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D.3.3.1. Training material on the application of the tool-box and the use of the Danube Region Geothermal Information Platform (DRGIP)

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Contents

Introduction

In order to provide practical methods and techniques for thermal water users, authorities, project developers for the sustainable management and effective operation of geothermal energy resources, three methods have been developed, that for complementary modules of a tool-box, presented below. They have been tested and evaluated in three transboundary pilot areas in the Pannonian basin using a unified and harmonised approach. These are, respectively, the Hungarian-Romanian-Serbian, the Slovenian-Hungarian-Croatian, and the Bosnian-Herzegovinian-Serbian basin-fill and basement geothermal aquifers.

The three methods that build on each other and follow the logic of the life-cycle of geothermal project development are the following:

1. How to assess the current state of thermal water use – BENCHMARK TOOL

2. Considering the status quo, how to decide for a new projct – DECISION TREE TOOL

3. How to deal with the risks of project development – RISK MITIGATION TOOL

The methods of each tool are discussed in details in D.6.3.1. (Manual on the use of the tool-box), therefore in this report the method itself is just briefly summarised and the focus is put on their use in practice, which is introduced in the first part.

The second part of the report deals with the Danube Region Geothermal Information Platform, a key output of the DRALINGe project, which is an informative, user friendly and stakeholder-engaging site that jointly presents all technical and non-technical information collected and evaluated during the project. The detailed instructions on the use of the portal are summarised in D.4.2.2. (DRGIP Users' Manual).

PART I: TOOL-BOX

I.1. Benchmarking

This aim of this tool is **to quantify and compare the state of geothermal water management** at different scales on a unique and harmonised way, and to support measures for more efficient energy production. During its development the main criteria were to make it transparent, harmonized, well-defined and have an understandable terminology; a methodology with worldwide applicability and which is not dependent on local geothermal exploitation characteristics; informative, showing quantitative results; and a clear delineation concerning the availability of information.

It has been developed for aquifers exploited by multiple users and/or in neighbouring countries to support water permit/concession granting process. It comprises a set of indicators presented on charts using five categories (from very poor to very good) and being calculated from allocated points based on physical data or metadata information using transparent formulae. The input requires detailed data on production, monitoring , permits per a well or sites, etc.; and the indicators themselves are calculated based on simple formulae. The results are generalised and should not have problems with data privacy.

There are altogether 12 benchmarking indicators grouped into four types (Table 1).

Name of the indicator	Smallest data collection level	Smallest data presentation level	Indicator type
Licencing procedure	Site/Country	Site or country	Management
Monitoring requirements	Site/Country	Site or country	Management
Monitoring setup	Object/Site	Site	Management
Passive monitoring	Aquifer/Region	Aquifer/Region	Management
Operational issues	Object	Site	Technology & energy
Cascade use	Site	Site	Technology & energy
Thermal efficiency	Object	Site	Technology & energy
Utilisation efficiency	Object	Site	Technology & energy
Reinjection	Object/Site	Site	Environmental
Over-exploitation	Site	Site	Environmental
Status of water balance assessment	Object/Site	Site	Environmental
Public awareness	Site	Site	Social

Table 1: List of benchmarking indicators, level of data collection and presentation, and indicator type

The calculation of each indicator is happening according to a given formula, summarized in Table 2

Name of the indicator	Calculation formula	Explanation of formula
Licencing procedure	$I_{LIC} = \sum_{i=1}^{n} P_i$	This indicator describes the transparency and simplicity of national or regional legislation. One has to give simple „yes” and „no” answers to a set of questions whether licencing is required (or not) to use thermal water, whether at least 80% of active objects have a licence granted, or whether only one type of concession fee has to be paid in order to produce thermal water by licence annually, etc. Relevant points are assigned to

		each question “yes” and “no” answer, which are summed up.
Monitoring requirements	$I_{REQ} = \sum_{i=1}^{n} P_i$	This indicator describes what the licence-owners within one country are obliged to monitor and report on, based on the licencing requirements. One has to give simple „yes” and „no” answers to a set of questions whether the following are carried out: (a) regular chemical analysis of thermal water, (b) regular performance of hydraulic testing of wells to determine their maximum and/or optimal discharge rate, (c) regular interpretation of measured values, and (d) regular reporting on monitoring to an authority. Relevant points are assigned to each question “yes” and “no” answer, which are summed up.
Monitoring setup	$I_{MON} = \frac{\sum_{i=1}^{n} P_i}{N_{tot}}$	This indicator is linked to the choice of parameters to be recorded at a utilization site, and it also requires available data at object level (i.e. wells). It can be simple (e.g. only at the water level), or it can involve complex monitoring. In the latter numerous parameters are recorded with respect to both the production and monitoring of wells. Inactive production wells with licences are also included in the calculation. One has to give simple „yes” and „no” answers to a set of questions related to different monitoring aspects of water quantitiy, piezometric level, temperature, water chemistry. Relevant points are assigned to each question “yes” and “no” answer, which are summed up.
Passive monitoring	$I_{MONP} = \frac{\sum_{i=1}^{n} P_i}{N_{tot}}$	This is a regionally specific indicator when there is/are observation wells in a geothermal aquifer monitored by a national/regional environmental agency or similar organization. One has to give simple „yes” and „no” answers to a set of questions related to different monitoring aspects of piezometric level, wellhead pressure, temperature, water chemistry. Relevant points are assigned to each question “yes” and “no” answer, which are summed up.
Operational issues	$I_{BAT} = \frac{\sum_{i=1}^{n} P_i \cdot Q_i}{\sum_{i=1}^{n} Q_i}$	This indicator shows (a) whether appropriate technical requirements are met at well installations, (b) whether problems (e.g. scaling, utilization of gas content) occurring during operation are successfully mitigated, (c) how efficiently the water usage is implemented and (d) it also describes the overall status of documentation at an

		operational site. One has to give simple „yes" and „no" answers to a set of questions related to the above operational issues. Relevant points are assigned to each question "yes" and "no" answer, which are summed up.
Cascade use	$I_{CAS} = \frac{\sum_{i=1}^{n} P_i}{N_{tot}}$	This indicator is related to the energy abstraction practice of a site, if geothermal resources are used for more than one sequential application. . One has to give simple „yes" and „no" answers to a set of questions related to cascade use, such as the number of stages of energy extraction is beyond 3, if thermal water is not additionally heated, or cooled down prior to its use, etc. Relevant points are assigned to each question "yes" and "no" answer, which are summed up.
Thermal efficiency	$I_{TEF} = \frac{\sum_{i=1}^{n} \eta_i \cdot Q_i}{\sum_{i=1}^{n} Q_i} [\%]$	This indicator is determined from the ratio between the actually used and the available heat energy, where the mean annual air temperature is applied as a reference, according to the formula: $\eta_i = \frac{T_{whd} - T_{out}}{T_{whd} - T_o}$
Utilisation efficiency	$I_{UEF} = \frac{\sum_{i=1}^{n} Q_i}{\sum_{i=1}^{n} Q_{cap\,i}} [\%]$	This indicator is the ratio of the average annual water production to the maximum water quantity that is permitted or, if this data is not available, the amount of water that could theoretically be produced.
Reinjection	$I_{REIN} = \frac{\sum_{i=1}^{n} P_i \cdot Q_i}{\sum_{i=1}^{n} Q_i}$	This indicator shows the reinjection status at a specific site. The reinjection rate is calculated based on the ratio of the volume of reinjected and abstracted thermal water used for geothermal energy production. $R_R = \sum_{1}^{n} \frac{Q_{reinj\,i}}{Q_{abs\,i}} [\%]$ One has to give simple „yes" and „no" answers to a set of questions related to reinjection, if the reinjection rate is between 20-40%, 40-60%, or beyond, etc. It also takes into account whether the reinjection is performed into the same aquifer from where the water is abstracted. Relevant points are assigned to each question "yes" and "no" answer, which are summed up.

Over-exploitation	$I_{OE} = \frac{\sum_{i=1}^{n} P_i \cdot Q_i}{\sum_{i=1}^{n} Q_i}$	This indicator is related to the potential significant impact of water abstraction on piezometric groundwater levels, water temperatures, groundwater availability, water quality, and groundwater-dependent ecosystems. One has to give simple „yes" and „no" answers related to a set of questions related to the presence of the above phenomena. Relevant points are assigned to each question "yes" and "no" answer, which are summed up.
Status of water balance assessment	$I_{WBA} = \frac{\sum_{i=1}^{n} P_i}{N_{tot}}$	This indicator is a measure of the respective levels of the type, availability and reliability of information on the evaluation of the water quantity status of an aquifer at a particular site. One has to give simple „yes" and „no" answers related to a set of questions whether critical point of abstraction and critical level point are defined, or not and on which basis. Relevant points are assigned to each question "yes" and "no" answer, which are summed up.
Public awareness	$I_{INF} = \frac{\sum_{i=1}^{n} P_i}{N_{tot}}$	This indicator highlights how much information on a particular geothermal resource (and its use) is publicly available through websites and easy-accessible promotional publications. One has to give simple „yes" and „no" answers related to a set of questions whether public information on utilization type, water water temperaturem, chemistry, monitoring etc, are available or not. Relevant points are assigned to each question "yes" and "no" answer, which are summed up.

P_i = number of assigned points to a geothermal object i

N_{tot} = total number of geothermal objects in the investigated area

Q_i = annual production rate of a geothermal object i (m^3/y)

T_o = average annual air temperature at a site, assigned as 12 °C

T_{out} = temperature of waste thermal water at a geothermal site (°C)

T_{whd} = outflow temperature at wellhead of a well or at spring (°C)

The resulting calculation for each indicator is grouped into one of five categories, pointing out how much efforts have to be taken to improve the current exploitation practice. Values high need for improvement and need for improvement highlight that much efforts have to be taken to improve current practice in future; reasonable practice could become better with not too much efforts, while good and very good practice may set an example and be used for knowledge-exchange to other sites worldwide.

The main stakeholders who can benefit from this methodology are: 1) management authorities, including international organizations, 2) licencing authorities, 3) thermal water users, 4) investors in geothermal use, and 5) research organizations and universities.

The key issues which can affect the quality of benchmarking are the existence of actual data, availability and reliability of information, reference dates, types of geothermal objects to be included, and weight assignment of the indicator. If the number of wells available for evaluation is small (e.g. <10), one has to be aware that the result will be rather subjective and, therefore, care and not-over-generalization have to be taken by interpretation.

The onlione version of the tool is available at: https://www.darlinge.eu/#/benchmarkingIntro

I.2. Decision Tree

The main aim of this tool is to raise the awareness on the complexity of geothermal project development and educate the readers what kind of various decision gates might occur during project development. The tool is presenting the most likely occurring questions during the project development from the initial idea until the geothermal system is set up and running. The type of questions is referring to the four most important fields:

1. Resource: including technological aspects of the subsurface and the surface part of the system,
2. Market: referring to the aspects of selling the product of the system, in our case the heat
3. Licensing: permitting, procurement of licences to be submitted to the relevant authorities,
4. Funding: aspects of project financing.

When a project developer is running a geothermal project, one needs to harmonize the activities of these different fields to increase the successful completion of the project.

The tool is based on a relatively simple project, where a geothermal doublet (one injection well and one reinjection well) would be implemented with connecting surface pipes and heat centre providing heat for a local community.

The decisions included in the tool are results of answers to the questions of the developer and his expert teams.

The tool consists of series of questions and decisions. The answering of questions starts from the beginning of the ideal project and the questions are grouped according to the four main fields described above (Resource, Market, Licensing, Funding). The answers to be provided are simply "yes" or "no". After answering several questions, a decision is needed concerning the continuation of the project. Then questions will be given again until the next decision. The tool helps to find the most reasonable decision by indicating the share of "yes" or "no" answers previously given for each field separately. There is explanatory text for almost all questions, which helps to understand better the meaning of the relevant question. The decisions included in the tool according to project's periods are the next:

Period	Estimated	Decision

	duration (months)	
Preliminary evaluation	2	Exploration permit
Preparatory work	9	Heat purchase agreement
		Drilling the first well
Construction of wells	8	Feasibility study
		Drilling the second well
		Constructing the surface system
Construction of surface system	5	Operational permit

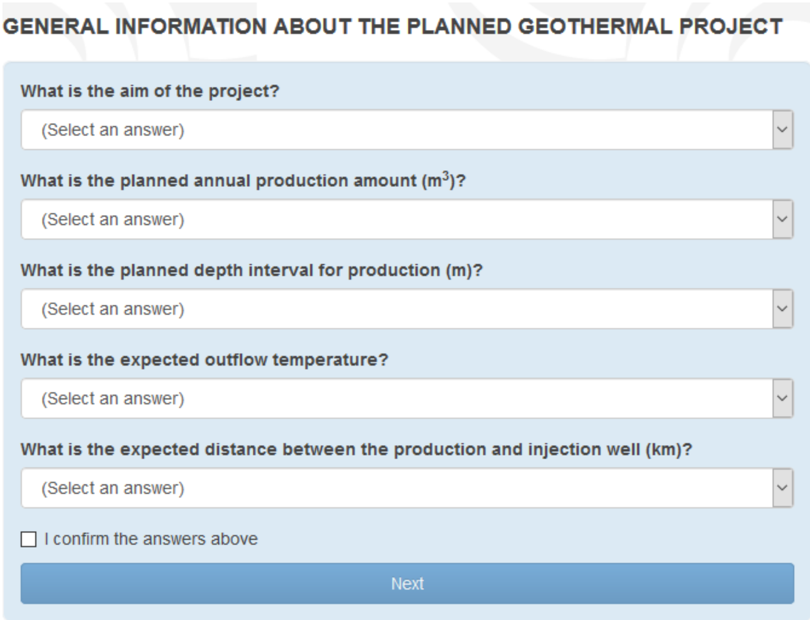
Giving “no” answer at a decision means the end of project. The user has the freedom of choice to approve a decision even the amount of previous “no” answers does not support it.

The online version of the tool is available at: https://www.darlinge.eu/#/decisiontreeIntro

I.3. Risk Mitigation

The aim of this tool is to define those geological risk mitigation measures of a given project, by which the avoidance of highly probable damages is possible. The tool is dealing with one idealised project, which consists of planning and drilling of a doublet (one production and one injection well), connecting the wells via pipelines and circulating the fluid through heat exchangers for heat and/or electricity production. The risk mitigation measures can be defined according to different project phases, when the measure(s) should be planned or performed.

As a first step, the tool is collecting information about the project. The information is collected along 5 subsequent questionnaires by answering a set of questions. The first page contains questions about the planned project in general, e.g. what is the aim and what is the size. The second is focussing on the available drilling, temperature and surface geophysical data, and the spatial distribution of different users, as possible receptors nearby. The third set of questions is collecting information on the properties of reservoir. The fourth page is dealing with basic fluid properties, e.g. gas content and total dissolved solids. On the fifth page the given project phase should be selected.


GENERAL INFORMATION ABOUT THE PLANNED GEOTHERMAL PROJECT

What is the aim of the project?

(Select an answer)

What is the planned annual production amount (m^3)?

(Select an answer)

What is the planned depth interval for production (m)?

(Select an answer)

What is the expected outflow temperature?

(Select an answer)

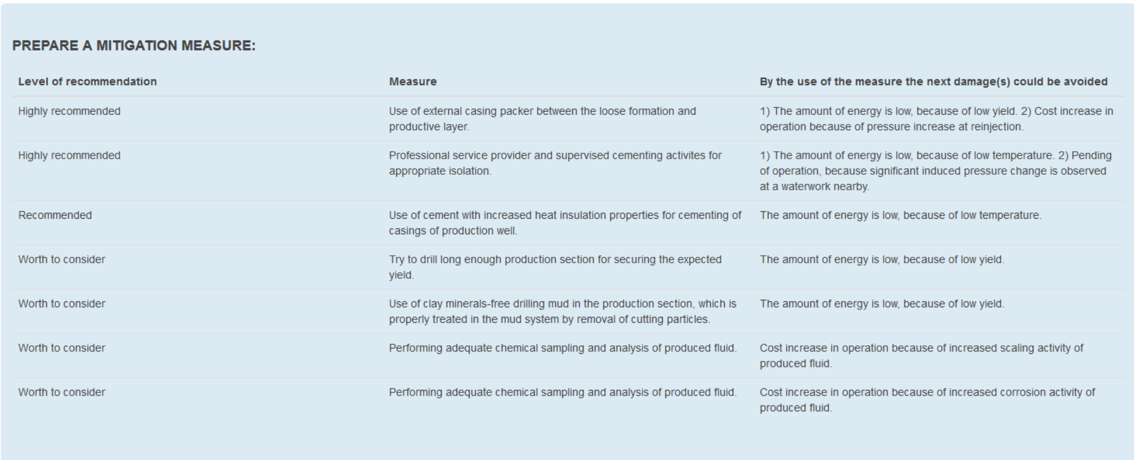
What is the expected distance between the production and injection well (km)?

(Select an answer)

☐ I confirm the answers above

Next

When the project phase is selected, the tool will list the suggested risk mitigation measures according to the level of recommendation. The tool will define what kind of damage(s) could be avoided by the given measure. By selecting another phase, the tool will identify the suggested measures relevant of that phase. For a new project, or for a change of a parameter previously given at the first 4 pages, the calculation should be started again from the beginning.


PREPARE A MITIGATION MEASURE:

Level of recommendation	Measure	By the use of the measure the next damage(s) could be avoided
Highly recommended	Use of external casing packer between the loose formation and productive layer.	1) The amount of energy is low, because of low yield. 2) Cost increase in operation because of pressure increase at reinjection.
Highly recommended	Professional service provider and supervised cementing activites for appropriate isolation.	1) The amount of energy is low, because of low temperature. 2) Pending of operation, because significant induced pressure change is observed at a waterwork nearby.
Recommended	Use of cement with increased heat insulation properties for cementing of casings of production well.	The amount of energy is low, because of low temperature.
Worth to consider	Try to drill long enough production section for securing the expected yield.	The amount of energy is low, because of low yield.
Worth to consider	Use of clay minerals-free drilling mud in the production section, which is properly treated in the mud system by removal of cutting particles.	The amount of energy is low, because of low yield.
Worth to consider	Performing adequate chemical sampling and analysis of produced fluid.	Cost increase in operation because of increased scaling activity of produced fluid.
Worth to consider	Performing adequate chemical sampling and analysis of produced fluid.	Cost increase in operation because of increased corrosion activity of produced fluid.

The online version of the tool is available at: https://www.darlinge.eu/#/riskmitigationIntro

PART II - Danube Region Geothermal Information Platform (DRGIP)

One of the main goals of the DARLINGe project was to establish a centralized entry point to facilitate the exchange of methods and ideas between those working in the field of geothermal energy in the Danube Region. The essential purpose of this goal was to integrate and harmonise geological, hydrogeological, geothermal- and to some extent other technical information and services. This is called the Danube Region Geothermal Information Platform (DRGIP – **https://www.darlinge.eu**). In short, the DRGIP is a data infrastructure system that provides data and information services, as well as core services allowing discovery, access, validation and download of data and information, and maintenance of the system itself. It follows an open-access policy, meaning that no user-authentication is required. Thus access to the material which encompasses the work of the DARLINGe project requires no more than acceptance of the general terms and conditions of the data- providing institutions. It is expected that DRGIP will serve as an informative, user-friendly and stakeholder-engaging site.

DRGIP jointly presents all technical and non-technical information collected and evaluated during the DARLINGe project and it consists of **two main parts**. The first part is represented by **thematic modules**, where more detailed information can be found on some relevant topics. The second part is a **web-map viewer**, which provides access to information on spatial-referenced datasets (boreholes, maps, etc.). The web-map viewer also enables the construction of interactive visualizations, data download, exports and queries.

System requirements:

Modern browser (Firefox, Chrome, Internet Explorer, Safari, Opera)

II.1. Home page

When navigating to the page https://www.darlinge.eu/ we get to the home page of the DRGIP portal. The home page is composed of five sections:

1. Navigation bar – in the uppermost part. It consists of project logo, home icon and names of specific modules:
   - Knowledge sharing
   - Glossary
   - Benchmarking
   - Decision tree
   - Risk mitigation
   - Legislation

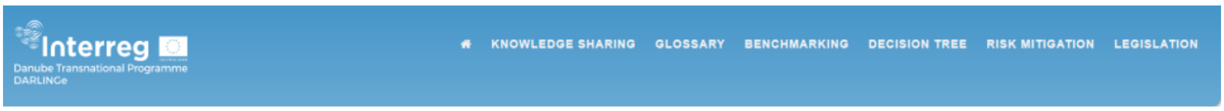
   Clicking on each of these module names in navigation takes us to the intro page of the specific module with description and explanation of the module.
2. Description of the portal and its purpose with additional links to web page of the project, user manual and contact list of people that contributed to portal's content, or its technical derivation.
3. Image of the Map viewer of DRGIP portal, which holds the visualization of spatially referenced data. Clicking on this image gets us to the map viewer.

4. Logos of the project partners - clicking on specific logo gets us to the home page of the project partner.
5. Disclaimer text in the bottom part of the page, in the footer.

General functionalities

Navigation bar

Clicking on links in the top navigation bar gets us from one module to the next. Clicking on home icon, or the logo takes us to the home page.



Filtering buttons

At modules Knowledge sharing and Contact of relevant authorities we will see the filtering buttons, that filter which content is to be displayed.

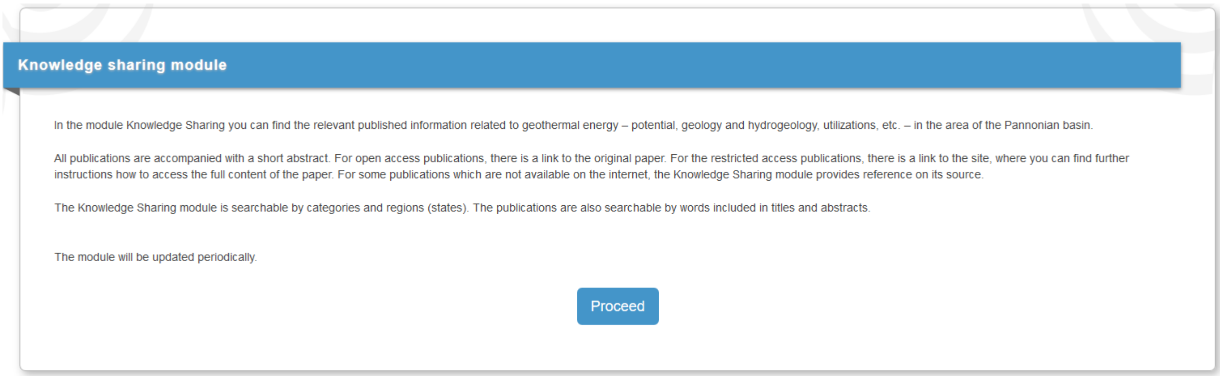
Go to the top of the page

At several modules we will also see the blue icon pointing upwards which gets us to the top of the current page.

II.2. MODULES

II.2.1. Knowledge sharing

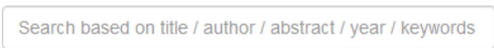
In the Knowledge-Sharing module one can find the relevant published information related to geothermal energy in the area of the Pannonian basin – namely, potential, geology and hydrogeology, utilization, etc. All publications are accompanied with a short abstract. For open access publications there is a link to the original paper, while for the restricted ones there is a link to the relevant site. At this site one can find further instructions about how to access the full contents of a particular paper. Publications are searchable by categories and regions (states), as well as by words included in titles and abstracts.

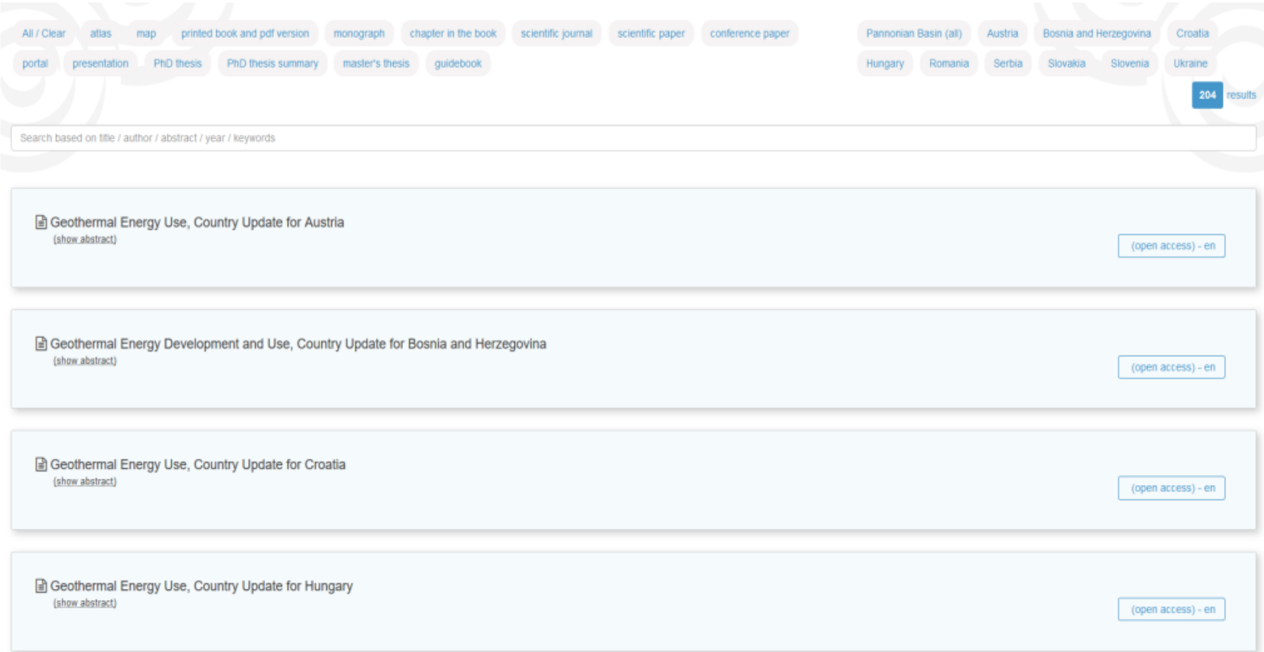


If we click **Proceed**, we get to the module itself.

This page consists of more than two hundred scientific publications which can be **filtered** by:

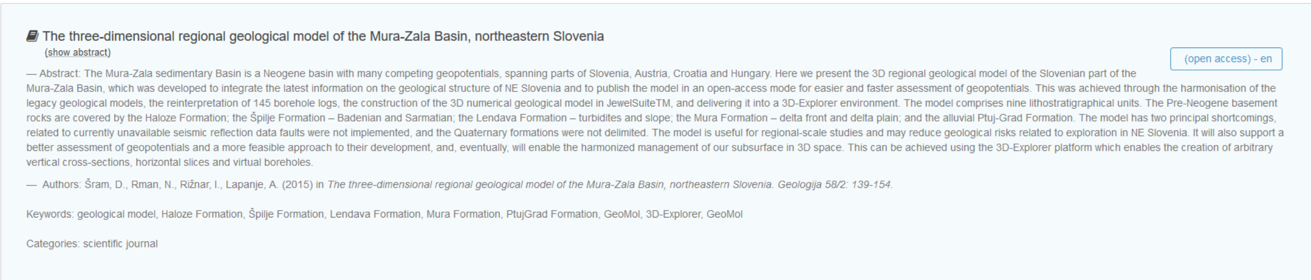
- Category of knowledge resource (atlas, map, printed book, monograph, chapter in the book, scientific journal, scientific paper, conference paper, portal, presentation, PhD thesis, PhD thesis summary, master's thesis, guidebook)
- Region (Pannonian Basin – all, Austria, Bosnia and Herzegovina, Croatia, Hungary, Romania, Serbia, Slovakia, Slovenia, Ukraine)
- Title, author, abstract, year, keyword





Categorical and region filtering can be done with buttons at the top, we can also **combine** the filter buttons from different types of filtering and filtering with input field.

If we click on the **show abstract** under the title of the knowledge resource, the panel expands:



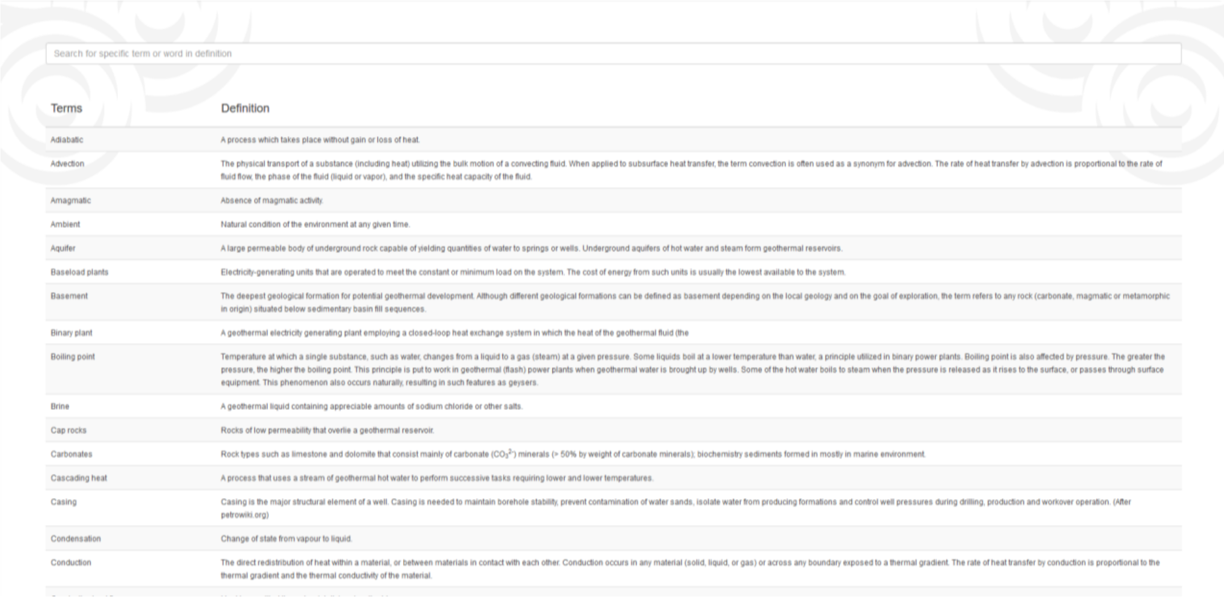
which shows us additional information about the knowledge resource:

- Title
- Abstract
- Authors
- Keywords
- Categories
- Type of access (in the top right side of the panel), language of resource

The input field mentioned above can filter data based on information from each of these data fields. And if we click on the button with type of access, it navigates us to the original page of the resource.

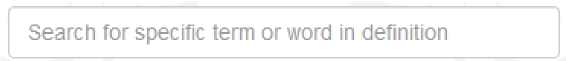
II.2.2. Glossary

The Glossary module provides the definitions / brief descriptions of the most commonly used terms related to geothermal energy and technologies.


Search for specific term or word in definition

Terms	Definition
Adiabatic	A process which takes place without gain or loss of heat.
Advection	The physical transport of a substance (including heat) utilizing the bulk motion of a convecting fluid. When applied to subsurface heat transfer, the term convection is often used as a synonym for advection. The rate of heat transfer by advection is proportional to the rate of fluid flow, the phase of the fluid (liquid or vapor), and the specific heat capacity of the fluid.
Amagmatic	Absence of magmatic activity.
Ambient	Natural condition of the environment at any given time.
Aquifer	A large permeable body of underground rock capable of yielding quantities of water to springs or wells. Underground aquifers of hot water and steam form geothermal reservoirs.
Baseload plants	Electricity-generating units that are operated to meet the constant or minimum load on the system. The cost of energy from such units is usually the lowest available to the system.
Basement	The deepest geological formation for potential geothermal development. Although different geological formations can be defined as basement depending on the local geology and on the goal of exploration, the term refers to any rock (carbonate, magmatic or metamorphic in origin) situated below sedimentary basin fill sequences.
Binary plant	A geothermal electricity generating plant employing a closed-loop heat exchange system in which the heat of the geothermal fluid (the
Boiling point	Temperature at which a single substance, such as water, changes from a liquid to a gas (steam) at a given pressure. Some liquids boil at a lower temperature than water, a principle utilized in binary power plants. Boiling point is also affected by pressure. The greater the pressure, the higher the boiling point. This principle is put to work in geothermal (flash) power plants when geothermal water is brought up by wells. Some of the hot water boils to steam when the pressure is released as it rises to the surface, or passes through surface equipment. This phenomenon also occurs naturally, resulting in such features as geysers.
Brine	A geothermal liquid containing appreciable amounts of sodium chloride or other salts.
Cap rocks	Rocks of low permeability that overlie a geothermal reservoir.
Carbonates	Rock types such as limestone and dolomite that consist mainly of carbonate (CO_3^{2-}) minerals (> 50% by weight of carbonate minerals); biochemistry sediments formed in mostly in marine environment.
Cascading heat	A process that uses a stream of geothermal hot water to perform successive tasks requiring lower and lower temperatures.
Casing	Casing is the major structural element of a well. Casing is needed to maintain borehole stability, prevent contamination of water sands, isolate water from producing formations and control well pressures during drilling, production and workover operation. (After petrowiki.org)
Condensation	Change of state from vapour to liquid.
Conduction	The direct redistribution of heat within a material, or between materials in contact with each other. Conduction occurs in any material (solid, liquid, or gas) or across any boundary exposed to a thermal gradient. The rate of heat transfer by conduction is proportional to the thermal gradient and the thermal conductivity of the material.

We can filter through terms and/or definitions by using the input field, similarly to knowledge resource module.



II.2.3. Benchmarking

The module on Benchmarking is the intercative representation of one of the tools developed for the sustainable management of transboundary geothermal resources (see also chapter I.1.). Its aim is assist in the evaluation of the strengths and weaknesses of current management and utilization practices involved in thermal water production. The tool enables the fast and graphical comparison of the 12 different indicators among themselves and selected entities. These are grouped into four general aspects: (1) Management, (2) Technology & energy, (3) Environment, and (4) Social. The tool has been tested and evaluated based on detailed information gathered for about 225 geothermal wells for 3 cross-border pilot areas: the Hungarian-Serbian-Romanian area, the Slovenian-Hungarian-Croatian-area, and the Bosnian & Herzegovinian-Serbian area. The resulting calculation for each indicator is grouped into one of five categories, pointing out how much effort is needed to improve the current exploitation practice.

In the upper part of the page we have countries grouped by the pilot area they belong to (3 cross-border pilot areas). We can check the Map viewer of DRGIP to look at the boundaries of each pilot area. By clicking the checkboxes next to the country labels, we can select which pilot area/country benchmarking results are to be shown.

☐ All / clear

BOSNIA & HERZEGOVINA - SERBIA PILOT AREA (N = 4 WATER SOURCES)

☐ Bosnia & Herzegovina (2 water sources)
☐ Serbia (2 water sources)

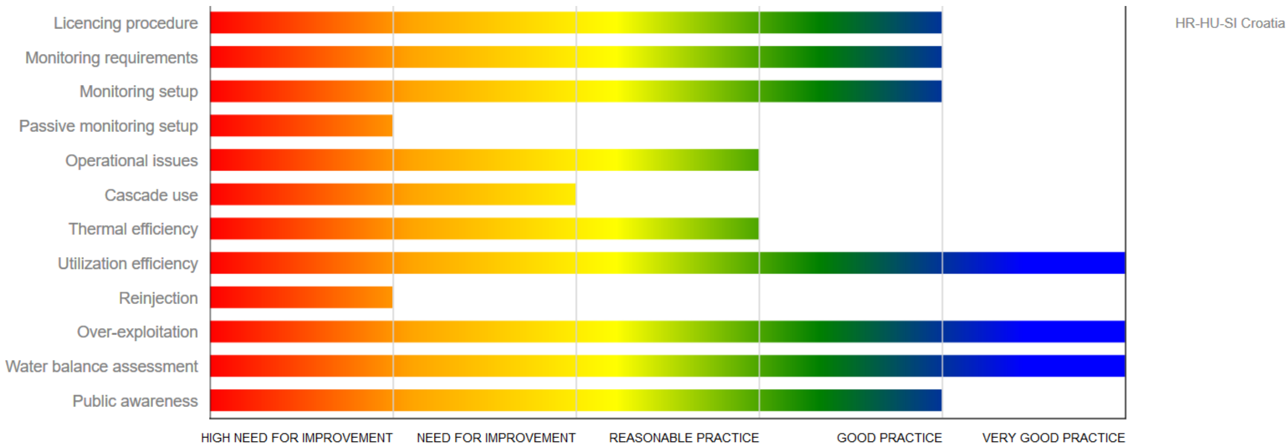
CROATIA - HUNGARY - SLOVENIA PILOT AREA (N = 54 WATER SOURCES)

☐ Croatia (9 water sources)
☐ Hungary (17 water sources)
☐ Slovenia (28 water sources)

HUNGARY - ROMANIA - SERBIA PILOT AREA (N ~ 167 WATER SOURCES)

☐ Hungary (~ 140 water sources)
☐ Romania (22 water sources)
☐ Serbia (5 water sources)

If we choose a specific country, the benchmarking tool provides us with the benchmarking results that are drawn as a bar chart.



If we select an additional country, it gives us legend for each country and a section of **indicators** by which we can compare countries. If we select/deselect these indicators, the bar charts redraw themselves accordingly.

When we click on a country inside the specific pilot area it also pops up detailed information about the specific pilot area below the bar chart.

In the bottom of the page we can see the descriptions of the indicators by which the benchmarking has been done. When we click the **more info** link, it gets us to a pdf file with explanations to the formulas of indicator calculation and detailed explanation of the specific parameter.

LICENCING PROCEDURE: HOW SYSTEMATIC IS THE PROCEDURE OF GRANTING PERMITS FOR EXPLOITATION?

This indicator describes the transparency and simplicity of a national or regional legislation. It takes into account, for example, whether licencing is required to use thermal water or not, if at least 80% of active (producing) objects have a licence granted, or if only one type of concession fee has to be paid annually to produce thermal water by a licence, etc. (more info...)

OPERATIONAL ISSUES: ARE TECHNOLOGICAL CHALLENGES SUCCESSFULLY ADDRESSED AND WELL DOCUMENTED?

This indicator shows whether appropriate technical requirements are met at wells' installations, if problems during operation are successfully mitigated (e.g. scaling, free gases....), how efficiently is the water usage implemented, and it also describes the overall status of archives of documentation at a site. (more info...)

REINJECTION: CAN WASTE THERMAL WATER BE REINJECTED AND IS IT AND WHERE?

This indicator is calculated based on the ratio of the volume of reinjected and produced thermal water which is used only for geothermal energy (heat) production as water used in swimming pools should not be reinjected. It considers whether the reinjection is implemented into the same aquifer from where the water is abstracted or not. (more info...)

MONITORING REQUIREMENTS: WHAT SHOULD PERMIT HOLDERS MONITOR AND REPORT TO AUTHORITIES?

This indicator describes what the licence owners are obliged to monitor and report to an authority in a region or a country. It checks if hydraulic and chemical properties of the aquifer and water are regularly observed, e.g.: groundwater levels, temperature, produced quantity, chemical composition of thermal water, hydraulic tests etc. It also checks if interpretation of these results is performed and reported to an authority or not. (more info...)

CASCADE USE: IS THERMAL WATER USED FOR MULTIPLE PURPOSES AND SEQUENTIALLY?

This indicator is related to a site's (it may have multiple wells used) practice in energy abstraction, denoting if thermal water is used in more than one sequential application. For example, first for hotel space heating, then for sanitary water heating, later for pool heating and at the last stage for greenhouse heating etc. (more info...)

OVER-EXPLOITATION: ARE THERE ANY CHANGES IN QUANTITY AND QUALITY STATE OF GEOTHERMAL AQUIFERS NOTICED?

This indicator highlights whether obvious changes in piezometric groundwater levels, water temperatures, groundwater availability and water quality or groundwater dependent ecosystems have been observed. In the DARLINGe project area, the subsidence is not relevant issue and was therefore not included in this indicator. (more info...)

MONITORING SETUP: WHAT DO PERMIT HOLDERS MONITOR AND REPORT IN REALITY?

This indicator is linked to monitoring requirements and it identifies which parameters are observed at an individual geothermal well or a spring. These can be quite simple (eg. only water level) or varying up to complex monitoring with numerous parameters recorded, both, at production and monitoring wells. Inactive production wells with licences are also included in this calculation. (more info...)

THERMAL EFFICIENCY: HOW MUCH AVAILABLE ENERGY DO USERS EXPLOIT IN REALITY?

This indicator is determined as a ratio between the used and available heat energy on an annual scale, where the mean annual air temperature of 12 °C is used as a treshold value for 100%. It means that all temperatures above the latter are available to the user as available geothermal energy (heat). (more info...)

STATUS OF WATER BALANCE ASSESSMENT: HOW RELIABLE IS THE INFORMATION ON THE EXISTING WATER BALANCE ASSESSMENT?

This indicator is a measure of the availability and reliability of information used to evaluate the quantity and quality status of a geothermal aquifer. (more info...)

PASSIVE MONITORING SETUP: WHAT KIND OF INDEPENDENT MONITORING SYSTEMS EXIST?

This is a region or country specific indicator highlighting whether there is/are geothermal observation wells monitored and their state interpreted by a national or regional environmental agency or similar organization. (more info...)

UTILIZATION EFFICIENCY: HOW MUCH LICENCED WATER QUANTITY DO USERS EXPLOIT IN REALITY?

This indicator is a ratio between the actual annual water production and the maximum permitted annual production rate. If this data is not available, the theoretical capacity of the well can be applied as the latter. (more info...)

PUBLIC AWARENESS: WHICH AND HOW MUCH PUBLIC INFORMATION IS PROVIDED BY THE USERS THEMSELVES?

This indicator highlights how much and which type of information is publicly available at websites and easy-accessible promotional publications for an individual geothermal resource and practice of its use. Scientific articles and expert reports are not relevant for general public, and therefore, are neglected in this indicator. (more info...)

II.2.4. Decision tree

The module on the Decision tree is the second element of the tool-box (see also chapter I.2.). Its main aim is to inform readers about what types of decision gates might occur during the development of a geothermal project. The tool focuses on one idealised project involving the planning and drilling of a doublet (i.e. one production well and one injection well). The wells are connected via pipelines and the fluid is circulated through heat exchangers for heat and/or electricity production. The tool consists of a series of questions to be considered during the project development: namely, from the initial idea until the geothermal system is set up and running. There is an explanatory text for almost all the questions and this helps to provide a better understanding of the meaning of the relevant question.

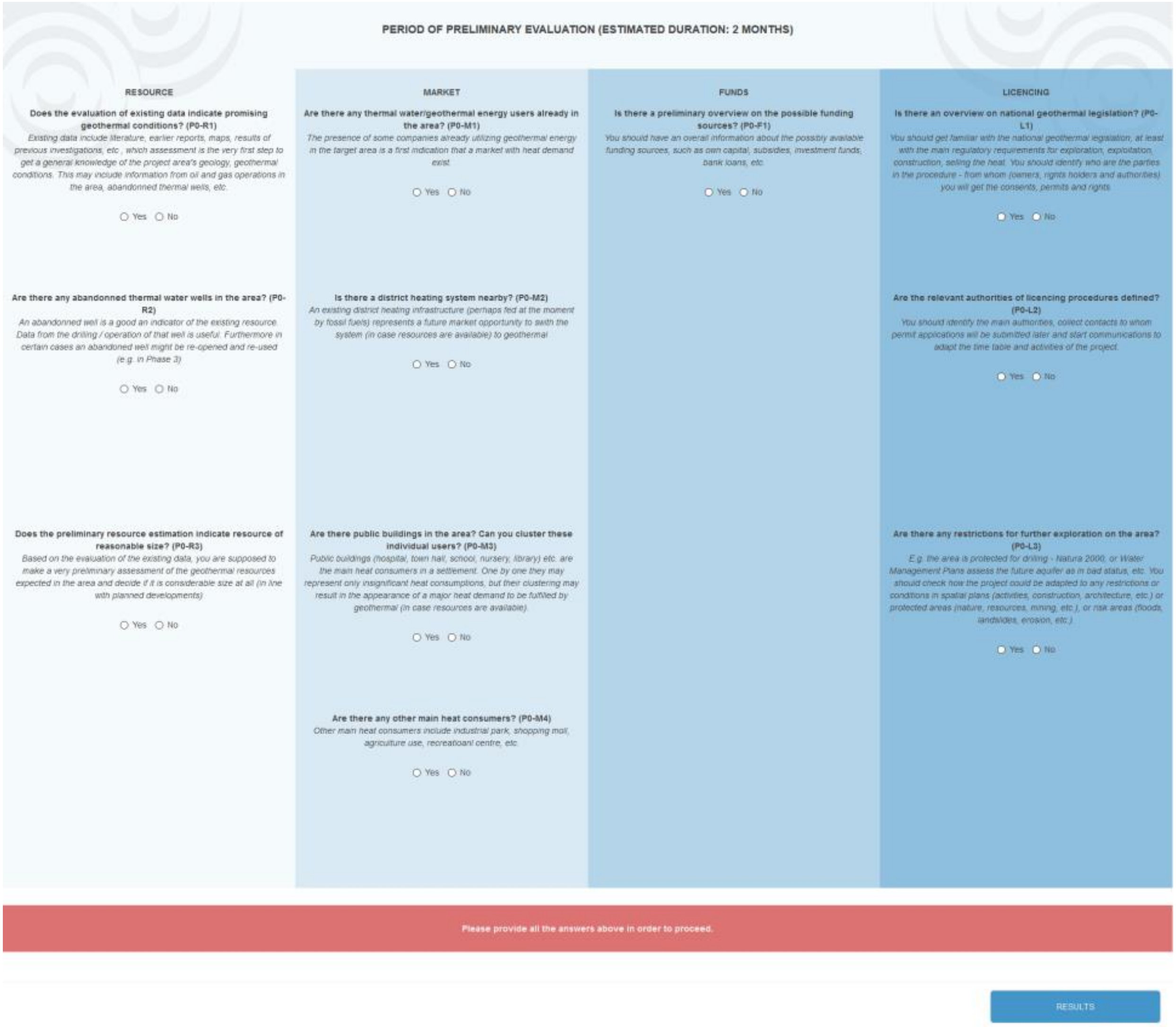
Emphasis is placed on related decisions referring to the four most important fields:

1. Resources: including technological aspects of the subsurface and the surface parts of the system,
2. Markets: referring to the aspects of selling the product of the system, in this case the heat,
3. Licensing: procurement of licences and applications for permission, to be submitted to the relevant authorities,
4. Funding: aspects of project financing.

The questions of each field are grouped by corresponding phases of project development:

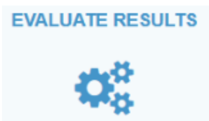
- Period of preliminary evaluation
- Period of preparatory work
- Period of construction of wells

- Period of construction of surface system

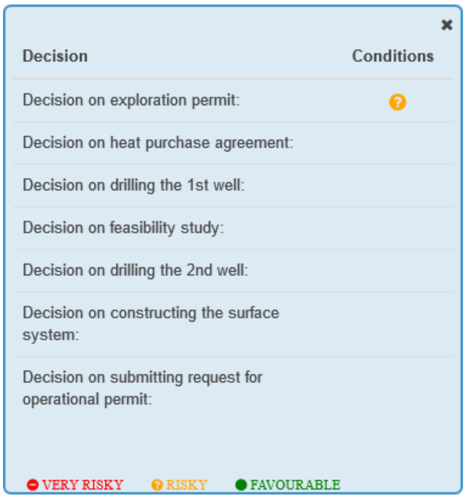


The answers to be provided are simply of the “yes” or “no” type.

We must answer all questions in order to be able to proceed. Until we answer to all the questions, we see the alert: “Please provide all the answers above in order to proceed.” When you answer to all questions in the section, the sign disappears and changes to:



After clicking on the icon, our answers are evaluated and the **Results window** pops up in the downright corner of the screen:



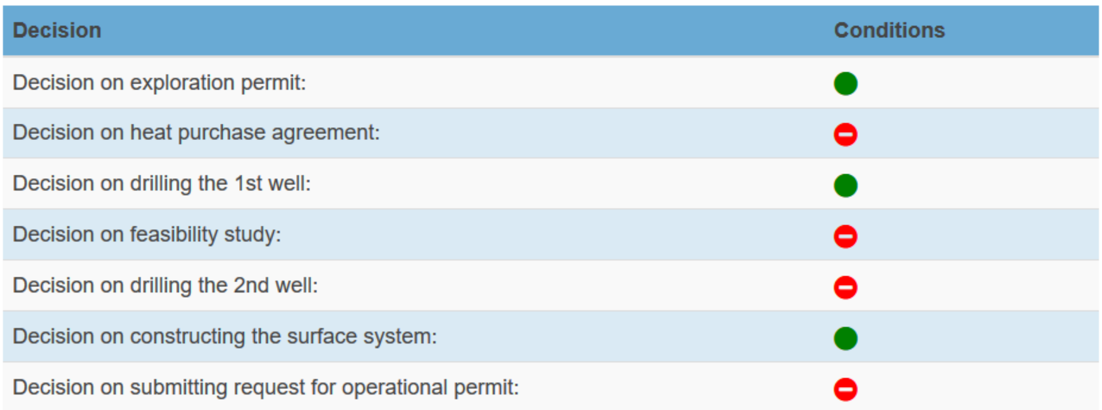
Here it shows us the condition of the specific decision we are going to make. It evaluates according to three levels: very risky, risky and favourable.

After the evaluation we also get a pair of new icons:

This gives us two options:

- Back – it slides us back to the questions section and in case we change an answer to some of the questions, we **must re-evaluate** results again by clicking on evaluate icon, to have the updated condition.
- Continue – it slides us down to the next series of questions. That corresponds e.g. to "You've decided to procure the exploration permit," which now also shows in the results window.

When we've answered all the questions, we get to the final table that summarizes conditions on all decisions.



II.2.5. Risk mitigation

The module on Risk Mitigation is a web application belonging to the third part of the tool-box (see also chapter I.3.). Here, assistance is available for reaching a definition of those geological risk-mitigation measures associated with a particular project. The primary aim is to avoid the most likely forms of damage which might occur. The tool centres on an idealised project which consists of the planning and drilling of a doublet (one production well and one injection well, and the wells are connected via pipelines and the fluid is circulated through heat exchangers for heat and/or electricity production. The risk mitigation measures can be defined according to the different project phases at which the measure(s) should be planned or performed.

As a first step, the tool is used to collect information about the project with the aid of 4 questionnaires concerning, respectively: (1) general information about the project, (2) available drilling, temperature and surface geophysical data, (3) reservoir properties, and (4) basic fluid properties. We have to answer to all the questions in order to proceed. We also have to tick the “I confirm the answers above” checkbox. This enables the button “Next” and after clicking it gets us to the next topic of questions.

GENERAL INFORMATION ABOUT THE PLANNED GEOTHERMAL PROJECT

What is the aim of the project?

(Select an answer)

What is the planned annual production amount (m^3)?

(Select an answer)

What is the planned depth interval for production (m)?

(Select an answer)

What is the expected outflow temperature?

(Select an answer)

What is the expected distance between the production and injection well (km)?

(Select an answer)

☐ I confirm the answers above

Next

After answering all the questions, the given project phase should be selected. Based on all these pieces of information, the tool lists the suggested risk- mitigation measures according to the level of recommendation; it also defines what types of damage could be avoided by the given measure.

PERFORM A MITIGATION MEASURE:

Level of recommendation	Measure	If the measure is not applied, the following damage might occur with higher probability
Highly recommended	Designing the production section of the well with 8 1/2" diameter.	The amount of energy is low, because of low yield.
Recommended	Accurate hydrogeological modelling including data collection and interpretation.	Pending of operation, because significant induced pressure change is observed at a waterwork nearby.

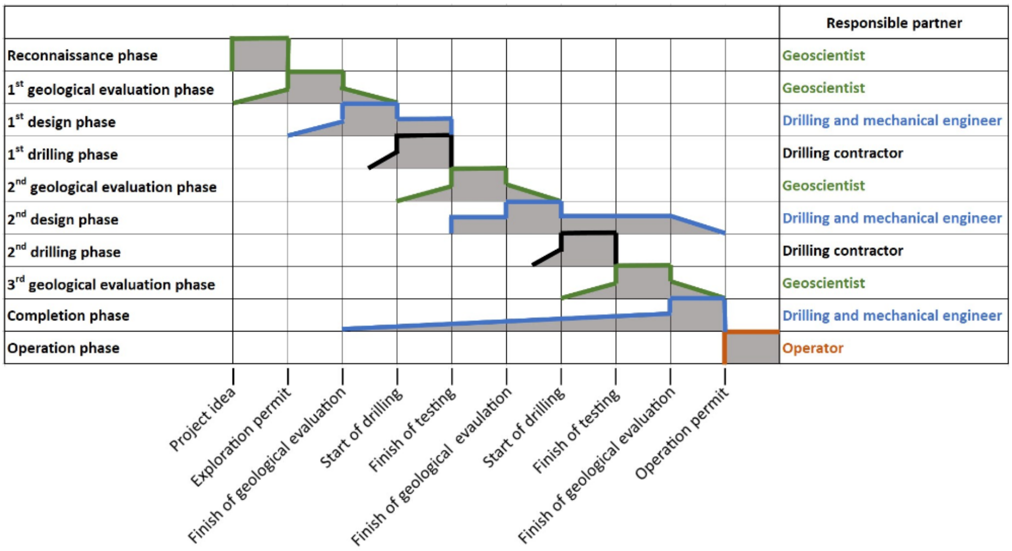
PREPARE A MITIGATION MEASURE:

Level of recommendation	Measure	By the use of the measure the next damage(s) could be avoided
Highly recommended	Use of external casing packer between the loose formation and productive layer.	1) The amount of energy is low, because of low yield. 2) Cost increase in operation because of pressure increase at reinjection.
Highly recommended	Professional service provider and supervised cementing activites for appropriate isolation.	1) The amount of energy is low, because of low temperature. 2) Pending of operation, because significant induced pressure change is observed at a waterwork nearby.
Recommended	Use of cement with increased heat insulation properties for cementing of casings of production well.	The amount of energy is low, because of low temperature.
Worth to consider	Try to drill long enough production section for securing the expected yield.	The amount of energy is low, because of low yield.
Worth to consider	Use of clay minerals-free drilling mud in the production section, which is properly treated in the mud system by removal of cutting particles.	The amount of energy is low, because of low yield.
Worth to consider	Performing adequate chemical sampling and analysis of produced fluid.	Cost increase in operation because of increased scaling activity of produced fluid.
Worth to consider	Performing adequate chemical sampling and analysis of produced fluid.	Cost increase in operation because of increased corrosion activity of produced fluid.

A separate section also explains the specific project phases and there duration.

PROJECT PHASES:

Show / Hide report

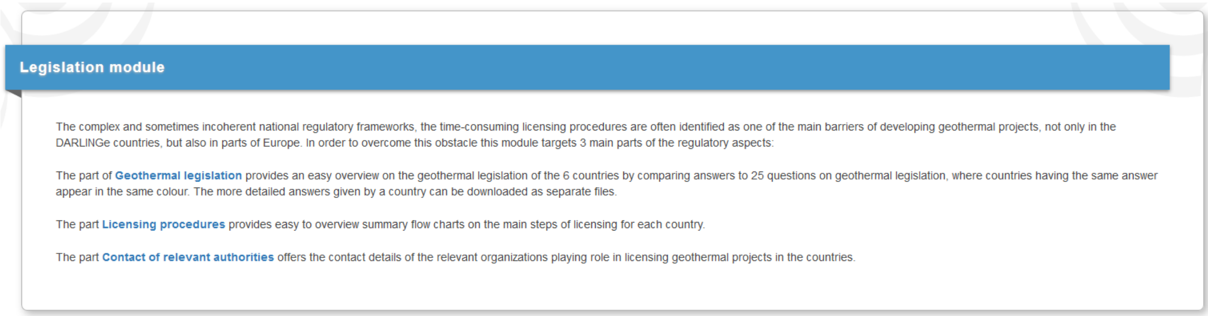


EXPLANATION:

Reconnaissance phase - Reconnaissance phase starts from the project idea and lasts until the decision to obtain an exploration permit or not
1st geological evaluation phase - This phase theoretically starts in the reconnaissance phase and last until the drilling, but the main activity is made between the approved exploration permit and the start of the design phase.
1st design phase - The main activity o this phase is between the geological evaluation and drilling
1st drilling phase - The drilling phase starts from the mobilization of the rig and lasts until the finish of operation of end of drilling (OED), which period (OED) covers the testing activities in general.
2nd geological evaluation phase - This phase theoretically starts together with the 1st drilling phase and last until the 2nd drilling, but the main activity is made between the finish of testing and the start of the 2nd design phase.
2nd design phase - The main activity o this phase is between the geological evaluation and drilling
2nd drilling phase - The drilling phase starts from the mobilization of the rig and lasts until the finish of operation of end of drilling (OED), which period (OED) covers the testing activities in general.
3rd geological evaluation phase - The 3rd geological evaluation is based on the data collected during the completion of second drilling.
Completion phase - The completion phase covers the activities of surface works excluding drilling activities
Operation phase - The operation phase is when the construction is finished, and the plant is working continuously according to the approved operational permit.

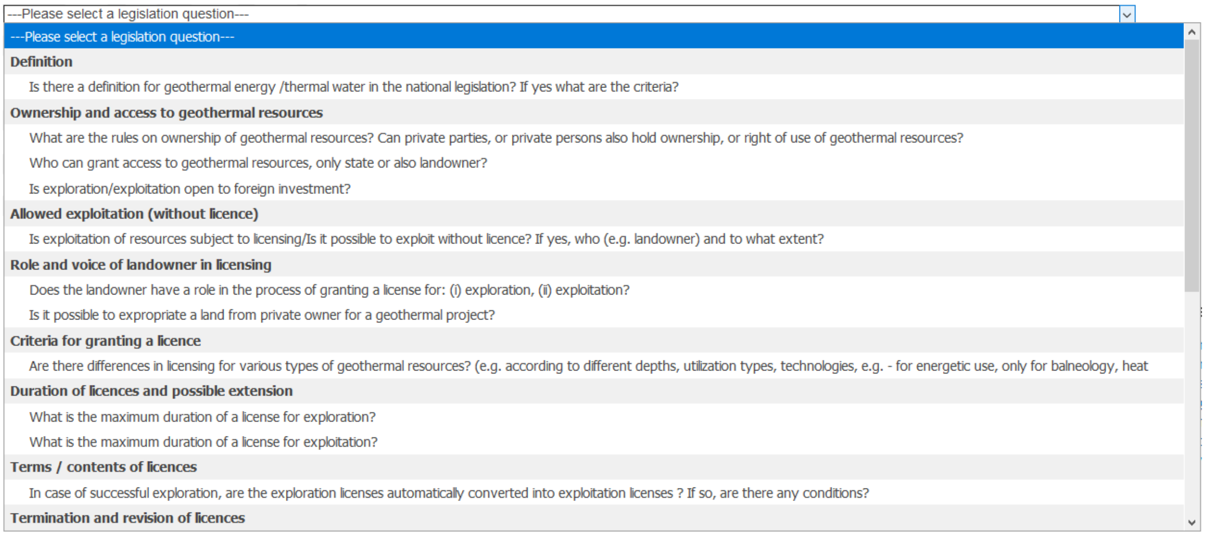
II.2.6. Legislation

The module on Legislation targets the most significant non-technical barriers facing geothermal developments – i.e. the complex and sometimes incoherent – national regulatory frameworks and the time-consuming licensing procedures. The module has 3 parts:



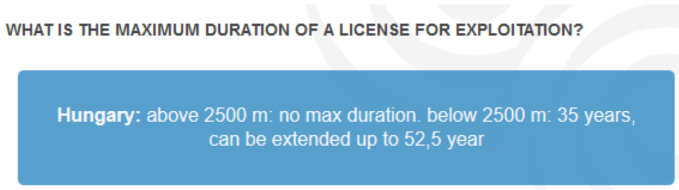
Part 1 refers to **"Geothermal legislation"** and provides an easy overview about the respective geothermal legislatory procedures of the 6 DARLINGe countries by comparing the answers of each country to 25 questions on geothermal legislation.

At first we have to select a specific legislation question from a set of questions assessing various aspects of the geothermal regulatory framework in the DARLINGe countries.



When we select one question, the responsive image with DARLINGe countries pops-up, coloured in accordance to similarity of the legislation answers between countries. When there are the same legislation directives, the countries will have the same colours.

When we click over a specific country, the question and summed up answer to that question for that country pops-up.



We can also download the pdf file for a specific country with detailed answers to all the legislation questions, if we choose from this list:

MORE DETAILED ANSWERS BY COUNTRIES IN THE LIST BELOW:

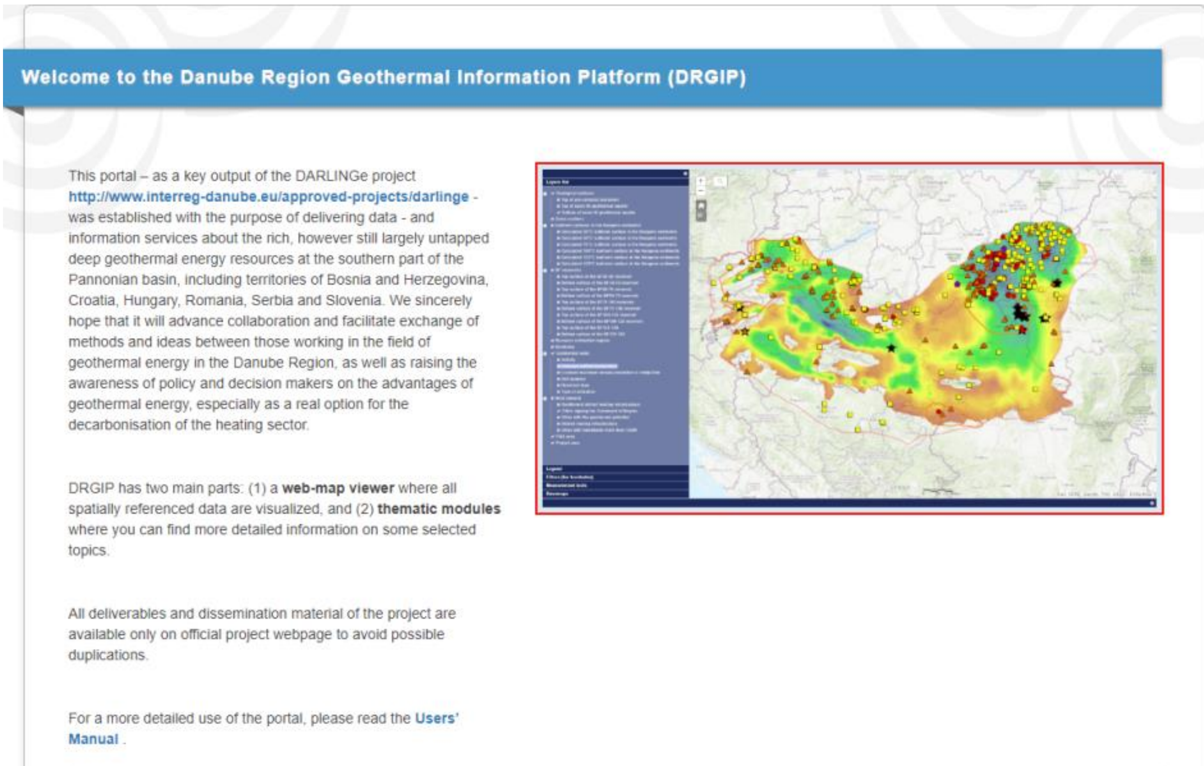
- Bosnia and Herzegovina - Federation of Bosnia and Herzegovina
- Bosnia and Herzegovina - Republika Srpska
- Croatia
- Hungary
- Romania
- Serbia
- Slovenia

Part 2 concerns **"Licensing procedures".** This part provides an easy guide to the respective flow charts which summarize the main steps of licensing for each country. If we click on the image, the full resolution image fills up the screen that can be closed by cross tick at the top right corner of the screen

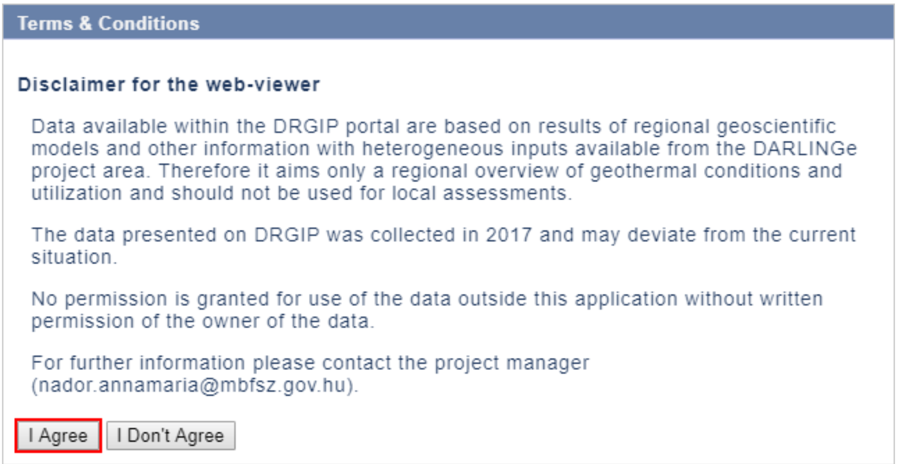
Part 3 deals focuses on **"Contact with relevant authorities"** and offers the contact details of the relevant organizations which play a role in licensing geothermal projects in the project countries. We can filter by each country by selecting buttons with the country name at the top.

II.3. MAP VIEWER

To access the **Map viewer**, click on its image on the front page *(highlighted with red in the screenshot)*.



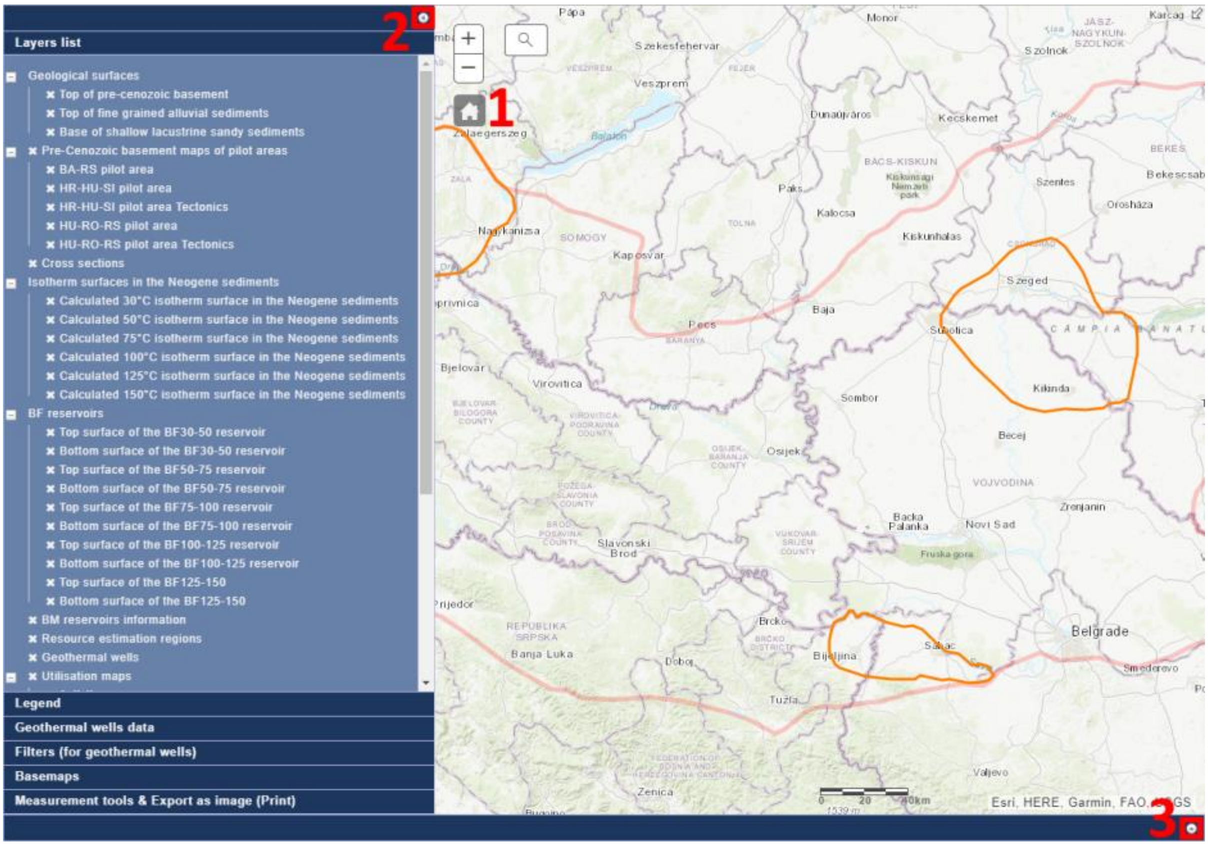
The Terms & Conditions window pops up. If you agree with them, click on the **I Agree** button *(highlighted with red in the screenshot)* to proceed to the Map viewer.



In general the viewer can be divided into three sections, all of which will be explained further down.

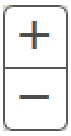
- **Map** itself is *marked with a red 1*
- **Sidebar** with **layers, geothermal objects data, filters, measurement tools, basemaps, measurement tools** is *marked with a red 2*
- **Tables menu**, which can be expanded by clicking the button *marked with a red 3,* shows us different attribute tables

The arrow buttons *highlighted with red* allow you to **collapse** or **expand** either the entire layer or table menu.



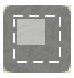
II.3.1. Map

Basic map viewer functionality:

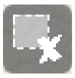


Zoom in (+) or **Zoom out** (-) *you can zoom in or zoom out by clicking on these buttons*.

Default extent: *reverts the map back to its default extent.*

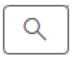


Select multiple geothermal objects (only available if you have the layer Geothermal objects enabled) *This allows you to select multiple geothermal objects on the map, by dragging a selection box over their points.*

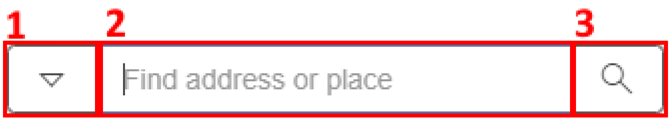


Deselect geothermal objects*: this deselects previously selected geothermal objects*

Button in top right corner: *opens up a **Map Overview** in the upper right corner.*



Search bar: *by clicking on this button different search options expand:*



The button *marked with a red 1*: You can specify by objects in which layer you can search in (geothermal objects and pilot areas are enabled). The button *marked with a red 2*: The text box, where you can input your **search terms**. The button *marked with a red 3*: By clicking on it, you execute the **search**.

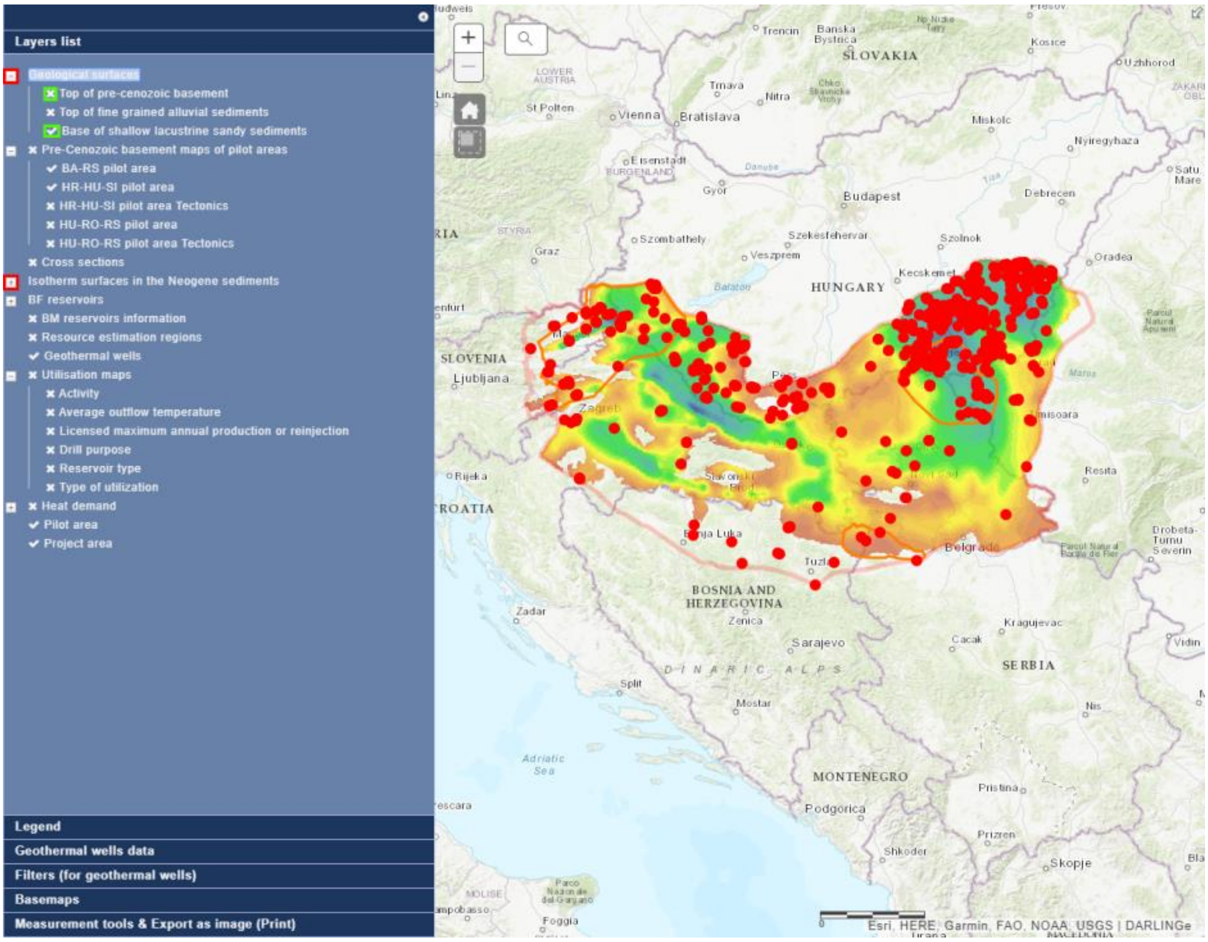
II.3.2 Sidebar menu

To open a specific submenu with specific functionality, click on its name.

II.3.2.1. Layers list

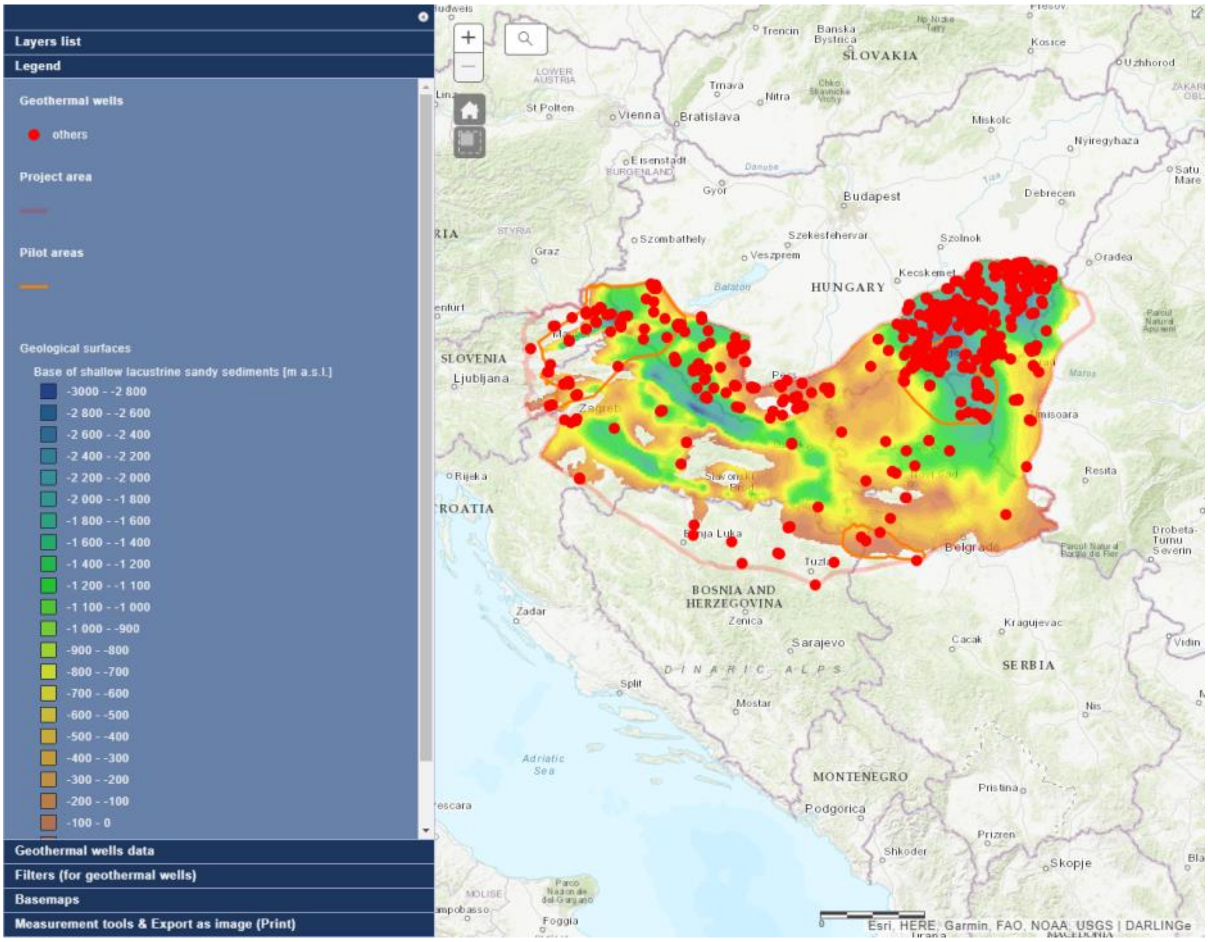
The buttons *highlighted with red* allow you to **collapse** or **expand** different groups of layer types.

The buttons *highlighted with green* allow you to activate specific layers. Certain sub-layers need their main layer activated first.



Only one raster layer can be selected at the time, if you select the second raster layer, previously selected ones get deselected.

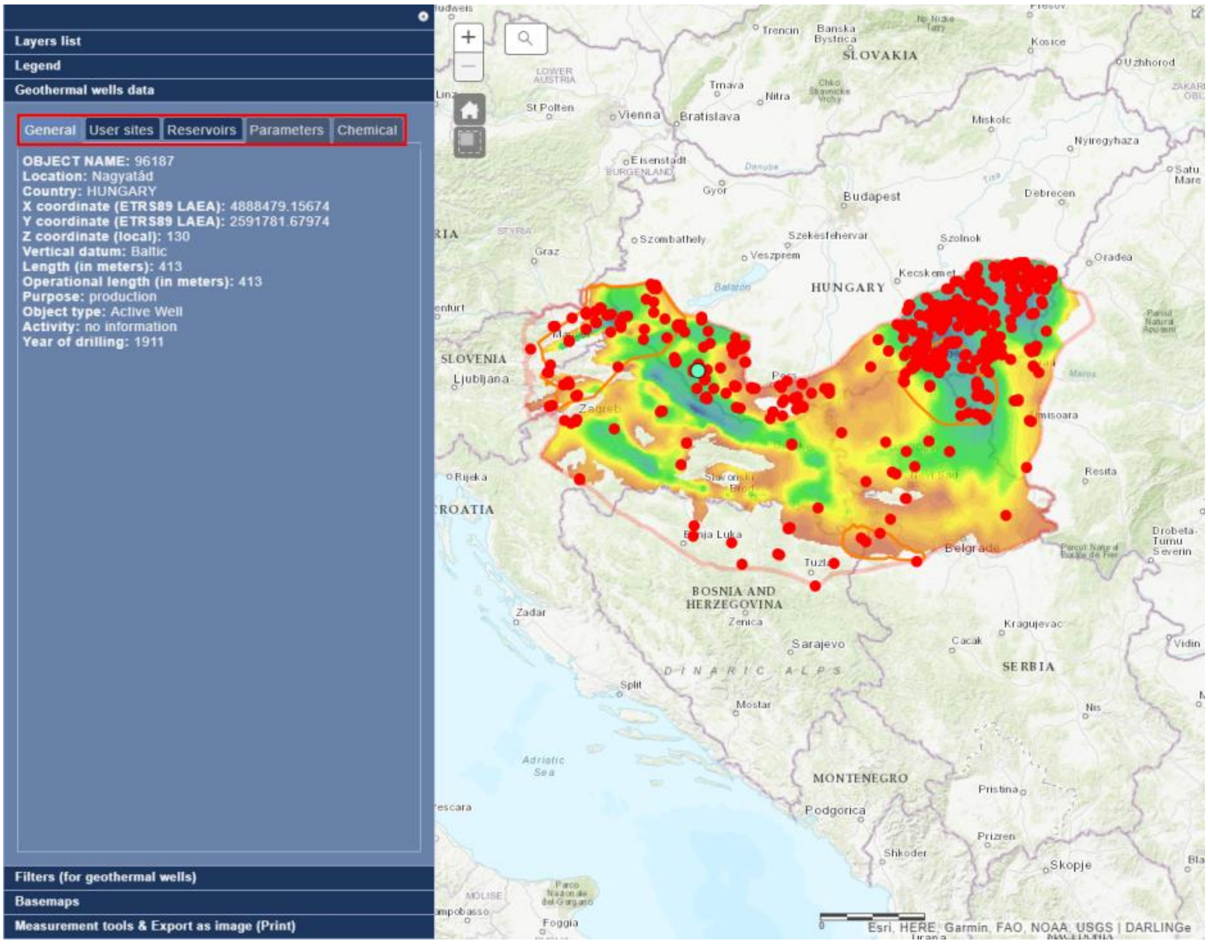
II.3.2.2. Legend



Legend shows different colored categories of data based on the currently selected layers.

II.3.2.3. Geothermal objects

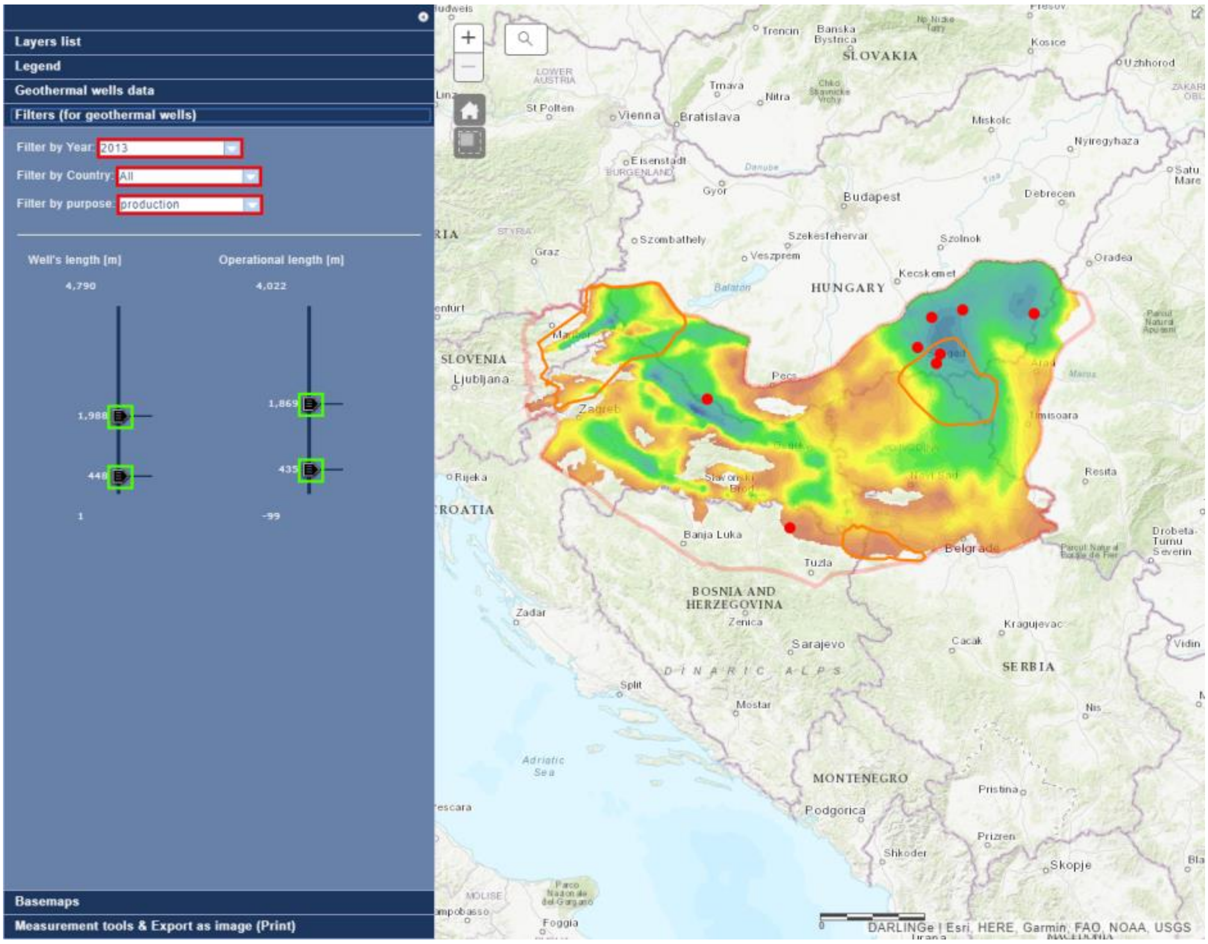
The buttons *highlighted with red* allow you to switch between different types of **information** on the specific geothermal object you've previously selected. A selected geothermal object is shown as a blue circle on the map.



II.3.2.4. Filters (for geothermal objects)

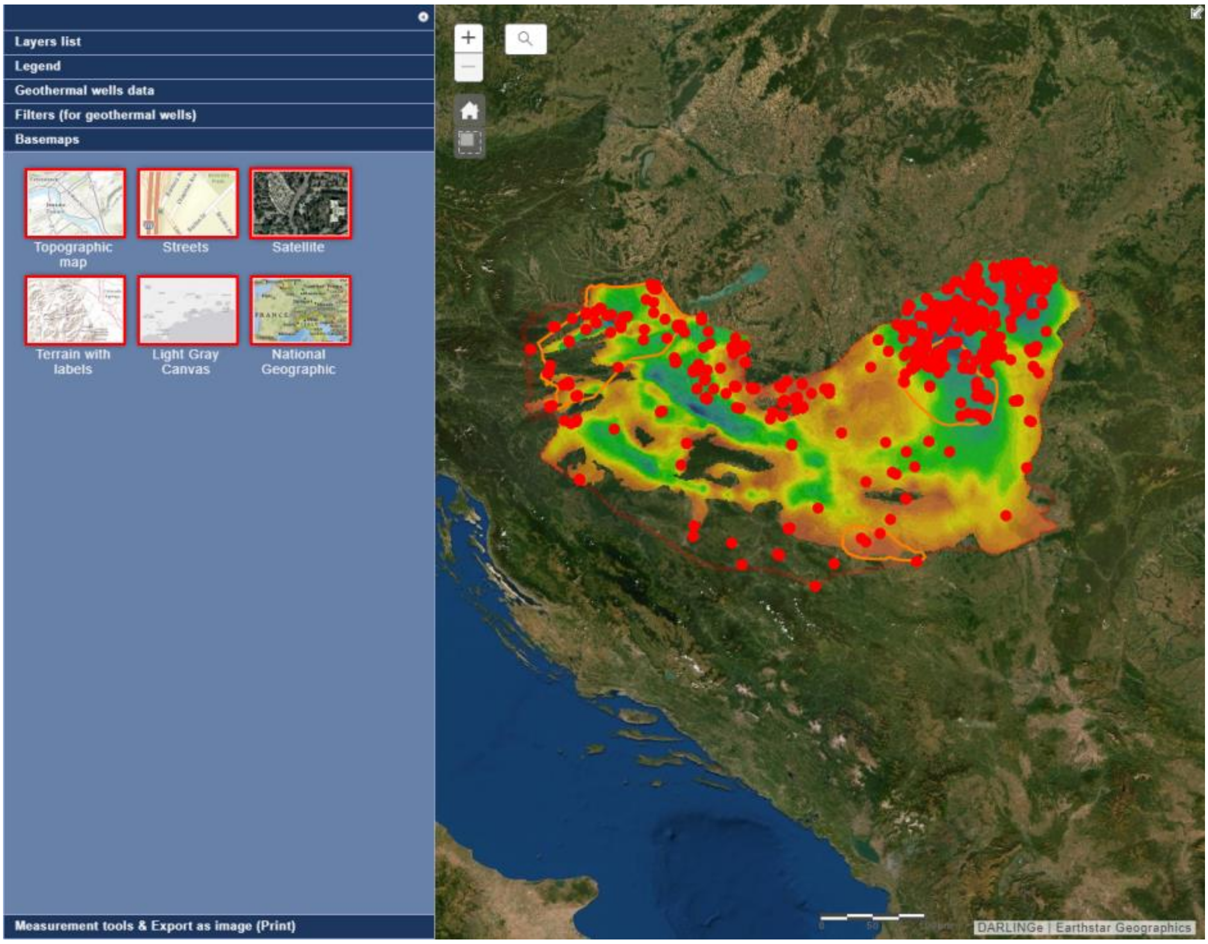
The menus *highlighted with red* allow you **to filter** the displayed geothermal objects by **year**, **country** and **purpose**. You can **combine** these three filters.

The sliders *highlighted with green* allow you **to filter** the displayed geothermal objects depending on their **length** and operational length.



II.3.2.5. Basemaps

The thumbnail images *highlighted with red* allows you to **change the basemap** of the map.

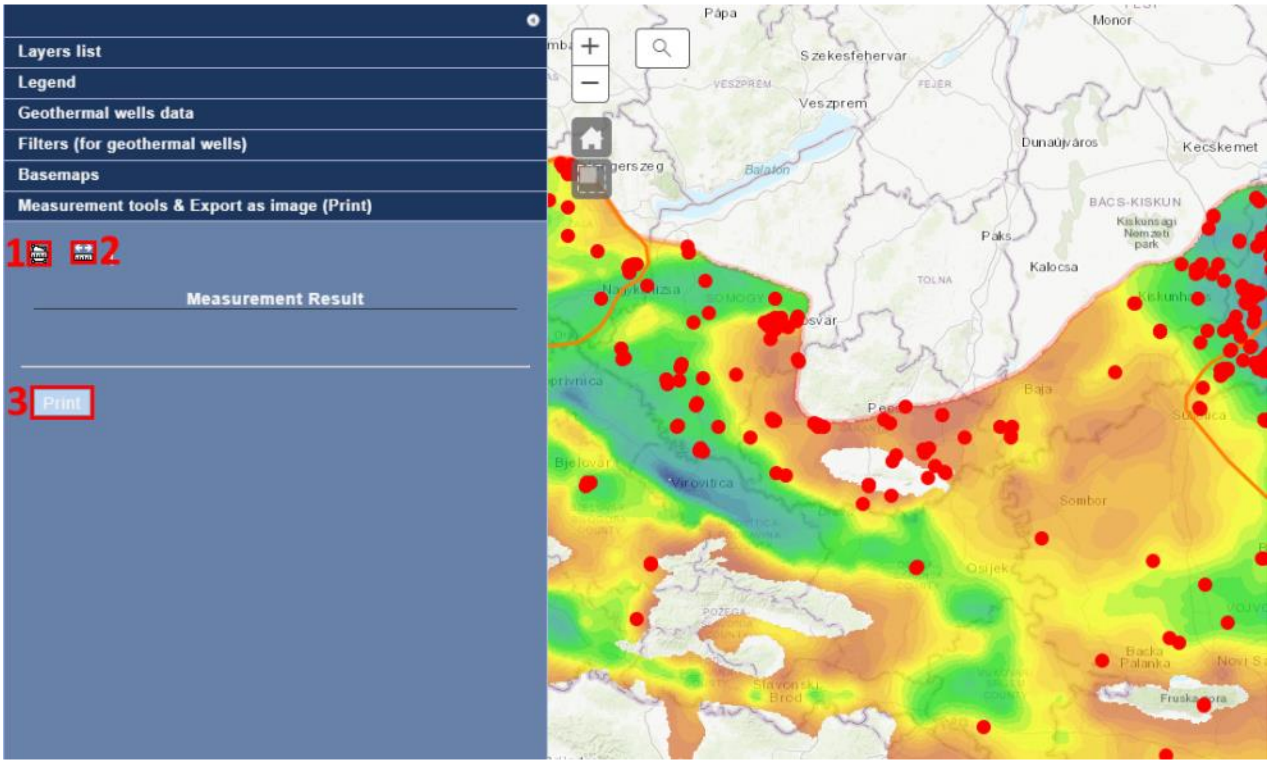


II.3.2. 6. Measurement tools & Export as image (Print) tab:

Button *marked with a red 1*: Allows you to **measure** an **area** on the map.

Button *marked with a red 2*: Allows you to **measure** a **line** on the map.

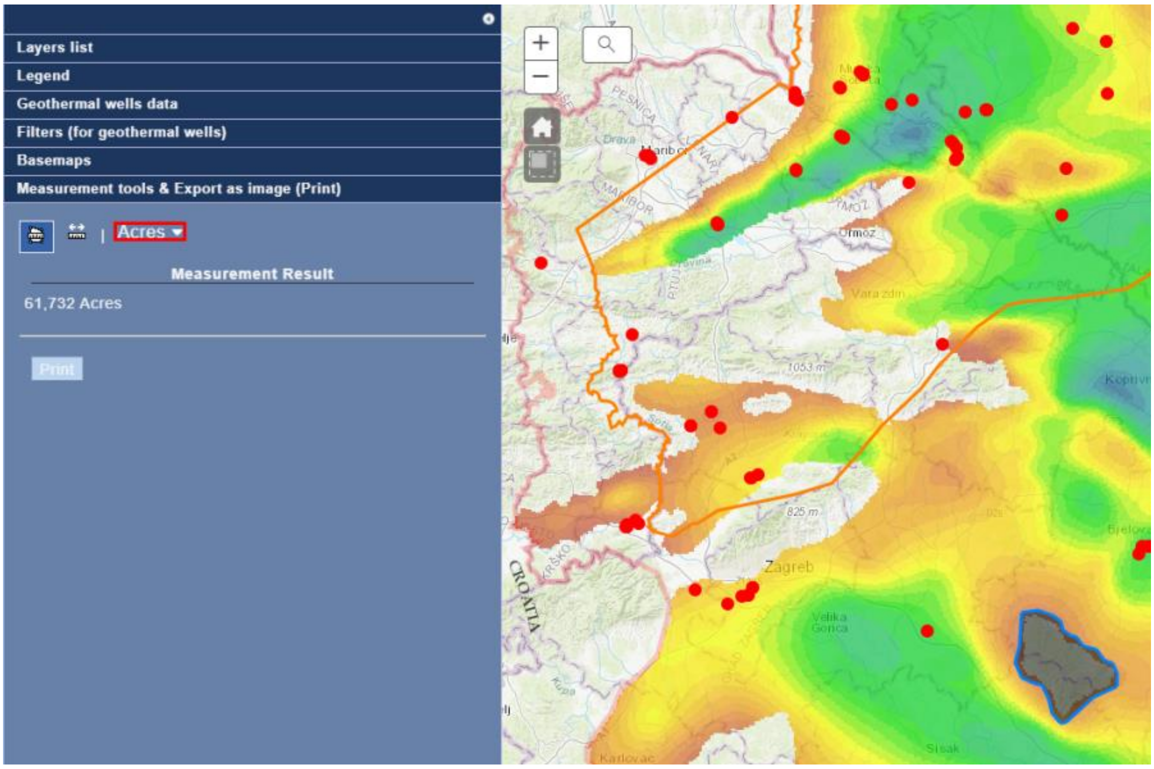
Button *marked with a red 3*: Converts your current map to a PDF and opens it in a separate tab. You can then **save** or **print** the file.



Measuring an area

The button *highlighted in red* changes the unit of measurement.

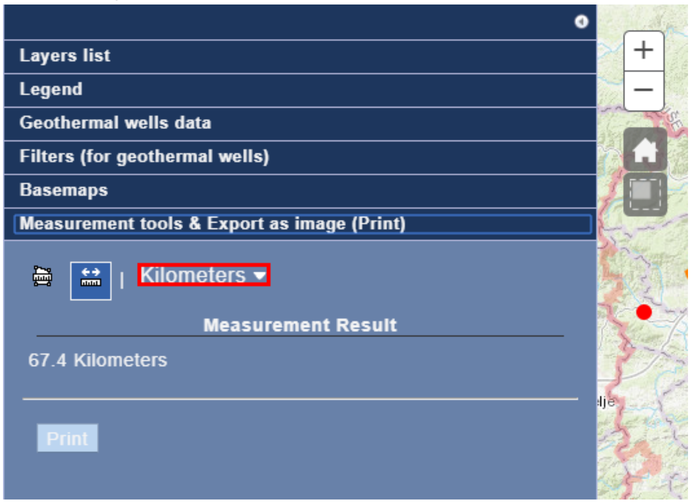
To mark your area, choose at least three points on the map.



Measuring distance

The button *highlighted in red* changes the unit of measurement.

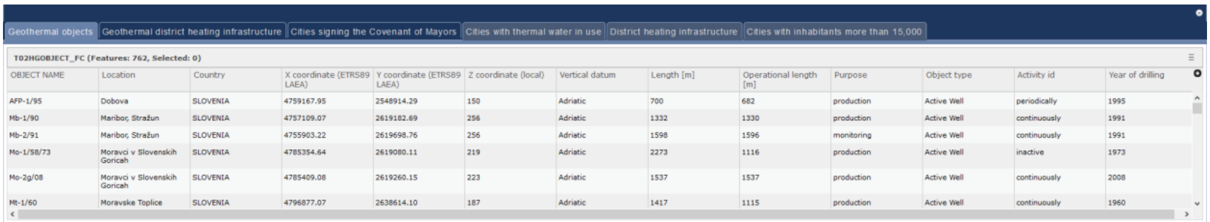
To mark your line, choose at least two points on the map.



The buttons *marked with a red 1*: Switch between different types of **information**.

II.3.3. Tables menu

At the top you have different tabs that belong to specific layers, and when you click on the specific tab, attribute table of specific layer with its data shows up.

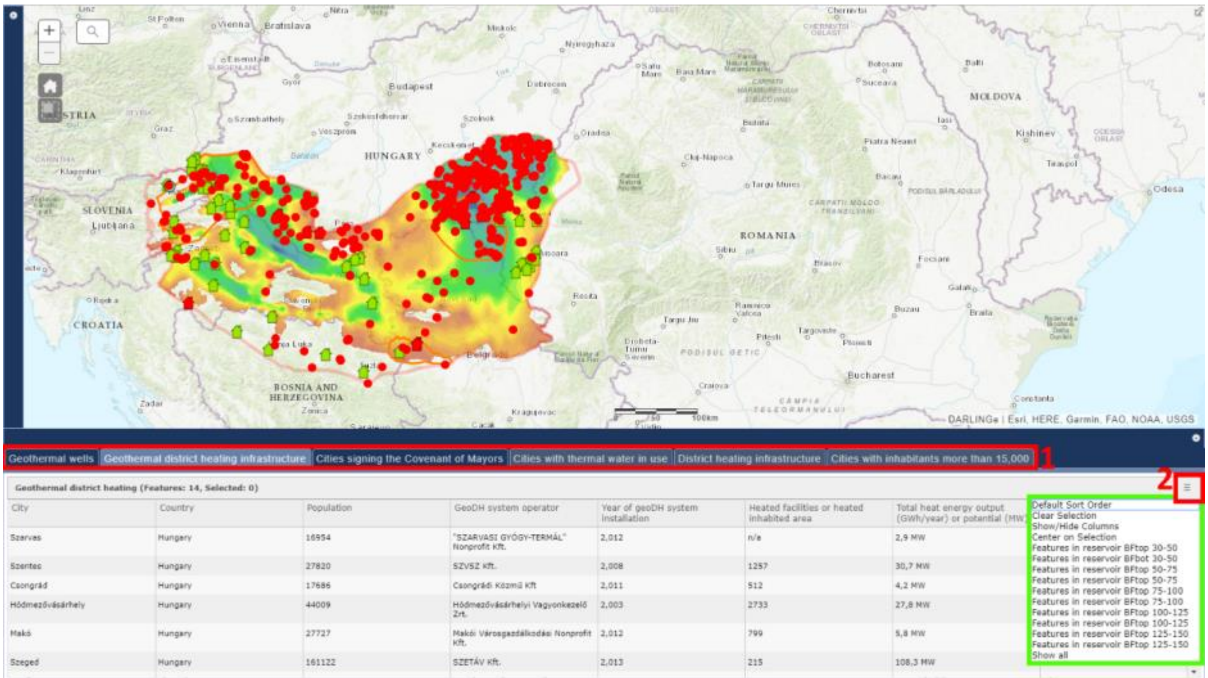


OBJECT NAME	Location	Country	X coordinate (ETRS89 LAEA)	Y coordinate (ETRS89 LAEA)	Z coordinate (local)	Vertical datum	Length [m]	Operational length [m]	Purpose	Object type	Activity id	Year of drilling
AFP-1/95	Dobova	SLOVENIA	4759167.95	2548914.29	150	Adriatic	700	682	production	Active Well	periodically	1995
Mb-1/90	Maribor, Stražun	SLOVENIA	4757109.07	2619182.69	256	Adriatic	1332	1330	production	Active Well	continuously	1991
Mb-2/91	Maribor, Stražun	SLOVENIA	4755903.22	2619698.76	256	Adriatic	1598	1596	monitoring	Active Well	continuously	1991
Mo-1/58/73	Moravci v Slovenskih Goricah	SLOVENIA	4785354.64	2619080.11	219	Adriatic	2273	1116	production	Active Well	inactive	1973
Mo-2g/08	Moravci v Slovenskih Goricah	SLOVENIA	4785409.08	2619260.15	223	Adriatic	1537	1537	production	Active Well	continuously	2008
Mt-1/60	Moravske Toplice	SLOVENIA	4796877.07	2638614.10	187	Adriatic	1417	1115	production	Active Well	continuously	1960

There are attribute tables for:

- Geothermal objects
- Geothermal district heating infrastructure
- Cities signing the Covenant of Mayors
- Cities with thermal water in use
- District heating infrastructure
- Cities with inhabitants more than 15000 layer

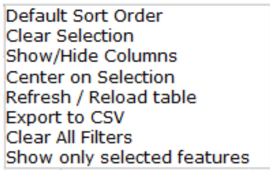
The button *marked with a red 2*: Opens the **available features** (*highlighted with green)* for specific layer's attribute table.



City	Country	Population	GeoDH system operator	Year of geoDH system installation	Heated facilities or heated inhabited area	Total heat energy output (GWh/year) or potential (MW
Szarvas	Hungary	16954	"SZARVASI GYÓGY-TERMÁL" Nonprofit Kft.	2,012	n/a	2,9 MW
Szentes	Hungary	27820	SZVSZ Kft.	2,008	1257	30,7 MW
Csongrád	Hungary	17686	Csongrádi Közmű Kft	2,011	512	4,2 MW
Hódmezővásárhely	Hungary	44009	Hódmezővásárhelyi Vagyonkezelő Zrt.	2,003	2733	27,8 MW
Makó	Hungary	27727	Makói Városgazdálkodási Nonprofit Kft.	2,012	799	5,8 MW
Szeged	Hungary	161122	SZETÁV Kft.	2,013	215	108,3 MW

Geothermal objects attribute table's options

Most of the options are general and allow you to work with the data in the attribute table.

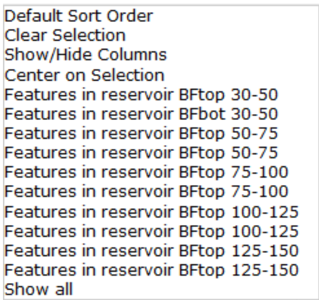


Specific for geothermal objects are:

- Export to CSV, which exports all the attribute table data to the csv file to download
- Show only selected features, which filters and shows in the attribute table just the geothermal objects you've previously selected with the Select multiple geothermal objects tool
- Refresh / Reload table, which does what the name says, used in case data doesn't get filled in the attribute table

Heat demand objects attribute table's options

Most of the options are general to attribute tables and allow you to work with the data in the attribute table.



Specific for Heat demand objects are:

- Features in reservoir BFtop 30-50,
- Features in reservoir BFbot 30-50,
- ...
- Features in reservoir BFtop 125-150

This option should be used in combination with specific BF reservoirs layer. It filters Heat demand objects so that it shows only the ones that overlay (fall onto) with specific BF reservoir layer.