REFLECT DELIVERABLE D3.2

Data compilation by REFLECT partners

Summary:
This deliverable summarises the methodology and results of the data collection for the European Fluid Atlas by the REFLECT project partners.

Authors:
Éva Hartai, Honorary Professor, University of Miskolc
Tamás Madarász, Associate Professor, University of Miskolc
Károly Kovács, Assistant Researcher, University of Miskolc
Anna Seres, Researcher, University of Miskolc
Zsombor Fekete, Assistant Researcher, University of Miskolc

Title:	Data compilation by REFLECT partners
Lead beneficiary:	University of Miskolc
Other beneficiaries:	GFZ, IzTech, BRGM, ISOR, UKRI, TNO, HI
Due date:	30 November 2021
Nature:	Public
Diffusion:	All Partners
Status:	Draft
Document code:	REFLECT_D3.2
DOI:	10.48440/gfz.4.8.2021.004
License information:	CC-BY-4.0
Recommended citation:	Hartai, É., Madarász, T., Kovács, K., Seres, A., Fekete, Zs., The H2020 REFLECT project: Deliverable 3.2 - Data compilation by REFLECT partners, *GFZ* German Research Centre for Geosciences, DOI: 10.48440/gfz.4.8.2021.004
ORCID:	

Revision history	Author	Delivery date	Summary of changes and comments
Version 01	Éva Hartai et al.	22.11.2021	Draft version
Version 02	Éva Hartai et al.	29.11.2021	Minor corrections, completions
Final version	Éva Hartai et al.	03.12.2021	Corrections to tables 1,3,4

	Name	Function	Date
Deliverable responsible	Éva Hartai	Project participant	29.11.2021
WP leader	Tamás Madarász	WP leader	
Reviewer			
Reviewer	Katrin Kieling	Project manager	03.12.2021
Project Coordinator	Simona Regenspurg	Project coordinator	1.12.2021

Table of Contents

List of Tables

1 EXECUTIVE SUMMARY

The recent deliverable summarises the process and the outcomes from the data collection by the project partners for the European Fluid Atlas. The collected data are divided into two main groups: (1) formerly existing ('old') data of geothermal fluids and the relevant wells, rock types and reservoirs, (2) new data generated within the project timeframe, derived from fluid sampling and analysis.

A template for the data collection with detailed guidelines was worked out in the early phase of the project. The template includes all kinds of information that will be presented in the European Fluid Atlas (data on wells, fluid and rock samples and reservoirs). This template was used by the LTPS when they collected formerly existing data at national level, as well as by the project partners when they compiled 'old' and new data.

Eleven sampling sites were identified and seven project partners were involved in the fluid sampling. These partners also provided formerly existing data for the sampling sites and for other geothermal sites in their countries, mostly from their own publications ('old' data). The collected samples were analysed in the laboratories of GFZ, Hydroisotop GmbH and BRGM. new data came from these analyses. A shared NextCloud platform was established and a separate data collection template was created for each sampling site, these were populated by the responsible partners.

In the recent report, the status of data collection on 28th November 2021 is considered. However, the database will be completed by additional data from further sampling and analysis during the project lifetime. Further 'old' data will also be added both from the project partners' and the LTPs' side. After thorough assessment, all data will be comprised in the European Fluid Atlas, which is under development and will be presented by the end of the REFLECT project.

2 INTRODUCTION

In geothermal plants, processes like precipitation or corrosion can cause serious problems for power plant operations and reduce project economics. These processes are in close connection with the physical and chemical properties of the geothermal fluids, which are often poorly defined.

The REFLECT project focuses on clarifying and re-defining geothermal fluid properties. For achieving this goal, among other activities, formerly existing data are collected and re-evaluated, and new data are also generated by field observations, laboratory measurements and modelling. These data are inserted in predictive models to determine fluid reactions at extreme conditions and will also be visualised through the European Fluid Atlas. The Atlas will include variations in fluid properties with geography, geology, and depth, and thus will facilitate the selection of new potential geothermal locations.

The collection of data and the creation of the Fluid Atlas are implemented in the frame of Work Package 3. During the data collection, the focus is on fluids that are used for electricity generation (> 100 °C) but lower temperature fluids (down to 50°C) are also considered. The Atlas will have the potential to be extended over time to include data from old and new heat projects. Using the data from the Atlas, operators can have access to information about fluid properties at a certain location, which help them in assessing the associated risks when they install a geothermal power plant. The Atlas will combine and interpolate geographical, geological and fluid property data to obtain open access maps. In addition, a methodology will be developed to transfer these compositional maps into risk maps for the different operational problems.

3 COLLECTION OF DATA FOR THE FLUID ATLAS

3.1 TYPES OF THE COLLECTED DATA

The Fluid Atlas will include 'old' and new data. 'Old' data are formerly existing data, while the 'new' data are generated in the frame of the project.

Old data come from two sources:

1) National member associations of the European Federation of Geologists, acting as linked third parties (LTPs) in the project, collected data from 20 European countries. This action was carried out by literature research at a national level from freely accessible sources, like scientific publications, reports, datasets, and documents in national archives. Most of this work was completed in the frame of Task 3.1 - Collection of existing data. The results were assessed and published in Deliverable 3.1 - Report on the collection of data on geothermal fluids at a European level, submitted in March 2021 (Sanchez Miravalles & Hartai 2021). These datasets will be updated and complemented with new data during the project lifetime.
2) Project partners also provide old data from their own scientific publications and related literature research, both for the sampling sites and other geothermal locations within their countries.

New data are generated during the project implementation. These data are provided by the project partners and originate from field measurements and laboratory analysis.

In the recent report, the status of data collection on 29th November 2021 is considered. However, the database will be completed by additional data from further sampling and analysis during the project lifetime.

The recent report describes the process and the outcomes from the collection of old and new data by the project partners.

3.2 TEMPLATE FOR THE DATA COLLECTION

A template for data collection was developed at University of Miskolc in the early phase of the project, in order to harmonise the work by the different project entities and make the data assessable for the Fluid Atlas. This template was used both by the LTPs for collecting data on national level and by the project partners for collecting old and new data. Content of this template is described in Deliverable 3.1 in details (Sanchez Miravalles & Hartai, 2021); in the recent report only a short summary is provided.

The template is an excel file including four working sheets (Annex 1). Guidelines for the correct use of IDs, units, coordinates, references, and the interpretation of the comments at the cells were also presented (Annex 2). The requested data types are indicated in the headlines of columns on each sheet. Explanatory notes are provided in most of the cells in the headlines and the selection from drop-down menus make the harmonisation of the data easier. Wells are listed vertically, and the data to the relevant wells are filled in horizontally. References to the data are requested on each sheet.

The four working sheets include the following data groups:

- Well data. On this sheet the ID, the location and the geographical and physical characteristics of wells are arranged in 20 columns.
- Fluid sample data. These data are listed by wells and fluid samples. Data are divided into three main groups:
    - Fluid sample identification (5 data items, e.g. sampling method, date, etc.)
    - Fluid sample physical properties (9 data items, e.g. temperature, density, etc.)
    - Fluid sample chemical properties (64 data items, e.g. pH, dissolved cations, anions, organics, etc.)
- Rock sample data. Data are listed by wells and rock samples and divided into three groups:
    - Rock sample identification (5 data items, e.g. sampling method, depth, etc.)
    - Rock sample geological information (5 data items, e.g. rock name, mineralogical composition, etc.)
    - Rock sample physical properties (5 data items, e.g. porosity, permeability, etc.)
- Reservoir data. On this working sheet, 24 data items are listed on the location, position, extent and physical properties of the reservoir.

3.3 PARTNERS INVOLVED IN THE DATA COLLECTION

The following partners were involved in the data collection:

- Helmholtz Zentrum Potsdam Deutsches Geoforschungszentrum (GFZ), Germany
- Bureau de Recherches Geologiques et Minieres (BRGM), France
- Hydroisotop GmbH (HI), Germany
- Islenskar Orkurannsoknir (ISOR), Iceland
- Izmir Institute of Technology (IzTech), Turkey
- Nederlandse Organisatie voor Toegepast Natuurwetenschappelijk Onderzoek (TNO), The Netherlands
- United Kingdom Research and Innovation (UKRI), UK
- Miskolci Egyetem (UNIM), Hungary, managing the data collection by the project partners

3.4 COLLECTION OF OLD DATA

The collection of old data by the project partners from scientific publications started in July 2020 in the frame of Task 3.2. Partners collected data from literature and from their own publications, mostly for the sampling sites, but also for other locations in their country.

In the frame of the REFLECT project, 11 fluid sampling sites were identified from 7 countries (Table 1).

Table 1: REFLECT fluid sampling sites

Country	Sampling site	Geological formation	Responsible partner
Austria	Bad Blumau	Carbonate	HI
France	Bouillante	Volcanic	BRGM
Germany	Groß Schönebeck	Sandstone, volcanic	GFZ
	Insheim	Carbonate, sandstone	HI
	Neustadt-Glewe	Sandstone	GFZ
Iceland	Krafla	Volcanic	ISOR
	Theistareykir	Volcanic	ISOR
The Netherlands	Heemskerk	Sandstone	TNO
Turkey	Aydin	Volcanic	IzTech
	Tuzla	Volcanic	IzTech
UK	United Downs	Granite	UKRI

A separate data collection template for each site was set up and uploaded to a shared folder on the REFLECT NextCloud platform. Data have been populated online to these templates. In the recent report those data are assessed which were compiled until 29th November 2021. However, further data will be collected during the later phase of the project and these will also be added to the database for the Fluid Atlas.

Project partners compiled former old data for the wells, fluids, rocks and reservoirs for the identified sampling sites, mostly from their own publications. The number of these data groups is shown in Table 2. Data for the largest number of fluid samples were collected from Bouillante and Krafla. For Bouillante, the dates of sampling range from 1970-2015, while at Krafla, old fluid data are from the period 1974-2012.

Table 2: Old data by the project partners from the REFLECT fluid sampling sites (number of wells, fluid and rock samples, and reservoirs from which data have been collected)

Partner	Geothermal site	Number of wells	Number of fluid samples	Number of rock samples	Number of reservoirs
BRGM	Bouillante	8	320	7	8
GFZ	Groß Schönebeck	2	30	3	2
	Insheim	2	2	1	1
	Neustadt-Glewe	2	13	2	2
ISOR	Krafla	48	831	44	
	Theistareykir	18	44	15	

Old data for other geothermal sites than the sampling sites in their country were collected by GFZ, IzTech and UKRI. The number of wells, fluid and rock samples and reservoirs from which data were collected are indicated in Table 3. For Germany, data are from the period 1957-2017. In Turkey, the dates of fluid analyses range from 1947 to 2001. From the UK, the covered time interval is 1985-2014.

Table 3: Old data from other geothermal locations than the sampling sites collected by the project partners

Partner	Country / Region	Number of wells	Number of fluid samples	Number of rock samples	Number of reservoirs
GFZ	Germany	89	114	20	69
IzTech	Turkey	254	233		
UKRI	UK	12	149	36	
BRGM	France/ French Rhine Graben	17	93		17
	France/ Lamentin	4	9	4	4

3.5 COLLECTION OF NEW DATA

New data are from those samples, which were taken within the project lifetime. Fluid sampling by the project partners was carried out in 2020 and 2021. Until November 2021, 85 fluid samples have been collected from the sampling sites.

Project partners carried out on-site measurements and the fluid samples were analysed in GFZ laboratory, at Hydroisotop GmbH, in IzTech laboratory and in BRGM laboratory. The numbers of fluid and rock samples at the specific sites are summarised in Table 4. At Aydin and Tuzla, rock samples were also taken and examined by IzTech.

Table 4: Number of wells, fluid and rock samples involved in the collection of new data

Partner	Sampling site	Number of wells	Number of fluid samples	Number of rock samples
BRGM	Bouillante	1	6	
HI	Bad Blumau	3	17	
	Insheim	2	6	
GFZ	Groß Schönebeck	2	5	
	Neustadt-Glewe	2	3	
TNO	Heemskerk	2	4	
ISOR	Krafla	8	8	
	Theistareykir	3	9	
IzTech	Aydin	12	14	22
	Tuzla	4	6	7
UKRI	United Downs		2	

Due to the restrictions by the site operator, new data from United Downs are very limited. Although sampling was carried out during the summer of 2021, these data remain embargoed until further notice, and they can be included into the Fluid Atlas when they will be made public.

4 CONCLUSIONS

Data collection for the European Fluid Atlas was carried out in two steps:

- National member associations as linked third parties (LTPs) of the European Federation of Geologists, collected existing, publicly available data on national level from scientific publications, reports and manuscripts;
- Project partners collected data during fluid sampling and laboratory analysis in the frame of the project (new data). They also provided formerly existing data from their own publications, both for the sampling sites and other geothermal sites in their country (old data).

The recent report describes the process and the outcomes from the collection of old and new data by the project partners. The data themselves are not discussed here; this would go beyond the scope of this report, as the data need further assessment for the use in the Fluid Atlas.

A complex and comprehensive data collection template with detailed guidelines was created for data collection. The same template was used by the LTPs and the project partners. Data in the template are divided into four groups: well data, fluid sample data, rock sample data and reservoir data.

Fourteen fluid sampling sites were identified covering seven countries. Five project partners were responsible for the sampling and providing the old and new data for the Fluid Atlas.

For the sampling sites, project partners compiled the following amount of old data:

- Data of 80 wells,
- Data of 1240 fluid samples,
- Data of 72 rock samples,
- Data of 13 reservoirs.

For other geothermal locations in their country, the following amount of old data were collected by the partners (from Germany, Turkey and the UK):

- Data of 376 wells,
- Data of 598 fluid samples,
- Data of 60 rock samples,
- Data of 90 reservoirs.

The distribution of new data from the fluid sampling is as follows:

- Data of 39 wells,
- Data of 80 fluid samples,
- Data of 29 rock samples.

Collection of new data is an ongoing process. During the project lifetime, further sampling and analyses will be carried out and new data will be added to the Fluid Atlas database. The same goes for the old data: both project partners and LTPs will refine the existing data or collect further data if needed in the last project year.

Data processing started with checking the coordinates for the wells, and setting them to the correct format. This was followed by putting the well dataset to ESRI shp format and importing it into geodatabase. The rest of the data groups (fluid, rock and reservoir) were imported to the geodatabase and assigned to the well dataset using the IDs. The processing uses ArcGIS (commercial) environment due to the GIS lab infrastructure, but the resulting dataset is interoperable and convertible to the open source environment, which will be used for the web publishing.

5 REFERENCES

Sanchez Miravalles, A., Hartai, É. (2021): Report on the collection of data on geothermal fluids at a European level. REFLECT project report, Deliverable 3.1 - GFZ German Research Centre for Geosciences, DOI: 10.48440/gfz.4.8.2021.001

6 ANNEXES

6.1 ANNEX1 REFLECT FLUID ATLAS DATA COLLECTION TEMPLATE

6.1.1 Well data template

Well data

Well ID	Local ID for the well	Latitude/ Northing	Longitude/ Easting	Country	Date of well completion (year)	Wellhead elevation (m, amsl)	Surface elevation (m, amsl)	Well depth (m)	Top of screened interval (m, below wellhead)	Bottom of screened interval (m, below wellhead)	Reservoir ID (list, if multiple)	Hydraulic head (m, amsl)	PZ data (Pa/m)	Bottomhole temperature (°C)	Outflow temperature (°C)	Well yield (m3/hour)	Scaling exists (Y/N)	Inhibitor added (Y/N)	Geothermal gradient in well (°C/m)	References for the data (link/DOI/ISBN/ISSN/national archive identifier; list if multiple)	Remarks

6.1.2 Fluid data template

Fluid sample data

Fluid sample identification							**Fluid sample physical properties**															
Well ID	Fluid sample ID	Local ID for fluid sample	Sampling method (please select)	Sample depth	Sampling date and hour	Analysis date	Dominant phase (please select)	Tempera-ture (°C)	Pressure (Pa)	Hydraulic head (m)	Density (kg/dm3)	Kinematic viscosity (m2/s)	Dynamic viscosity (kg/m/s)	Specific heat capacity (J/K/kg)	Electrical conductivity (µS/cm, EC25)	pH	Dissolved oxigen (mg/L)	Eh (mV)	Alkalinity (meq/L)	TDS (mg/L)	TDG (Nml/kg)	GLR

Fluid sample chemical properties																																												
Dissolved major cations (mg/L)					Dissolved major anions (mg/L)									Dissolved silica (mg/L)	Dissolved trace elements (mg/L)																						Organics and petr. comp.						
Ca	Mg	Na	K	TMC	Cl	S	F	CO3	HCO3	SO4	PO4	HBO2	TMA	Si	Br	B	I	Al	Fe	Mn	Sr	Ba	Li	Cs	Rb	Ge	Zn	Cu	Pb	Ni	As	Ag	Co	Cr	Hg	W	TOC	DOC	TPH	BTEX	Formate	Acetate	Propionate

Dissolved gas (Vol%)								Isotopes (‰)										**References for the data (link/DOI/ISBN/ISSN/national archive identifier; list if multiple)**	**Remarks**
CO2	O2	H2S	N2	CH4	Ar	H2	He	Oxigen-18	Deuterium (2H)	Tritium (3H)	Oxigen-18 (SO4)	Sulfur-34 (SO4)	Sulfur-34 (H2S)	Carbon-13 (CO2)	Lithium-7	Boron-11	87Sr/86Sr		

6.1.3 Rock sample data template

Rock sample data

Rock sample identification							Rock sample geological information					Rock sample physical properties					References for the data (link/DOI/ISBN/ISSN/national archive identifier; list if multiple)	Remarks
Well ID	Rock sample ID	Local ID for rock sample	Sampling method	Sample depth (m)	Sampling date (year)	Analysis date (year)	Rock type (please select)	Mineralogical composition	Formation name	Formation code on geological map	Link to geological map	Hydraulic conductivity (m/s)	Permeability (m2)	Porosity	Heat capacity (J/K/kg)	Thermal conductivity (W/m/K)		

6.1.4 Reservoir data template

Reservoir data

Well ID in reservoir (list if multiple)	Reservoir ID	Local name/ID of reservoir	Name of geological formation as reservoir	Age of formation (please select)	Formation code on geological map	Link to geological map	Underlying unit (name of geological formation)	Formation code for underlying unit on geological map	Hydrogeologic role of underlying unit (please select)	Overlying unit (name of geological formation)	Formation code for overlying unit on geological map	Hydrogeologic role of overlying unit (please select)	Reservoir type (please select)	Depth interval below wellhead (m-m)	Lateral extent (km2)	Link to GIS information if available	Fluid phases in reservoir	Average hydraulic conductivity (m/s)	Average permeability (m2)	Average hydraulic heads (m)	Average hydraulic gradient	Average temperature (°C)	Average geothermal gradient (°C/m)	References for the data (link/DOI/ISBN/ISSN/national archive identifier; list if multiple)	Remarks

6.2 ANNEX 2 GUIDELINES FOR THE REFLECT DATA COLLECTION TEMPLATE

Background

The aim of Work Package 3 in the REFLECT project is to collect information on the properties of geothermal fluids throughout Europe and develop a comprehensive, digital Fluid Atlas, which will involve existing and newly measured fluid data, including geographical, geological, physical and chemical characteristics. The Atlas and especially the associated risk maps will provide investors and geothermal operators with information needed for the planning and managing of geothermal facilities, as well as the potential geochemical risks, and thus facilitates future geothermal projects. The recent template has been prepared for collecting data on wells, fluid and rock samples, and reservoirs, as well as the references to the sources of the data. Basically, fluids of >100°C are targeted but as data compilation is extended to operating heating facilities, fluids of >50° should also be considered.

IDs

Well IDs, fluid and rock sample IDs and reservoir IDs should be specific, unique and uniform in the Fluid Atlas' database. The IDs of the samples and the reservoirs have to refer to the relevant wells. Beside the IDs in our database, please also indicate the local IDs. When creating the IDs in the data collection template, please follow the following rules:

- Well ID: first the initial of well (W), then the two-digit country code, then the numbering of the wells in increasing order from 001. Example: W_HU_002.
- Fluid sample ID: first the reference to the well ID, then the initials of 'fluid sample' (FS), then the numbering of the fluid samples in increasing order from 001. Example: W_HU_002_FS_018.
- Rock sample: first the reference to the well ID, then the initials of 'rock sample' (RS), then the numbering of the rock samples in increasing order from 001. Example: W_HU_002_RS_112.
- Reservoir: first the reference to the well ID, then the initial of 'reservoir' (R), then the numbering of the reservoirs in increasing order from 01. Example: W_HU_002_R_05. If there are more than one wells in a reservoir, please list all of them in the given cell, but for creating the reservoir ID, use only the ID of the first well in the list. A reservoir may be a delineated aquifer, an aquifer system, or one or more geologic formations or layers. Any lithostratigraphic or hydrostratigraphic units may be used, which is accepted in the given country.

Units and coordinates

With a few exceptions, SI units should be used. Please use geographic coordinates in WGS84. Elevations and hydraulic heads should be given above mean sea level. Depth information should be measured from the wellhead, with a positive downward axis.

Comments at the cells

In the template, comments are added to several cells. These comments explain in details what is requested in the given cell, please read them carefully.

References

Please indicate the references to the collected data according to the followings:
- Link to the website or DOI of the article if the information is online available,
- ISBN identifier of publication if the information is available in form of a book or a monograph,
- ISSN identifier of publication if the geological information was published in a printed periodical,
- Identifier of reports and documents available in national archives.

Remarks

Any information that you think important can be provided in the 'Remarks' column.