GEO-Pot: Geothermal Energy Potential in Austria

V. Ostermann[1]

ABSTRACT

Currently the keywords geothermal energy, renewable energy, passive house technology and energy efficiency are evident in connection with global warming and climatic change. They serve for an efficient and sustainable utilization of energy resources for heating and cooling of houses. In the context of renewable energy sources geothermal energy is often ignored as it is difficult to evaluate, although it contains by far an immense potential compared to other energy sources. A sustainable energy policy demands a comparable data base to form the basis for an impartial evaluation of energy sources.

To overcome this deficiency a comprehensive study was done to determine the effective geothermal energy potential for Austria by a group of geotechnical engineers, geologists, system engineers, facility managers, infrastructure experts, structural engineers as well as spatial planners.

The aim of the project "GEO-Pot: Geothermal Energy Potential in Austria" was the nationwide investigation and demonstration of the useable shallow geothermal energy potential for heating purposes in buildings.

Keywords: Geothermal energy, potential, database, renewable energy, absorber technology

1 INTRODUCTION

The ground contains an enormous potential of geothermal energy that can be used for heating and cooling purposes. The basic requirement for the use of geothermal energy is a more or less constant ground temperature from a depth of approximately 10-15 m. In most European climate zones the temperature in these depths varies between 10°C and 15°C and remains at that level down to a depth of approximately 50 m.

The aim of the project "GEO-Pot: Geothermal Energy Potential in Austria" was the nationwide investigation and demonstration of the useable shallow geothermal energy potential for heating purposes in buildings.

To guarantee an explicit calculation of the useable geothermal potential a fragmentation of the entire Austrian territory into a basic grid was generated. The minimum cell size was chosen to 250 m x 250 m. Consequently, the geothermal energy potential for shallow geothermal energy

[1] Corresponding Author: Vienna University of Technology, Institute for Geotechnics, Karlsplatz 13, 1040 Vienna, Austria, viktoria.ostermann@tuwien.ac.at

applications was analysed for every cell separately and finally put together for the entire territory.

The input values to analyse the potential for each cell were:

- useable areas and areas to be excluded,
- climatic conditions and altitude,
- natural thermal availability,
- typical building patterns and thermal energy demand,
- types of geothermal energy plants,
- cost and economic aspects.

2 DETERMINATION OF THE AVAILABLE GEOTHERMAL ENERGY POTENTIAL OF THE GROUND

The potential for the shallow geothermal energy is influenced by numerous spatial properties. A geoscientific data model was generated for the Austrian territory in order to take into account the complex areal conditions.

The geoscientific data model consists of a generalization of the geological structure and its characterization using technical parameters as well as prognoses of the ground temperature (figure 1).

2.1 Geology

The main challenge was to simplify the three-dimensional ground conditions in order to establish a two-dimensional projection (figure 2). The geological model was based on the hydrogeological map of Austria [1] in the scale 1:500.000. Subsequently, a geological reference profile was determined for every geological homogeneous area, which described the geological structure of the first 150 m below surface. This implied that the ground of the surface-near geological structure of the Austrian territory could be simplified to 41 significant reference profiles. These reference profiles are like virtual drilling profiles, which include petrographic descriptions of the involved geological layers according to the Austrian Standard ÖNORM B4401 [2]. The geological reference profiles form the basis for the determination of the available geothermal power and represent the two-dimensional projection of the three-dimensional ground.

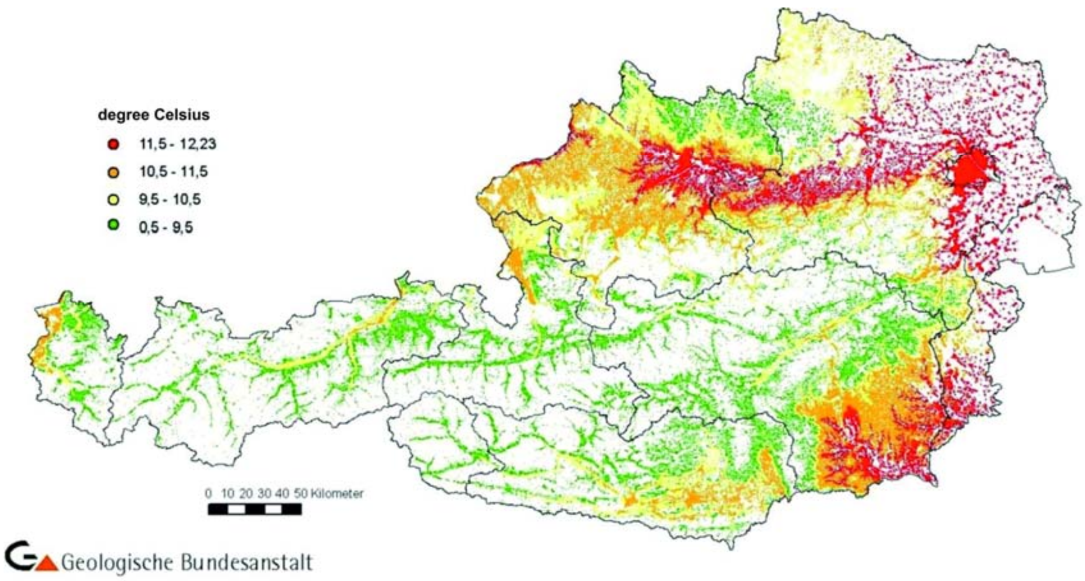

Figure 1: Average temperature in a depth of 2 m below surface [3].

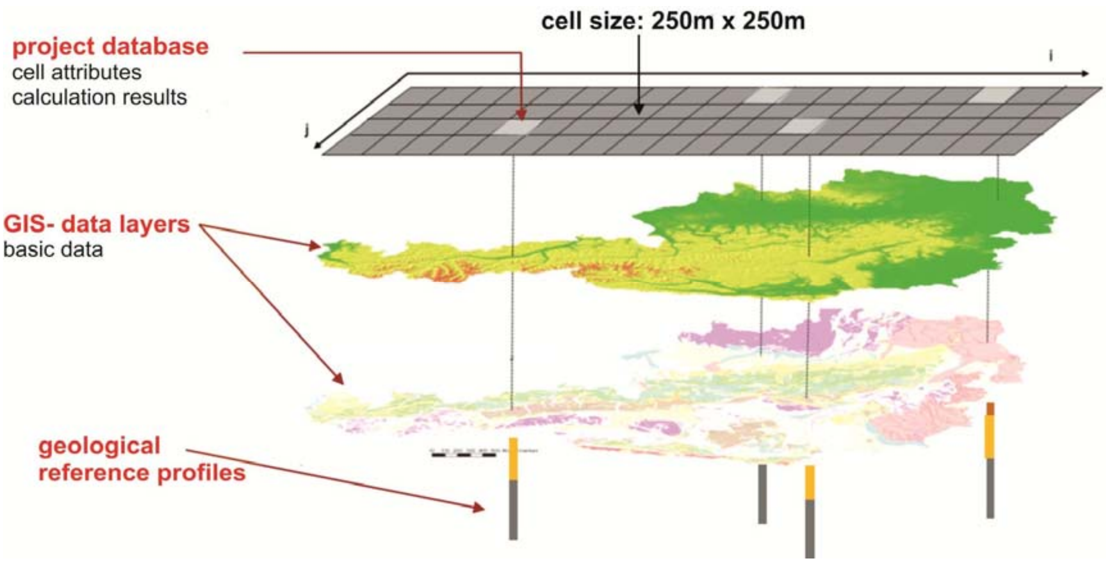

Figure 2: 2D working grid as basis for the study GEO-Pot [3].

2.2 *Determination of available geothermal Power*

The idea of the study GEO-Pot was to define a cell-based calculation approach for the available geothermal power (P_{tech}), which takes into account all relevant input parameters, like geology, ground temperature, residential areas and areas to be excluded. The initial of the chosen approach was the cell-related determination of the available geothermal power of a single probe (P^*) depending on the absorber type, the geological structure of the surface-near ground and the expected ground temperature. In the study Geo-Pot the available geothermal power (P_{tech}) was calculated only for borehole heat exchanger. In addition the geothermal potential was analyzed exemplarily for future tunnels.

In the next step the area specifically required for the borehole heat exchanger (A_{probe}) was determined. The specific required area comprises the cross-section of the probe and the thermal influenced area around it. The thermal influenced area is depending on the geological ground structure. The available geothermal power (P_{tech}) for each cell can then be calculated by the following equation:

$$P_{tech} = P^* \cdot L_{ref} \cdot \underbrace{\frac{A_{poss}}{A_{probe}}}_{N_{poss}} \qquad (1)$$

P_{tech}… technical available geothermal power of the specific cell [kW/a]

P^*… technical available geothermal power of a single probe [kW/m.a]

L_{ref}… Length of the reference borehole heat exchanger [m]

A_{probe}… required area per probe [m²]

A_{poss}… total useable area per cell [m²]

The total number of borehole heat exchangers (N_{poss}) per cell is defined by:

$$N_{poss} = \frac{A_{poss}}{A_{probe}} \qquad (2)$$

The available geothermal power of a single probe (P^*) was calculated numerically with a finite volume algorithm (according to B. Glück [4]). For the reference borehole heat exchanger a duplex probe with a length of 90 m and a diameter of 140 mm was chosen. The absorber pipes exhibit a diameter of 30 mm.

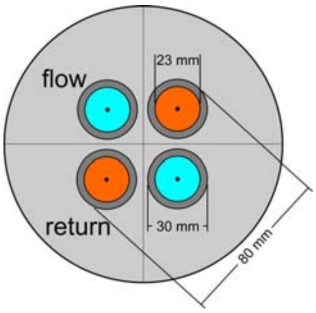

Figure 3: Sketch of the reference borehole heat exchanger.

3 THERMAL ENERGY DEMAND

3.1 *Determination of the heating energy demand (W_{HED})*

For the determination of the heating energy demand (W_{HED}) 5 different building types according to the housing stock in Austria were defined. Based on [5], [6], [7] the W_{HED} was calculated taking into account the following parameters:

- building type (5 types): single family house (EFH), row house (MFH-4WE), small multi-family house (MFH-8WE), mid-size multi-family house (MFH-12WE), large multi-family house (MFH-32WE);

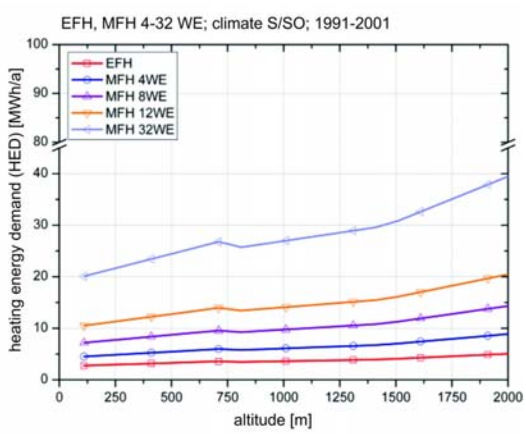

Figure 4: Exemplary correlation of the heating energy demand and the altitude for one construction period [3].

- construction period (5 periods): before 1945, 1946 - 1980, 1981-1990, 1991 - 2001 and after 2001;
- gross building area per building type;
- altitude;
- climatic conditions (consideration of 7 zones in Austria);
- power losses of the building services.

3.2 *Determination of the geothermal energy demand (W_{GEO})*

The geothermal energy demand (W_{GEO}) is the amount of energy to be extracted from the ground to cover the required heating energy demand (W_{HED}). The geothermal energy demand (W_{GEO}) can be calculated from the heating energy demand (W_{HED}) less the external energy which is required for the operation of the heat pump (Figure 5).

To determine the geothermal energy demand (W_{GEO}) the program Polysun 5.2 [8] was used.

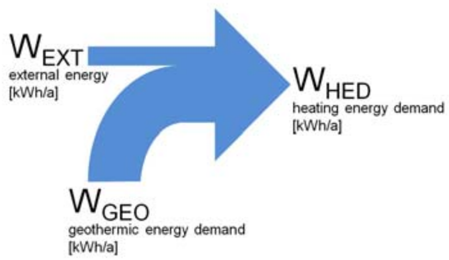

Figure 5: Illustration of the calculation of W_{HED}

3.3 *Determination of the spatial distribution of the heating energy demand*

A European-wide satellite dataset, which provided the dimensions of the sealed cell-areas, was used to determine the potential area to be utilized for geothermal energy applications (A_{poss}) for all cells.

3.4 *Analyses of the residential areas and building structures*

For shallow geothermal energy the spatial distribution of the residential structure and the residential use is a limiting factor due to the fact that only short supply distances enable an efficient energy distribution. The specification and the spatial allocation of the residential area units are essential for the modeling of the spatially disaggregated population, household and housing situation. The challenge and difficulty was to assign the specified building types in the project cells. The used data is based on the building and housing census 2001 provided by the central bureau of statistics in Austria (Statistik Austria) [9].

For every cell the 5 defined building types (with their respective energy consumption ratios) were identified and quantified through the community based data [9]. The modeling of the heating energy demand (W_{HED} per cell) taking into account the actual small-scale differentiated settlement structure was accomplished in consideration of the parameters listed above (see chapter 3.1).

4 DETERMINATION OF THE USEABLE GEOTHERMAL ENERGY POTENTIAL

The usable geothermal energy potential is derived from two individual potentials, the available geothermal energy potential (see chapter 2) and the thermal energy demand (see chapter 3).

4.1 *Geothermal energy cover ratio (CR)*

The determination of the geothermal energy cover ratio (CR) is based on the comparison of the geothermal energy demand (W_{GEO}) and the available geothermal energy (W^*_L). The available geothermal energy (W^*_L) is calculated by the available geothermal power of a single probe (P*) (see chapter 2.2) multiplied by the annual working time, which is set by a function of the time f(t).

$$W*_L = P* \cdot f(t) \quad [kWh/m \cdot a] \tag{3}$$

Subsequently, the sum of the probe length (L^1) to cover the heating demand per cell can be determined to:

$$L^1 = \frac{\sum_{cell} W_{GEO}}{\sum_{cell} W*_L} [m] \tag{4}$$

The number of the required borehole heat exchangers (N_{req}) taking into consideration the length of the reference probe (L_{ref}) is given by:

$$N_{req} = \frac{L^1}{L_{ref} = 90m} \tag{5}$$

Finally, the geothermal energy cover ratio (CR) is calculated by dividing the number of possible borehole heat exchangers (N_{poss}) by the number of the required borehole heat exchangers (N_{req}) to cover the thermal energy demand. The number of possible borehole heat exchangers (N_{poss}) is depending on the required area per probe (A_{probe}) and the total useable area per cell (A_{poss}) (see chapter 2.2):

$$CR = \frac{N_{poss}}{N_{req}} . \tag{6}$$

The three different possibilities of the geothermal energy cover ratio (CR) are:

- CR = 0: A lack of useable areas, no possibility to use geothermal energy in the cell.
- CR < 1: The heating energy demand cannot be covered within the cell.
- CR ≥ 1: The heating energy demand can be covered with geothermal energy within the cell.

The resulting geothermal energy cover ratio (CR) shows that in only 1.424 cells of in total 266.347 populated cells in Austria the heating energy demand cannot be covered by geothermal energy, i.e. 0.5% only (!). Figure 6 shows that these cells are situated in densely populated areas (cities). In 247.678 cells (93%) the geothermal potential varies from a low to a high surplus. In the remaining cells (6.5%) a lack of useable areas was identified or no data were available, thus these cells were excluded from the potential use of geothermal energy.

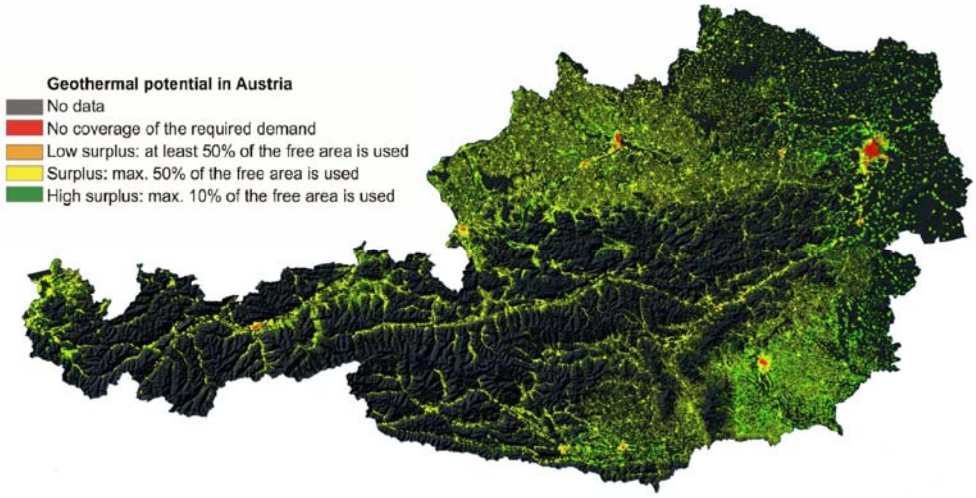

Figure 6: The potential of geothermal energy in Austria [3]

5 RESULTS AND CONCLUSIONS

Geothermal energy is a renewable, economic and environmental friendly energy source which contributes to climate protection and to the fulfilment of international obligations. The customers of geothermal energy get a pollution-free energy source which is independent of fossil fuels.

In the scope of the study GEO-Pot a nationwide grid-based dataset has been generated for the entire Austrian territory. The results of the study show that it is possible to provide heating from geothermal energy in most of the populated areas. Only in residential areas with a high concentration of buildings (centres of the larger cities of Austria) and a lack of open areas, a full coverage cannot be achieved.

In conclusion, the study shows that there is huge potential to save primary energy and minimize CO_2 emissions by utilizing geothermal energy all over Austria.

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