Nepal. The immediate plan is to update the geothermal data and undertake feasibility studies for direct heating use.

## 4. GEOTHERMAL SPACE HEATING IN ASIA

Of the eight countries mentioned in the geothermal country update section above, China, Korea and Mongolia are already utilising some of their geothermal potential for space heating and Kamchatka were initialising a project in 2005 to supply the Elizovo region with geothermal heating. Two of the four remaining countries with no use of geothermal for heating (Nepal and India) include areas in the Himalayas where geothermal resources are abundant and winters are harsh and cold. Chandrasekharam and Chandrasekhar (2008) describe that children living in the Tibetan residential Schools have to brave of the winter cold as there is no heating in the bedrooms.

In the following, Iran and China will be mentioned as case studies for geothermal space heating in Asia, givng an account of the current status, the possible applications of geothermal space heating and the solutions for solving space heating with the application of geothermal energy.

### 4.1 Geothermal space heating in China

4.1.1 Illogical phase of welfare heating

In the previous plan economic era, winter space heating belonged to the socialistic welfare in China. The state designated the region located north of Yellow River to be a space heating area. The staff in local businesses supplied with district heating got allowances for heating at working places and for their family homes. In other regions located south of the Yellow River there were no such deals.

The average air temperature in January in major cities along the Yellow River is: Jinan −1.7°C, Zhengzhou −0.3°C, Xi’an −1.3°C and Lanzhou −7.3°C. For major cities along the Yangtze River it is: Shanghai 3.3°C, Nanjing 1.9°C and Wuhan 2.8°C. With regards to the climate, all these cities need space heating in winter but they did not use to have so. Most people in these regions suffered during the cold winters and only a few families used small stoves to burn charcoal or coal for heating in order to care for old people and babies.

An additional reason for not meeting the space heating needs is connected with tradition/old habit based on the previous poor economy in China. Lhasa city is the capital of Tibet, located at an elevation of 3,700 m a.s.l. At this location there are 149 days with a temperature lower than 5°C, regardless there is little space heating in winter. Even in new buildings constructed in the 1990s, space heating facilities only cover 10%. However, along with the raising living standard, people enjoy the comfort of space heating and are even willing to pay for it themselves.

4.1.2 Status of space heating pattern

There are two patterns of space heating at present in China. Tall buildings, group buildings and bigger institutions or communities are supplied by **district heating** by heating boilers. Old boilers burned coal but increased environmental requirement no longer permit coal boilers to supply the heating demand, and new boilers and small reformed boilers burn crude oil or natural gas. Only old heating boilers of large capacity can still burn coal. In addition, geothermal supplies heat through pipeline networks from thermal-power plants to at least a few cities.

**Decentralized space heating** solves space heating for individual families by the use of family stoves for cooking. In addition, for above mentioned “no heating” areas, people install air-conditioners or electric heaters in offices and family homes. In the highlands and rural areas in north China farmers burn firewood and lead the smoke through vents in the “kang” (heatable brick bed) to keep warm at night. In south China in some rural areas people use “warm walls” heated by solar energy.

4.1.3 Feasibility of geothermal space heating

The Geothermally heated area has reached 12 million m$^2$ in Tianjin (in 2007). Low enthalpy geothermal resources (>80°C for most bedrock reservoirs) with larger flow rates are widely distributed in Tianjin. A single well can supply 100,000 m$^2$ of space heating. However, including floor heating and GSHPs the single well has supplies 180,000~200,000 m$^2$ of space heating. Lindian County is located in the colder area of China at a latitude north above 47°. Here, local people exploit geothermal water for district heating from old oil exploration wells. Geothermal water, with a temperature of 52°C, supplies space heating, for an area of 640,000 m$^2$, from these wells. There is a 1.6 million m$^2$ and a 1.0 million m$^2$ district heating area in Xianyang and Xi'an cities of Shaanxi Province respectively. In addition, Beijing City and the Hebei Province have nearly 2.0 million m$^2$ space heating area. The total geothermal space heating areas in China is 17.0 million m$^2$ (in 2007).

There are 319 sedimentary basins with a total area of 4.17 million km$^2$ in China. These include 9 large basins (>10 km$^2$) and 39 medium basins (1~10 km$^2$) occupying most of the area (Figure 8). Geothermal resources are restricted to these large-medium basins. The 103 explored geothermal comprises an approved exploitable yields of 330 million m$^3$/yr. Detailed surveys have been carried out for an additional 214 geothermal fields with an exploitable yields of 500 million m$^3$/yr. The exploitable geothermal reservoirs in China have been estimated to carry a yield of 6,840 million m$^3$/yr, accounting for a total heat of 972.28×10$^{15}$J, whereof about 65% of are contained within sedimentary basins. These basins are mainly distributed in northern China and most large to medium cities are located in these basins. Geothermal resources, therefore, offer potential for district heating in most large to medium cities in northern China. It is worth to mention that detailed geothermal surveys have not yet been carried out in all cities.

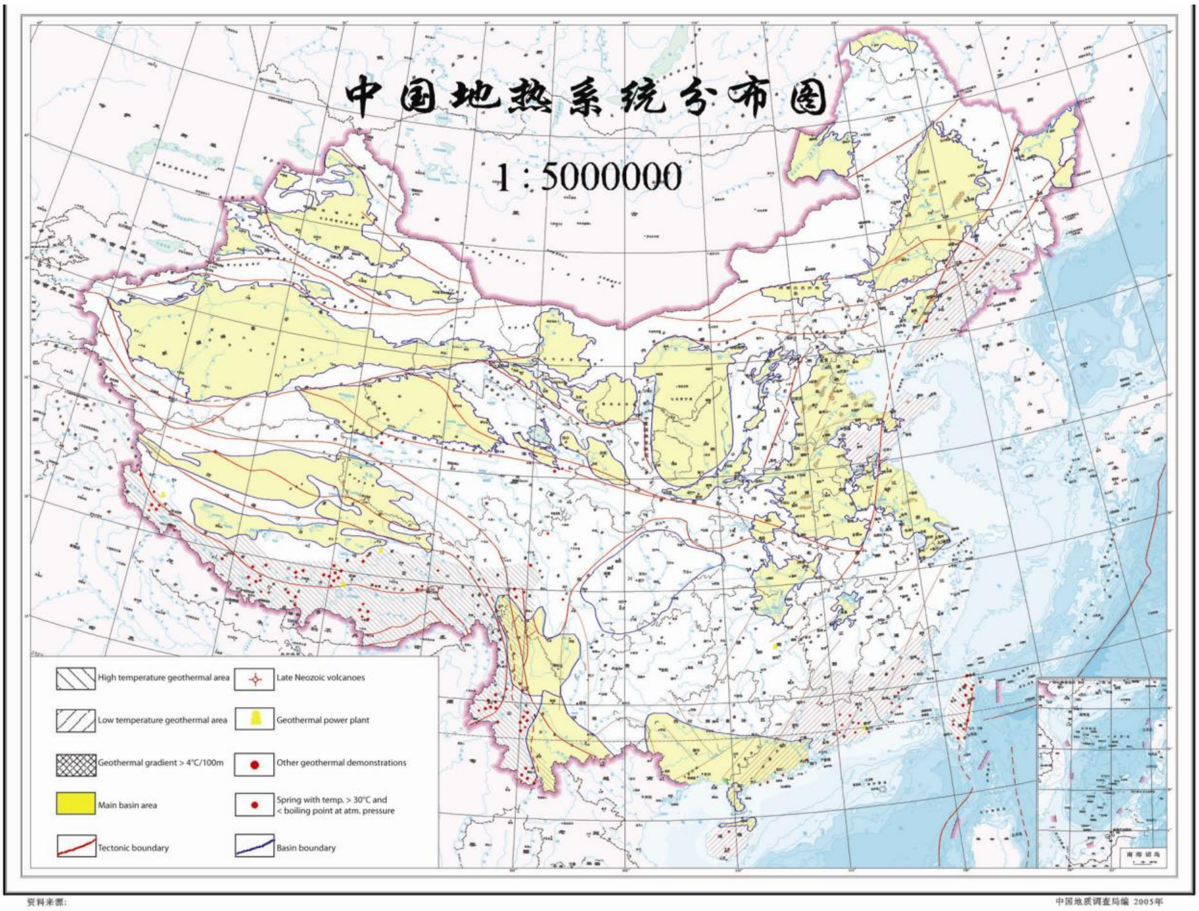


FIGURE 8: Geothermal map of China

4.1.4 Approach of solving heating

According to previously mentioned estimations, one third of the resources for geothermal district heating would satisfy the heating needs for an area of 573 million $m^2$. This is 33.7 times the existing heating area. However, due to Chinas large population, the prospects show no ability to solve the entire space heating need. Perhaps one tenth of the demand can be covered by the present geothermal district heating technology.

For these reasons, shallow geothermal resources are important supplementary resources. By the use of GSHPs the shallow resources can be exploited efficiently. The Shenyang Municipality of the Liaoning Province have applied GSHPs to serve their space heating needs. The GSHP heating area has reached 20 million $m^2$ (in 2007) and has been planned to cover 65 million $m^2$ in 2010 occupying 37% of the total build-up area. In 2007 Beijing covered an area of 11 million $m^2$ of heating by GSHP. This has been planned to increase to 100 million $m^2$ by 2020. The shallow geothermal energy is widespread, rich in resources, and is favourable for energy savings; its COP equals 3. It can be utilized as an important supplement for conventional geothermal district heating, and can potentially satisfy the demands in densely populated areas in north-eastern China (Figure 1).

### 4.2 Geothermal space heating in Iran

Iran has abundant oil and gas resources, and therefore, these energy forms are the ones predominantly used for space heating. According to the report from the NIGC (National Iranian Gas Company), in 2005, 11.6 million families or a total population of 49.4 million are covered by the gas distribution network, through 118,000 km of gas piping. 560 cities and more than 3,073 villages are included in the coverage area. The share of natural gas was 39% of the total fuel usage in Iran in 2005 (iranenergy, 2005).

According to Figure 7, it is apparent that the northern, north-western, north-eastern and western parts of Iran need heating throughout a considerable period of the year. Figure 9 shows the location of geothermal areas in Iran. The north-western part of Iran is the area with the greatest population density (figure 2), and this area seems to coincides with areas of vast geothermal potential, and also, the area with the greatest demand for space heating (Figure 7). In the central and southern parts of Iran the climate is warmer and heating is only needed sporadically in the winter time, and it probably is not feasible to install and run geothermal district heating systems in these areas.

The Sabalan Geothermal project is located in one of the coldest region in the country. Figure 10 shows a duration curve of outdoor temperatures from May 2000 to April 2001 in the Moeil village, in this area. The maximum and minimum temperatures are about 30°C and -22°C in July and January respectively. The annual average temperature is about 7°C; consequently, space heating is needed for large parts of the year (more than 4 months).

Meshkinshahr is a city in North-western Iran with a population of 164,000. Sabalan Mountain is located southeast of Meshkinshahr at an altitude of 4,811m and a distance of 25 km from the city.


FIGURE 9: Geothermal potential areas in Iran (Yousefi et al., 2007).

Heating demand in Moeil and Meshkinshahr is high and space heating is extensively needed. Currently natural gas and oil are the main heating sources but with the growing environmental awareness and geothermal acceptance these areas could benefit significantly from geothermal district heating and thereby contribute significantly to $CO_2$ emission reduction.

The Sabalan area is one of the most important tourist areas because of its unique environment. Sarein city, south of Sabalan, is famous for its geothermal hot springs. A district heating network, green houses, and swimming pools are examples of possible direct uses that might be applied in association with a geothermal power plant planned to be constructed in Sabalan in the next few years. A first option, is a district heating system for Moeil village with more that 3,000 inhabitants. A study was carried out for a sample building with four stories of 271 $m^2$ each, and results were promising. For references the outdoor temperature was fixed at -5°C, the indoor temperature at 20°C, and the building was planned to have single glass windows and wooden doors.

Figure 11 shows the relationship between outdoor temperature and mass flow for a geothermal district heating systems and a fuel fired systems, supplying heat to the sample building in Moil village. It is evident from the graphs that the geothermal district heating system is the superior system, needing less mass than the fuel fired system. The mass flow is a measure of the logarithmic temperature difference between supply and return water. The supply/return temperature in geothermal heating systems and fuel fired systems are 80/35 °C and 90/65 °C, respectively. Hence, the effective utilization of geothermal energy is the greater. For greater utilization (lower back flow temperatures) of the geothermal water the radiator area must be larger, than for the fuel fired system. This will require an additional one time cost for the geothermal system during construction but will also limit the implementation of geothermal wells, and the geothermal system is hence more cost efficient than the fuel fired system.

Figure 12 shows the duration curve for mass flow in a geothermal district heating system supplying space heating for the sample building in Moil village. Approximately 1,000 half hours (22 days) per year require a mass flow greater than 0.3 kg/s in order to keep up with heating demand. If the maximum mass flow is limited the system will not operate efficiently, and enhancing the mass flow, by use of additional geothermal wells, will involve supplementary costs. There are two possible solutions to solving the peak demand for the 22 days. Either, larger radiator areas will have to be installed or a supplementary fuel fired boiler.

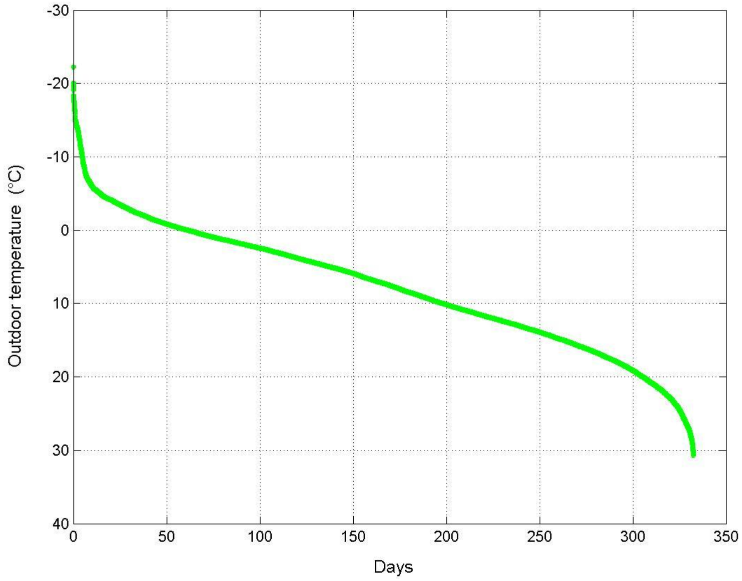


FIGURE 10: Duration curve of outdoor temperature (Jalili, 2004).

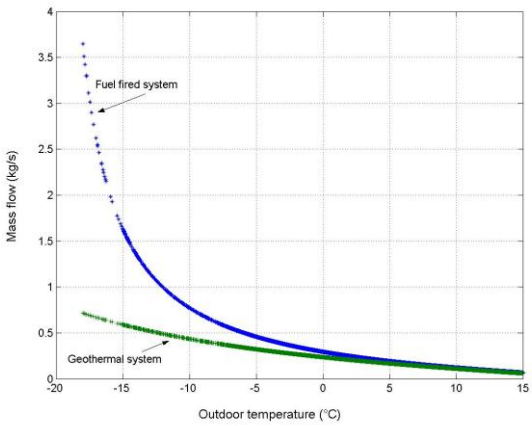


FIGURE 11: Comparison of mass flow for two heating systems (Jalili, 2004).

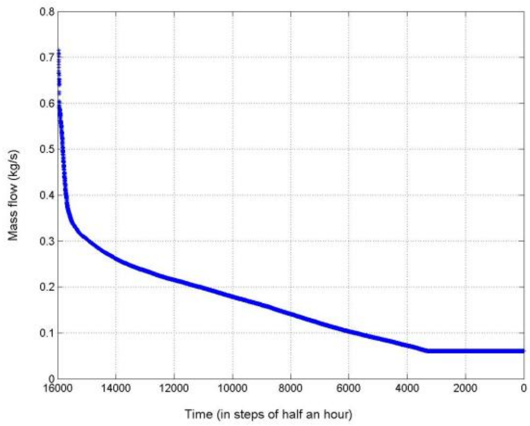


FIGURE 12: Duration curve of mass flow (Jalili, 2004).

According to calculations using Engineering Equation Solver (EES) the planned Sabalan 55 $MW_e$ double flash cycle production will produce 400 kg/s of back water with a temperature of around 95°C. The back water can either be reinjected or used for district heating. Compared with 0.3 kg/s used as a base load for the sample building in Moil village (Figure 12) the Sabalan project seems to be very feasible in deed.

## 5. DISCUSSION

There are many factors determining whether it is economically viable to implement geothermal district heating to meet local space heating demands. Among these factors are population density, heating demand according to climatic circumstances and none the least availability of resource.

Figure 13, clearly shows how the location of geothermal resources in southern and eastern Asia coincide with areas needing space heating for more than four months of the year. There is excellent agreement between availability of geothermal resources and residential areas with high heating demand. For example, northern India and Tibet are among the coldest areas in Asia and they are blessed with abundant geothermal resources along the suture line bounding the Eurasian and Indian plates. Also, the area in Iran with demand for space heating for more than four months a year includes Sabalan, the most promising geothermal prospect area in Iran. Nevertheless, according to Figure 13 it seems that the geothermal resources in China, as a general, only covers a small part of the area with space heating demand for more than four months a year. Here it should be mentioned that the geothermal resources represented in Figure 13 do not include the abundant shallow geothermal resources, presented in Figure 8, that are greatly utilized for space heating and other direct use purposes in China. It should also be mentioned that the geothermal areas for Korea are estimated from a heatflow map portrayed in Song et al. (2005), and that geothermal areas for Jordan and Mongolia are based on location of hot springs.

The correspondence of geothermal areas and densely populated can be envisaged by comparing Figure 13 and Figure 2. The areas that might struggle with feasibility issues, due to population density are central Iran, west and central China and large parts of south and eastern Mongolia

Detailed feasibility studies are needed for each individual country in Asia in order to assess if geothermal district heating is applicable to residential areas with high heating demand.

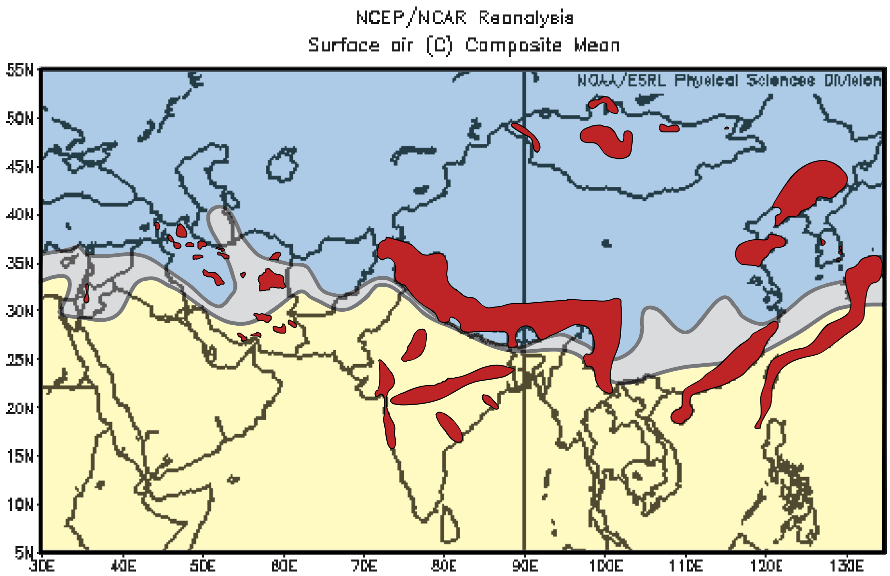


FIGURE 13: Coincidence of heating requirement segments and geothermal resources. The northern segment (blue) requiring heating for more than four months of the year, the southern segment (yellow) needing less than four months of heating a year and a boundary segment (grey) where heating is needed on a basis of heating tradition, living standard and availability of resource. Red areas represent geothermal resources (high and low enthalpy) (Modified from images provided by the NOAA/ESRL Physical Science Division, Boulder Colorado from their website: http://www.cdc.noaa.gov/ and Country reports (country reports, 2005: Proceedings World Geothermal Congress 2005)).

## 6. CONCLUSIONS

- Vast areas in southern and eastern Asia have a demand for space heating for a minimum of four months a year. The extend of the area is mainly controlled by the South-West and North-East Monsoons.
- The comfort temperature, used to assess the areal extend of space heating needs, is dependent on heating traditions and living standard.
- In most parts of southern and eastern Asia district heating is non-existing and mixed fuels (gas, petrol, oil, fire wood, animal dung etc.) are used for space heating in residential areas.
- The staggering economic growth rate in Asia is increasing the energy needs tremendously. As the countries become richer the population is utilizing more energy, including energy for space heating, in their homes, offices and factories.
- Geothermal space heating can help fulfil the heating demand in a clean and sustainable way.
- Only three out of eight countries in southern and eastern Asia with geothermal potential are currently employing geothermal space heating.
- In China shallow geothermal resources are used extensively for space heating and other direct uses, and China is currently number one on the list of geothermal direct use.
- At present, the resources mostly used for space heating in Iran are oil and gas. However, a geothermal power plant in the Sabalan geothermal area, in the coldest region of Iran, will be established in the next few years. A district heating network is among possible direct uses established in connection with the power plant.
- The location of geothermal resources in southern and eastern Asia correlates well with areas with high demand for space heating.
- Population density and availability of geothermal resources are of major importance for geothermal feasibility.
- Detailed feasibility studies should be carried out in individual countries in southern and eastern Asia in order to implement geothermal and thereby improve on living standard and lower the risk for respiratory and cardiovascular diseases in poorly heated areas.
- Finally, Asia can make a significant contribution to the mitigation of climate change by making full and sustainable use of its widespread geothermal resources.

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