Legend of the Geoindex viewer – Shallow geothermal potential

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<td>References</td>
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<td>Note</td>
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</tbody>
</table>
Geothermal potential

Geothermal potential for vertical closed-loop systems expressed in terms of energy (MWh/yr)

Information about the total amount of thermal energy (MWh/yr) that can be exchanged with the ground during the heating season for a Borehole Heat Exchanger (BHE) that is 100 m deep, have a diameter of 150 mm and have a thermal resistance of 0.095 mK/W. For the realization of this layer, the G.Pot method (Casasso, 2016) developed by DIATI (DIATI - Politecnico de Torino, Italy) has been used.

- < 3 (MWh/yr)
- 3 to 6 (MWh/yr)
- 6 to 9 (MWh/yr)
- 9 to 12 (MWh/yr)
- 12 to 15 (MWh/yr)
- 15 to 18 (MWh/yr)
- 18 to 21 (MWh/yr)
- 21 to 24 (MWh/yr)

Geothermal potential for vertical closed-loop systems expressed in terms of power (W)

Information about the total amount of thermal energy in terms of power (W) that can be exchanged with the ground during the heating season for a Borehole Heat Exchanger (BHE) that is 100 m deep, have a diameter of 150 mm and have a thermal resistance of 0.095 mK/W. For the realization of this layer, the G.Pot method (Casasso, 2016) developed by DIATI (DIATI - Politecnico de Torino, Italy) has been used.

- < 250 W
- 250 to 500 W
- 500 to 750 W
- 750 to 1000 W
- 1000 to 1250 W
- 1250 to 1500 W
- 1500 to 1750 W
- 1750 to 2000 W
- 2000 to 2250 W
- 2250 to 2500 W
Geothermal installations

Location of geothermal installations in the public administration

It is a compilation of heat exchange installations with geothermal heat pumps promoted by the public administration. Most of them correspond to buildings and facilities of the local and general Administration. Depending on the available data, it is possible to check the power and length of the total installed Borehole Heat Exchangers (BHEs) in each facility. There isn’t any official inventory of this kind of facilities in Catalonia; therefore the compilation was prepared using the available information provided by the ICAEN (Institut CATalà de l’Energia) and other free access information sources (Version 1.0. Last updated on December 2018).

- s/d
- 5 - 30 kW
- 31 - 70 kW
- 71 - 200 kW
- 201 - 750 kW
- 751 - 3200 kW

<table>
<thead>
<tr>
<th>Description</th>
<th>POWER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power installed (kW)</td>
<td></td>
</tr>
<tr>
<td>m_INTERCAN</td>
<td></td>
</tr>
<tr>
<td>Total length of installed exchangers (m)</td>
<td></td>
</tr>
</tbody>
</table>

Number of geothermal installations in the private sector

Number of heat exchange installations with geothermal heat pumps for each municipality promoted by the private sector. The total minimum power installed by municipality is indicated. There isn’t any official inventory of this kind of facilities in Catalonia and therefore, the compilation has been performed with the available information provided by the ICAEN (Institut CATalà de l’Energia) and other free access sources of information (Version 1.0. Last updated on December 2018).

<table>
<thead>
<tr>
<th>0 installations</th>
<th>6 to 10 installations</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 to 2 installations</td>
<td>11 to 15 installations</td>
</tr>
<tr>
<td>3 to 5 installations</td>
<td>20 to 25 installations</td>
</tr>
</tbody>
</table>

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Drilling difficulty

Potential drilling difficulty

Information about the potential difficulty to drill a 100 m long borehole (usually by rotary percussive drilling and/or direct rotary drilling) due to the presence of instable materials, alternation or non-consolidated hetero-granular deposits. The Seismic mesozonation map of Catalonia (1:100,000), adapted to the EC-8 classification (IGC 2011 and 2013) was used as a base information. Depending on the lithological profile the drilling difficulty is classified as:

- **Moderate drilling difficulty**: Consolidated materials, hard rock or poorly altered rock predominate.
- **Medium drilling difficulty**: Poorly consolidated or non-consolidated granular materials and/or soft rocks predominate. Non-altered rock or hard rock may appear at the bottom.
- **High drilling difficulty**: Granular materials with low degree of consolidation and/or alternation of materials with different consolidation degrees predominate.

Possible presence of karstification in the ground

Areas where karstification may occur and affect the drilling and the Borehole Heat Exchanger (BHE) installation are indicated in this layer. Map of aquifers and classification at a scale of 1: 50,000 from the Catalan Agency of Catalonia (ACA, 2013) were used as base information.
Edaphological information

Depth of edaphic soil

The depth of edaphic soil is the depth where chemical reactions and processes change the most superficial part of the ground into a layer with specific physical, chemical and biological characteristics. The depth of edaphic soil was estimated by taking into account the available data from the Soil map of Catalonia (1:250.000). Edaphic soil was divided into 5 classes according to the criteria used for the description of soil profiles and soil units defined in the methodological guide of ICGC projects about soil cartography.

- Very shallow: < 20 cm
- Shallow: 20 to 40 cm
- Moderately deep: 40 to 80 cm
- Deep: 80 to 120 cm
- Very deep: > 120 cm

Thermal conductivity of edaphic soil

Thermal conductivity defines the ability to conduct heat. The thermal conductivity of edaphic soil was estimated using the methodology proposed by Bertermann (2013) in the framework of the European Thermomap Project. It proposes to estimate ground thermal conductivity using Kersten (1949) and Dehner (2007) formulas. The main edaphological parameters that influence the heat transfer the most are: the density and the volumetric content of water in the soil.

- High: > 1.5 W/mK
- Medium-high: 1.31 to 1.5 W/mK
- Medium: 1.11 to 1.3 W/mK
Hydrogeological information

Points with special and/or thermal waters evidences

Compilation of points where special and/or thermal waters occur such as springs, wells or galleries that drain or pump thermal waters. Thermal water is water that is 4 °C warmer than the average annual air temperature at the same location, whereas special water is carbonated, sulphurous or salty water. In some cases they were selected because they are exploited as mineral and medical waters for balneotherapeutic treatments. In other cases the original place name is the evidence of some mineral characteristic. Wells drilled from 1970 to 1980 for geothermal resources investigation with geothermal measured gradients greater than 5 °C/100 m have been also included.

- Thermal water spring, well or gallery
- Thermal and carbonated water spring, well or gallery
- Thermal and sulphurous water spring, well or gallery
- Thermal, carbonated and sulphurous water spring, well or gallery
- Thermal and salty water spring, well or gallery
- Thermal, salty and sulphurous water spring, well or gallery
- Carbonated water spring, well or gallery
- Sulphurous water spring, well or gallery
- Salty water spring, well or gallery
- Sulphurous and carbonated water spring, well or gallery
- Water point with indicative place name
- Investigation borehole with geothermal gradient greater than 5 °C/100 m

The coordinates of the points have not been verified yet by the ICGC and correspond to those indicated in the original source of information.

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Ground thermal properties

Vertical distribution of thermal properties

This layer shows vertical distribution of thermal conductivity, thermal diffusivity and thermal volumetric capacity according to vertical lithology profiles available from different databases (ICGC and ACA). Depending on the age, the lithology of materials and their percentage, thermal parameters were assigned using the values proposed by the UNE 100715-1 (AENOR, 2014). For data visualization a PDF file for each vertical lithology profile can be downloaded.

Superficial thermal conductivity (W/mK)

Thermal conductivity defines the ability to conduct heat. This is characteristic of each lithological unit that depends on porosity, water content, crystalline composition and disposition of the rock. The thermal conductivity map is based on the Geological data base of Catalonia 1: 50,000 from the ICGC. Depending on the age, the lithology of materials and their percentage, the thermal conductivity of each of the outlying cartographic units was assigned using the values proposed by the UNE 100715-1 (AENOR, 2014) and several authors. Robertson (1988), Fernández & Banda (1986), Horai & Baldrige (1972), Marzán (2000), Peña (2013). The resulting value was corrected by means of a porosity coefficient that takes into account the compaction of the materials, which is the relationship defined by Manger (1963) for the reduction of porosity according to the geological age.

- < 1 W/mK
- 1 to 2 W/mK
- 2 to 3 W/mK
- 3 to 4 W/mK
- 4 to 5 W/mK
- > 5 W/mK
Superficial thermal diffusivity (mm²/s)

Thermal diffusivity defines the capacity of a rock or soil to dissipate heat and it depends on the thermal conductivity, density and the specific heat capacity of the materials. The thermal diffusivity map is based on the Geological data base of Catalonia 1: 50,000 from the ICGC. Density and specific heat capacity values were assigned to each one of the outlying cartographic units according to Waples & Waples (2004) and Robertson (1988). The resulting value was corrected by means of a porosity coefficient that takes into account the compaction of the materials, which is the relationship defined by Manger (1963) for the reduction of porosity according to the geological age.

![Color legend for thermal diffusivity](image)

Superficial thermal volumetric capacity (MJ/m³K)

The thermal capacity is defined as the amount of heat that is obtained from a volume of rock or soil by decreasing its temperature by 1 K. The thermal capacity is the ratio between thermal conductivity and thermal diffusivity.

![Color legend for thermal volumetric capacity](image)
Air temperatures and thermal oscillations

Average annual air temperature (°C)

This layer was prepared by the ICGC in collaboration with the Grumets team from the Animal Biology, Vegetal Biology and Ecology Department of the Autonomous University of Barcelona (UAB) based on available climatological data and using multiple regression techniques (Ninyerola et al, 2007). The factors that were considered in the theoretical model: altitude, potential solar radiation, topographic humidity index (Topographic Wetness Index, TWI), topographical position index (Topographic Position Index, TPI), the complexity of the terrain (Terrain Ruggedness Index, TRI), latitude and distance from the coast line.

![Temperature Ranges]

Average air temperatures of the coldest month (°C)

This layer was prepared by the ICGC in collaboration with the Grumets team (UAB). According to the average monthly temperature maps of December, January and February of 294 meteorological stations, and using maps algebra, the minimum value for each pixel was obtained. Thus, the average air temperature map of the coldest month was generated.

![Temperature Ranges]
**Average air temperatures of the hottest month (°C)**

This layer was prepared by the ICGC in collaboration with the Grumets team (UAB). According to the average monthly temperature maps of June, July and August of 298 meteorological stations and using maps algebra, the maximum value for each pixel was obtained. Thus, the average air temperature map of the hottest month was generated.

<table>
<thead>
<tr>
<th>Temperature Range</th>
<th>Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 to 10 °C</td>
<td>Blue</td>
</tr>
<tr>
<td>10 to 14 °C</td>
<td>Green</td>
</tr>
<tr>
<td>14 to 18 °C</td>
<td>Yellow</td>
</tr>
<tr>
<td>18 to 22 °C</td>
<td>Red</td>
</tr>
<tr>
<td>22 to 26 °C</td>
<td>Red</td>
</tr>
<tr>
<td>26 to 30 °C</td>
<td>Yellow</td>
</tr>
<tr>
<td>30 to 34 °C</td>
<td>Green</td>
</tr>
<tr>
<td>34 to 36 °C</td>
<td>Blue</td>
</tr>
</tbody>
</table>

**Superficial thermal semi-amplitude (°C)**

It is half the difference between the values of the average maximum temperatures of the hottest month and the values of the average minimum temperatures of the coldest month. This layer was prepared by the ICGC in collaboration with the Grumets team (UAB).

<table>
<thead>
<tr>
<th>Temperature Range</th>
<th>Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 to 7 °C</td>
<td>Blue</td>
</tr>
<tr>
<td>7 to 9 °C</td>
<td>Yellow</td>
</tr>
<tr>
<td>9 to 11 °C</td>
<td>Red</td>
</tr>
<tr>
<td>11 to 13 °C</td>
<td>Blue</td>
</tr>
<tr>
<td>13 to 15 °C</td>
<td>Yellow</td>
</tr>
<tr>
<td>15 to 17 °C</td>
<td>Red</td>
</tr>
<tr>
<td>17 to 19 °C</td>
<td>Blue</td>
</tr>
</tbody>
</table>
Climate severity

Heating Degree Days - HDD (°C⋅day/year)

It is a measurement to quantify how many degrees and for how long in one year, the outside temperature is below a threshold value generating a certain heat loss from the inside of a building that makes necessary to turn on the heating system. It is expressed in °C⋅day/year and the threshold value used to calculate this layer was 15 °C. It was performed by the Catalan Meteorological Services (SMC) in collaboration with the ICGC, based on half-hourly meteorological data from 2013 to 2018. A continuous and spatially distributed value of the HDD was obtained by using a Multiple Linear Regression (MLR) and anomaly corrections using real data from more than 200 automatic weather stations.

- 500 - 750 °C⋅day/year
- 750 - 1000 °C⋅day/year
- 1000 - 1250 °C⋅day/year
- 1250 - 1500 °C⋅day/year
- 1500 - 1750 °C⋅day/year
- 1750 - 2000 °C⋅day/year
- 2000 - 2500 °C⋅day/year
- 2500 - 3000 °C⋅day/year
- 3000 - 3500 °C⋅day/year
- 3500 - 4000 °C⋅day/year
- 4000 - 4500 °C⋅day/year
- 4500 - 5000 °C⋅day/year
- 5000 - 5500 °C⋅day/year
Cooling Degree Days - CDD (°C·day/year)

It is a measurement to quantify how many degrees and for how long in one year, the outside temperature is above a threshold value generating a certain heat gain inside of a building that makes necessary to turn on the cooling system. It is expressed in °C·day/year and the threshold value used to calculate this layer was 23 °C. It was performed by the SMC in collaboration with the ICGC, based on half-hourly meteorological data from 2013 to 2018. A continuous and spatially distributed value of the CDD was obtained by using a Multiple Linear Regression (MLR) and anomaly corrections using real data from more than 200 automatic weather stations.

<table>
<thead>
<tr>
<th>0 - 50 °C·day/year</th>
<th>200 - 250 °C·day/year</th>
</tr>
</thead>
<tbody>
<tr>
<td>50 - 100 °C·day/year</td>
<td>250 - 300 °C·day/year</td>
</tr>
<tr>
<td>100 - 150 °C·day/year</td>
<td>300 - 350 °C·day/year</td>
</tr>
<tr>
<td>150 - 200 °C·day/year</td>
<td>350 - 400 °C·day/year</td>
</tr>
</tbody>
</table>

Heating Season Length (HSL) (days)

The Heating Season Length (HSL) is defined as the average of the total number of days in a year, when the average outside daily temperature is below a threshold value. It is assumed that during that period it is necessary to turn on the heating system. It is expressed in days and the threshold value used to calculate this layer was 15 °C. Calculations were performed by the SMC in collaboration with the ICGC, based on half-hourly meteorological data from 2013 to 2018. A continuous and spatially distributed value of the HSL was obtained by using a Multiple Linear Regression (MLR) and anomaly corrections using real data from more than 200 automatic weather stations.

<table>
<thead>
<tr>
<th>150 - 175 days</th>
<th>275 - 300 days</th>
</tr>
</thead>
<tbody>
<tr>
<td>175 - 200 days</td>
<td>300 - 325 days</td>
</tr>
<tr>
<td>200 - 225 days</td>
<td>325 - 365 days</td>
</tr>
<tr>
<td>225 - 250 days</td>
<td>350 - 365 days</td>
</tr>
<tr>
<td>250 - 275 days</td>
<td></td>
</tr>
</tbody>
</table>
Cooling Season Length (CSL) (days)

The Cooling Season Length (HSL) is defined as the average of the total number of days in a year, when the average outside daily temperature is above a threshold value. It is assumed that during that period it is necessary to turn on the cooling system. It is expressed in days and the threshold value used to calculate this layer was 23 °C. Calculations were performed by the SMC in collaboration with the ICGC, based on half-hourly meteorological data from 2013 to 2018. A continuous and spatially distributed value of the CSL was obtained by using a Multiple Linear Regression (MLR) and anomaly corrections using real data from more than 200 automatic weather stations.
## Sub-superficial ground temperatures

### Minimum temperatures at a depth of 1,5 m (°C)

It is the minimum temperature of the ground at a depth of 1.5 m. It was performed using the Kusuda (1985) approach. It determines the ground temperature at a time "t" of the year for a certain depth "z" within the section where the temperature oscillates due to the seasonal variations of the air temperature. The average minimum temperature of the coldest month (°C), the superficial thermal semi-amplitude (°C), the average annual air temperature (°C) and the thermal diffusivity (mm²/s) was used to calculate this layer.

<table>
<thead>
<tr>
<th>Temperature Range</th>
<th>Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>-6 to -3 °C</td>
<td>6 to 9 °C</td>
</tr>
<tr>
<td>-3 to 0 °C</td>
<td>9 to 12 °C</td>
</tr>
<tr>
<td>0 to 3 °C</td>
<td>12 to 15 °C</td>
</tr>
<tr>
<td>3 to 6 °C</td>
<td></td>
</tr>
</tbody>
</table>

### Maximum temperatures at a depth of 1,5 m (°C)

It is the maximum temperature of the ground at a depth of 1.5 m. It was performed using the Kusuda (1985) approach. It determines the ground temperature at a time "t" of the year for a certain depth "z" within the section where the temperature oscillates due to the seasonal variations of the air temperature. The average maximum temperature of the hottest month (°C), the superficial thermal semi-amplitude (°C), the average annual air temperature (°C) and the thermal diffusivity (mm²/s) were used to calculate this layer.

<table>
<thead>
<tr>
<th>Temperature Range</th>
<th>Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 to 7 °C</td>
<td>15 to 19 °C</td>
</tr>
<tr>
<td>7 to 11 °C</td>
<td>19 to 23 °C</td>
</tr>
<tr>
<td>11 to 15 °C</td>
<td>23 to 27 °C</td>
</tr>
</tbody>
</table>
**Thermal amplitude at a depth of 1.5 m (°C)**

It is the numerical difference between the maximum and the minimum ground temperatures at a depth of 1.5 m.

- **7 to 10 °C**
- **10 to 13 °C**
- **13 to 16 °C**
- **16 to 19 °C**
- **19 to 22 °C**
- **22 to 25 °C**

**Depth where the thermal amplitude tends toward 0°C (m)**

It is the depth where a seasonal thermal oscillation in the ground tends toward zero reaching the average annual air temperature of a certain place. It was performed using the Kusuda (1985) approach using the average annual air temperature (°C), thermal diffusivity (mm²/s) and assuming a value of 0.1 °C for thermal semi-amplitude.

- **0 to 2 m**
- **2 to 4 m**
- **4 to 6 m**
- **6 to 8 m**
- **8 to 10 m**
- **10 to 12 m**
- **12 to 14 m**
- **14 to 16 m**
- **16 to 18 m**

*Index*
Ground temperatures at different depths

Ground temperature vertical profiles

Vertical profiles of ground temperature measured in wells, piezometers and boreholes. The geothermal gradient is estimated for each profile. For data visualization a PDF file for each vertical profile can be downloaded.

Ground temperature at a depth of 50 m (°C)

It is the theoretical ground temperature at a depth of 50 m. This layer was calculated using the theoretical geothermal gradient, heat flow and thermal conductivity maps of Catalonia. The resulting temperatures map was corrected using the interpolation of the errors between the obtained theoretical temperatures values and the observed values at wells, piezometers and boreholes.
Ground temperature at a depth of 100 m (°C)

It is the theoretical ground temperature at a depth of 100 m. This layer was calculated using the theoretical geothermal gradient, heat flow and thermal conductivity maps of Catalonia. The resulting temperatures map was corrected using the interpolation of the errors between the obtained theoretical temperatures values and the observed values at wells, piezometers and boreholes.
Ground temperature at a depth of 150 m (°C)

It is the theoretical ground temperature at a depth of 150 m. This layer was calculated using the theoretical geothermal gradient, heat flow and thermal conductivity maps of Catalonia. The resulting temperatures map was corrected using the interpolation of the errors between the obtained theoretical temperatures values and the observed values at wells, piezometers and boreholes.
References


Bertermann, D. (2013). ThermoMap – Area mapping of superficial geothermal resources by soil and groundwater data. EGTC, Pisa, Italy.


**Note**

The shallow geothermal viewer is a 2D representation and a digital format publication with a maximum resolution equivalent to 1:50,000 scale. The parameters included in it were approximated using several methodologies based on theoretical models about the thermal behaviour of the ground. These do not take into account the particularities of a certain area where, due to the heterogeneity of the territory, there could be anomalies and therefore deviations from the assumed theoretical models could occur.

For planning, sizing and designing ground source heat/cooling system in a particular location, it is recommended to carry out a detailed study, which includes in-situ data collection and 3D terrain analysis.

For vertical closed-loop Ground Source Heat Pumps (GSHP) installations, it is also recommended to follow the procedures of UNE 100715-1; a guide for the design, implementation and monitoring of a geothermal system for vertical closed-loop systems (AENOR, 2014).