Combined Heat, Power and Metal extraction from ultra-deep ore bodies - CHPM2030

3rd Periodic Report

Deliverable D8.5

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Periodic Technical Report

Part B

Period covered by the report: from 01/07/2018 to 30/06/2019

Periodic report: [3rd]

PART B

Contents

1 Explanation of the work carried out by the beneficiaries and overview of the progress

1.1 Objectives

General objectives

The strategic objective of CHPM2030 is to develop a novel and potentially disruptive technological solution that can help satisfy the European needs for energy and strategic metals in a single interlinked process. In the CHPM technology vision, the metal-bearing geological formation will be manipulated in a way that the co-production of energy and metals will be possible, and may be optimised according to the market demands at any given moment in the future.

Specific objectives

Below the specific objectives of the project are listed and the related work is detailed. Tasks and activities in the first and the second reporting periods are summarised shortly and more focus is put on the results in the recent reporting period. For several of the objectives described, work towards achieving them started in the former reporting periods and was completed in the recent reporting period.

Objective 1: Deliver proof of concept for the technological and economic feasibility of mobilisation of metals from ultra-deep mineral deposits using a combination of geo-engineering techniques to enhance the interconnected fracture systems within the orebody.

In the first reporting period, *Tasks 1.1* and *1.3* provided a background for reaching this objective. The internal qualities, the mineralogy, the geochemistry, the geometry, the extent, the structure and the textural characteristics of the metal enrichments were examined, as they influence the magmatic/hydrothermal processes and the fluid-rock interaction. These processes define the metal content and the possible ways of metal mobilisation. The achievement of *Objective 1* was carried out mostly in the second reporting period, in the frame of WP2. This work package included four tasks. Work within WP2 examined only the technological feasibility. The economic feasibility studies were carried out within WP5, in the recent reporting period.

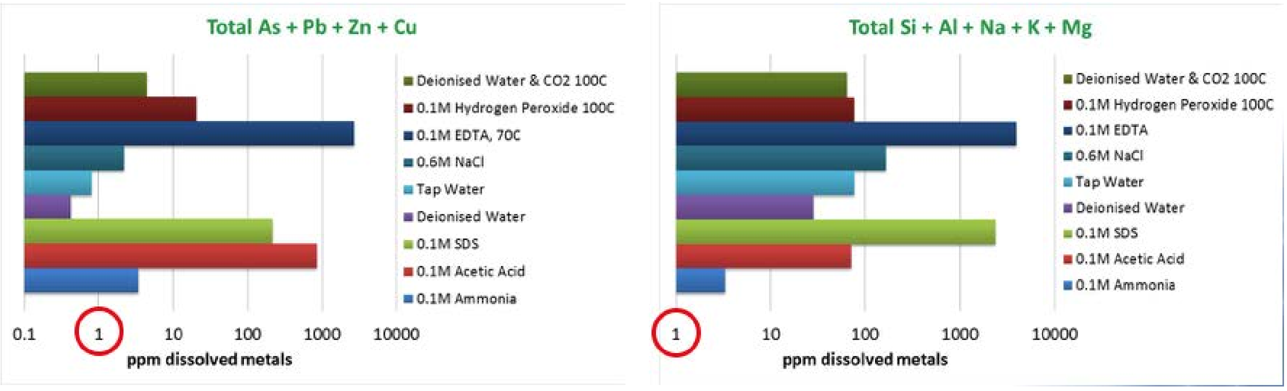

Figure 1.1: Combined concentrations of a range of ore-forming metals (on left) and other elements (on right) released in laboratory experiments after 4 weeks of reaction at 70-100°C. Note the higher mobilisation of ore-forming metals and other elements with dilute EDTA solution and dilute SDS solution, but the more specific mobilisation of ore-forming metals with dilute acetic acid solution.

Work within *Task 2.1* involved a combination of laboratory experiments and predictive computer modelling for the simulations for integrated reservoir management. The main achievement in this Task was determining the magnitude of possible metal production of an envisioned CHPM plant. *Task 2.2* investigated whether relatively 'mild', environmentally benign leaching agents are capable of liberating metals into the recirculating fluid within an EGS. The overall conclusion of the work was that some degree of enhanced metal mobilisation could be achieved. Dilute mineral acids liberated the most metals, and classical complexing agent such as EDTA kept them in solution. Dilute simple organic acids were also quite effective, and they had the benefit of mobilising lower concentrations of less desirable elements (such as aluminium and silica). Copper and silver appear to have been mobilised, but reprecipitated *(Figure 1.1).*

The achievement of *Task 2.3* involved the selection and screening of carbon nano-materials for metal mobilisation. This included the modification of selected materials for improved metal sorption selectivity/capacity under different temperature and pressure conditions One of the findings was that functionalisation changed the nature of the sorption performance. In some cases this resulted in lower overall sorption, but it occurred over a broader pH range over which metal sorption occurred, which might facilitate metal capture over a wider range of natural environments.

Objective 1 was completely attained in the first and the second reporting period.

Objective 2: Develop innovative pathways for leaching strategic metals from the geological formation and corresponding electrochemical methods for metal removal and recovery on the surface.

This complex objective is supported by *Tasks 2.2, 2.3, 3.1* and *3.2.* The results of *Tasks 2.2* and *2.3* were discussed at *Objective 1*. Investigations within WP2 proved that metals can be leached from deep metal enrichments over a prolonged period of time and may influence the economics of EGS. The continuous leaching of metals will increase the performance of the system over time in a controlled way.

WP3 aimed to prove that the dissolved metal content of geothermal fluids (naturally present or leached within the proposed concept) can be removed on surface by electrochemical methods. Within *Task 3.1* copper was recovered by high-temperature, high-pressure geothermal fluid electrolysis. In the first and second reporting periods, an electrochemical reactor system was designed and constructed to operate at temperatures up to 250 °C and pressures up to 200 bar, to evaluate kinetics and mechanistic aspects of electrochemical reactions at HTP *(Figure 1.2)*. Experiments with the instrument were carried out in the second and the third reporting periods.

The results of the work in *Task 3.1* can be summarised as follows: High temperature and high pressure electrolytic metal recovery results in comparable efficiencies, and it has a very positive impact on the energy required for recovery. Lower initial concentrations tend to reduce the recovery efficiency and increase energy consumption. Pb co-deposition with Cu occurred in predominant amounts at elevated temperatures and pressures. Minimal amount of silica was co-deposited with Cu and Pb. High temperature and high pressure electrodeposition from model samples was successful, although there is still a lot to investigate and optimize to reach conclusions towards the ultimate feasibility of this approach for metal recovery from real geothermal brines. This method only works for a limited number of metals (Cu, Ag, Ni, Pb, Sn, Fe, PGM).

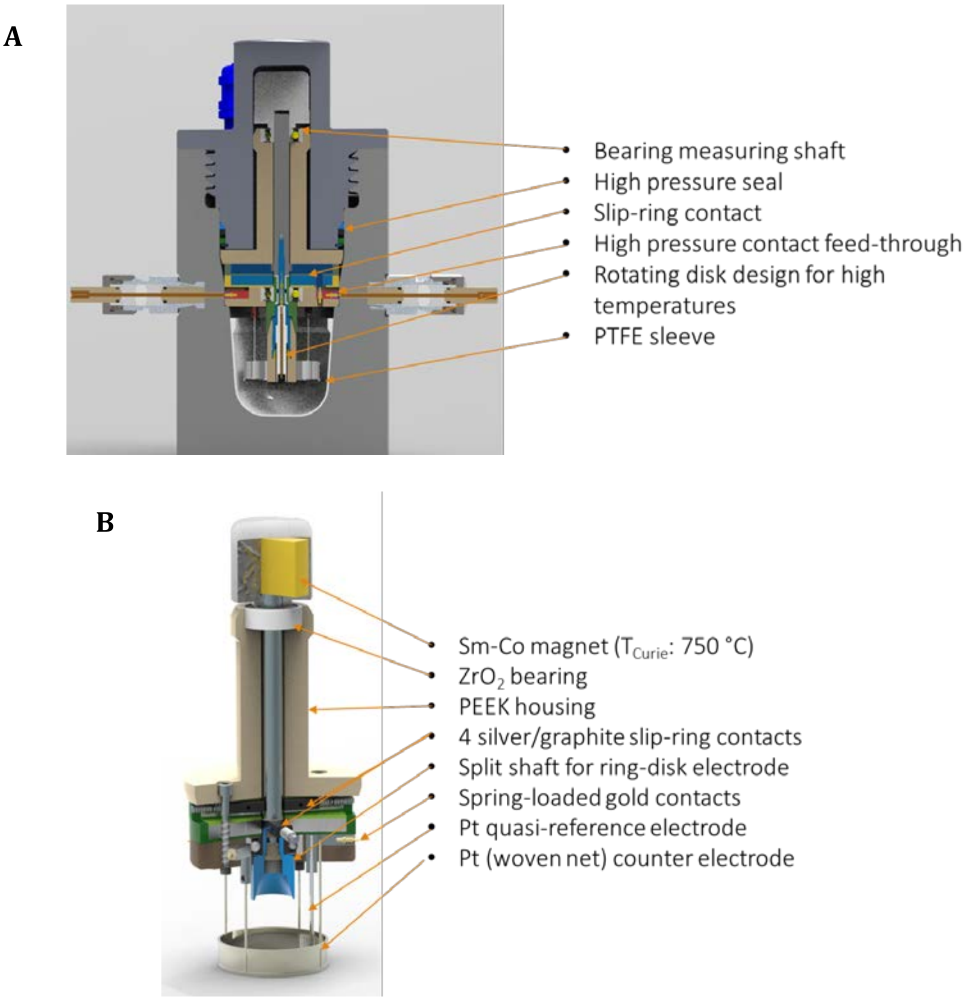

Figure 1.2: (A) Cross-sectional view of ETPER manufactured (B) High temperature and pressure rotating disk electrode designed to operate at 200 bar and 300 °C.

Related to *Task 3.2*, experiments on metal recovery took place by electroprecipitation and electrocrystallization. The preparation of the experimental setups was carried out and first tests with three relevant model geothermal brine compositions started in the first reporting period. Analysis of the performance of the gas-diffusion electroprecipitation and electrocrystallization (GDEx) process with respect to different operational parameters also started in the first reporting period as well as the analysis of the products formed through the GDEx process.

In the second reporting period, based on the relevant brine compositions obtained from the literature study, experiments with simulated Li-Al brines were conducted, as well as with real brines containing these metals. The formation of mixed metal hydroxides was obtained, which have commercial relevance. It was observed that when using O_2 as the oxidant gas for the GDEx process, oxides, hydroxides and mixed metal hydroxide could be recovered from model solutions and real geothermal brines. During the present reporting period, additional experiments conducted used CO_2 instead of O_2 (in air), with adequate modifications on the operational parameters to achieve the electrochemical reduction of this gas. The following metals (and metalloids) proved to be recoverable via the GDEx process (under different operational conditions, relevant to geothermal brines): Li, Al, Cr, Mn, Fe, Co, Ni, Cu, Zn, B, As, Si, Y, Rh, Pd, Pt, Au, La, Ce, Pr, Nd, Sm, Eu, and Er. No additional metals have been tested, but it is possible that others are also potentially recoverable.

Up-scaled experiments with real geothermal brines were also conducted, successfully recovering part of the metal content of the geothermal brine *(Figure 1.3)*. Sr, Mg, Ca, Mn, Ni, Zn, Pb, Si, and B were recoverable. The recovery of Mn, Zn and Pb was outstanding and it is possible that by reaching lower pH magnitudes, these three metals could be selectively separated from the geothermal brine.

Figure 1.3: Up-scaled GDEx reactor used to process 400 L of Landau geothermal brine with the purpose of metal recovery (left). Precipitate samples recovered from the up-scaled GDEx process operated in continuous mode using different currents.

Objective 2 was partly completed by the work in WP2 in the second reporting period, and it was completely achieved in the present reporting period by the following deliverables:

- D3.1: Report on performance, mass and energy balances and design criteria for high-temperature, high-pressure electrolysis (M32),
- D3.2: Report on performance, mass and energy balances and design criteria for gas-diffusion electroprecipitation and electrocrystallization (M32).

Objective 3: Develop metallic-mineral formation specific solutions for the co-generation of electricity using salt-gradient power reverse electrodialysis.

This objective is addressed by Task 3.3. The preparation of the experimental setup and the first experiments with pure NaCl at different concentrations were achieved in the first reporting period. In the second reporting period, different ion-exchange membranes were tested. The influence of divalent cations was also examined, and pilot scale experiments started to be carried out. In *Figure 1.4,* the instrumentation side of the pilot plant is shown.

Experiments carried out in the recent reporting period show that temperature has a very strong influence on the power output of the SGP-RE process. The power density increased with 60% by increasing the temperature from 25°C to 50°C. During the experiment with the artificial brine the performance dropped drastically however. This was largely due to the presence of multivalent ions. Fouling problems also occurred. The artificial brine had a tendency to precipitate inside the stack, causing clogging of the spacers and fouling of the membranes. For the final experiment with the Landau brine a surface water was used as low salinity source. During this experiment the power density increased to 4.4 W/m². No operational problems occurred during this test.

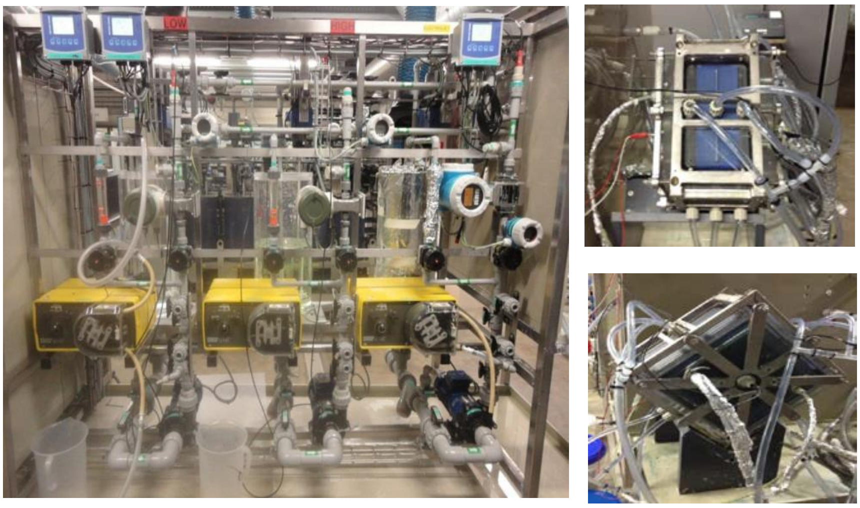

Figure 1.4: Picture of the SGP-RE (salinity gradient power extraction via reverse electrodialysis) pilot unit at VITO. The installation can accommodate RE (reverse electrodialysis)-stacks up to 10m² of cell pair surface and is able to run standardized experiments for evaluating the power output in different conditions such as varying salinity, brine composition, flow rate and temperature.

Results of the research related to *Objective 3* are published in the following deliverable:

- D3.2: Report on performance, energy balances and design criteria for salt gradient power reverse electrodialysis (M32).

Objective 4: Develop conceptual designs of a new type of future facility that is designed and operated from the very beginning as a combined heat, power and mineral extraction system.

This objective was realised by the implementation of *Tasks 4.2,* which started in M32. The task was developed through a mathematical model which integrates the different system components (sub-models) into a single system and use it to develop optimisation strategies for energy and metal production. The main components in the model are two different metal recovery units, a geothermal binary power plant and a salinity gradient power plant. A model framework was created based on component level models which enables linking downstream and upstream geothermal engineering subsystems.

The main model parameters are fluid temperature, salinity, flow rate and concentration of different metals. The sub-models are linked together to describe the overall system performance. A probabilistic approach was used by applying Monte Carlo simulation technique to take into account the uncertainties of the input parameters, resulting in a probability distribution of the calculated output values. The overall model can be used to study different scenarios and perform simulations, optimisation and other kinds of system analysis. Within the CHPM2030 project, the model has been tested on five different European geothermal fields by evaluating the amount of metal that can be extracted as well as the amount of energy generated or consumed by the individual components. Sensitivity analysis has also been performed in order to estimate the influence of different parameters on the final model results.

The model results from the selected test sites are very different, depending on the characteristics of each individual geothermal field. Thus, the results reflect the wide range in flow rate, temperature, salinity and last but not least, metal concentration. Also, the types of extractible metals vary a lot between the sites, and the potential for salinity gradient power generation is naturally limited to sites with very high salinity. On the other hand, potential power generation by a binary power plant depends mainly on the flow rate and temperature of the geothermal brine.

Objective 4 was completed by the submission of the following deliverable:

- D4.2: Report on CHPM Process Optimisation (M42).

Objective 5: Develop a new conceptual framework that increases the total number of economically viable geothermal resources in Europe below the depth of 4 km and deeper including high-enthalpy resources.

This objective was achieved by the implementation of *Task 4.1*, which started in M28. In the first reporting period, *Task 1.4* already provided initial methodological framework, which defines both the overall concept for converting different types of orebodies into an EGS reservoir and the series of experiments and measurements that will need to be conducted in order to validate the concepts to TRL4 in a laboratory environment. In the second reporting period, *Task 2.4* defined the main technological components, and a database started to be built on the critical parameters of each technological component. During the work in 4.1, the surface technological components were considered. The relevant components are: 1) electrolytic metal recovery, 2) geothermal binary power plant, 3) heat utilisation, 4) gas diffusion electro-precipitation metal extraction and 5) salt gradient power generation *(Figure 1.5)*.

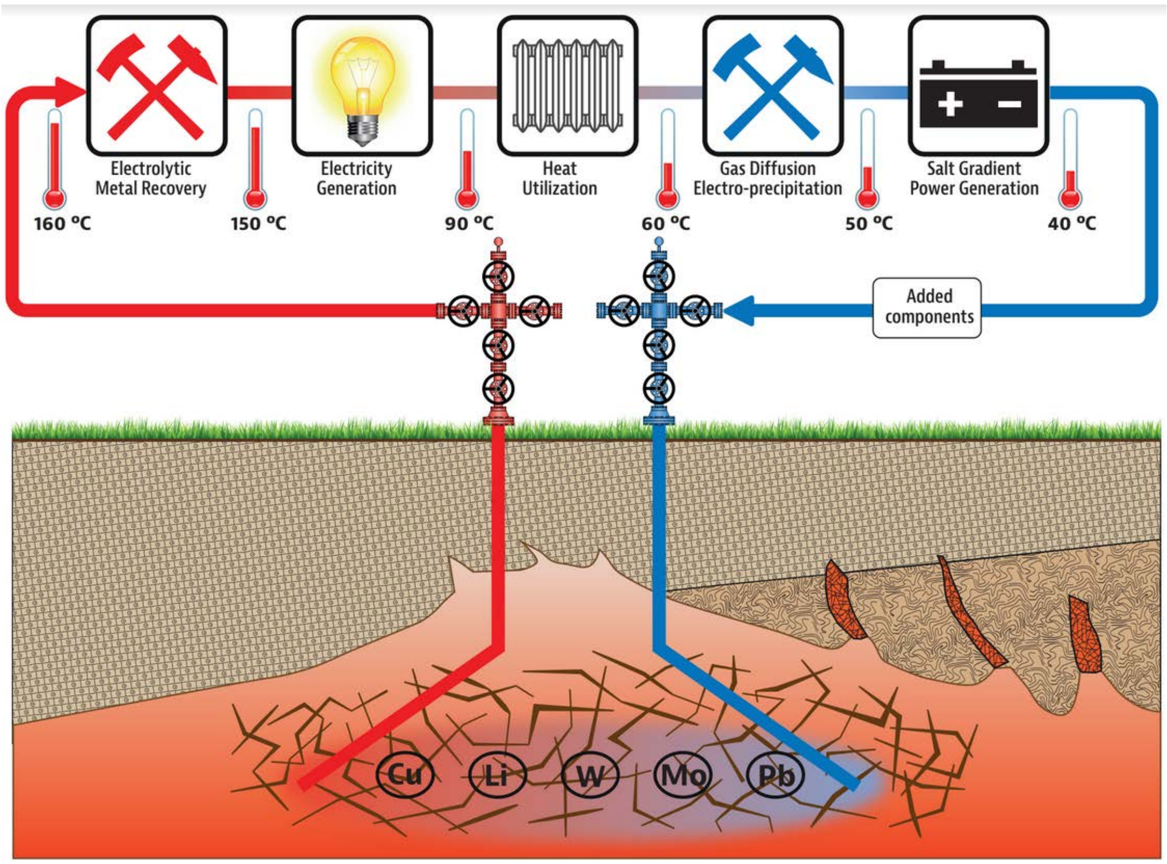

Figure 1.5: Schematic diagram of the overall CHPM system showing the surface technological components.

Task 4.1 started in M28 and summarised the outputs of WP1-WP3 into the architecture design components of the envisioned CHPM facility. The development of the conceptual framework was built on existing component level models of geothermal power plants, but considered the outcomes of WP2 and WP3 to add metal recovery to the overall process flow.

Objective 5 was accomplished by the submission of the following deliverable:

- D4.1: Conceptual Framework for CHPM power plant (M33).

Objective 6: Turn the inherent characteristics of these new resources (extreme content of dissolved metals and often very high temperatures) into an advantage by proposing a new type of geothermal facility.

This objective was addressed by *Task 4.3* which started in M36. The technical specifications were finalised and design specifications were be provided.

The goal is to design a new type of facility that will be operate as a combined heat, power and mineral extraction system. In the technology envisioned the metal-bearing geological formation will be manipulated in a way that the co-production of energy and metals will be possible and may be optimised according to the market demands at any given time in the future. However, at this stage of the development of the technology for building and operating a CHPM pilot plant the consortium finds it impossible to provide detailed technical specifications or drawings of such an integrated system. Therefore, an emphasis has been put on preparing drawings and schematics of the laboratory equipment and other instruments that have been used in the project as well as relevant process schemes for the different CHPM technologies.

The objective was completed by the following deliverable:

- D4.3: CHPM schematics and blueprints (M42).

Objective 7: Develop an economic feasibility assessment model to be applied for such new facilities.

This objective is addressed by *Tasks 5.1, 5.2* and *5.3.* Within *Task 5.1*, the elaboration of the integrated sustainability assessment framework started in M18. Economical, social and environmental aspects of the proposed CHPM technology were considered. Guidelines were developed for the other tasks within the work package, suggesting possible routes to compile the necessary framework documents. these should be further developed when the current technology will be applied at a larger scale. The structure of the proposed framework was inspired by those industry standard documents that were conceived to ensure the sustainable operation of this specific technology.

Baseline economics for energy and mineral raw materials, and decision support for economic feasibility assessment started to be worked out in the second reporting period and became finalised in the recent reporting period in the frame of *Tasks 5.2* and *5.3.*

Work in *Task 5.2* focused on the economic aspects of the CHPM technology. From economic side, EGS is not a current rival to other conventional energy sources due to very high capital and operational costs. However, simulations predict competitiveness of EGS in the timeframe of the CHPM development indicated in the project. Extraction of metals from geothermal fluids is a commercially untested technology, which has no clearly defined operational costs. This makes the economic feasibility assessment difficult. Theoretical models suggest that positive economic feasibility can be achieved only on sites with higher concentrations of dissolved metals in brines and/or higher fluid flow.

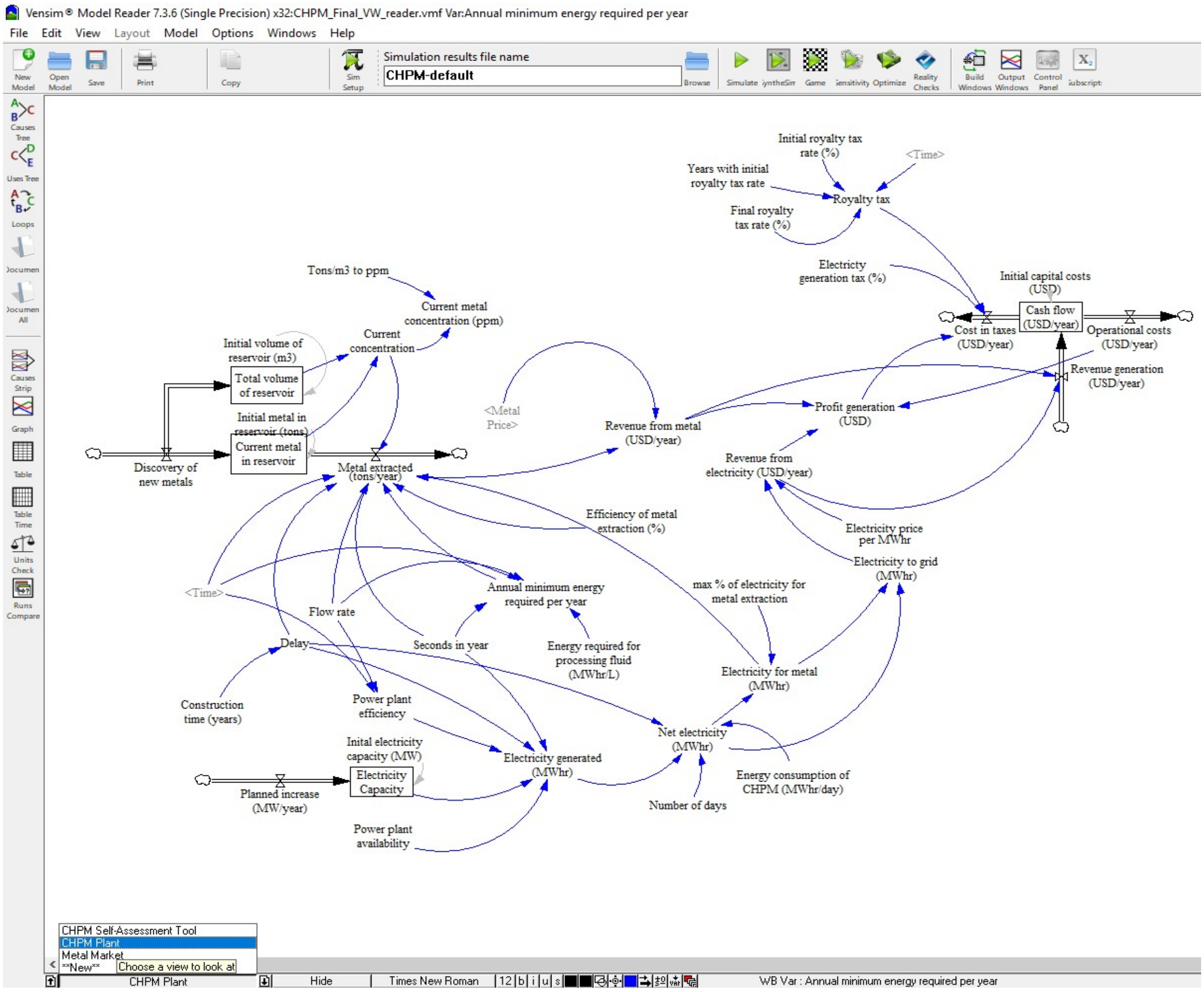

Figure 1.6: Software environment of the Vensim Model Reader with the CHPM plant view.

Based on the outcomes from *Task 5.2*, a tool was developed in *Task 5.3*, using a system dynamics approach and the Vensim simulation software *(Figure 1.6)*. The CHPM Self-Assessment Tool allows users to simulate revenue stream from both energy and metal extraction levels. The tool also shows how it is influenced by costs, metal market, economic growth, taxes, and other aspects. Users can modify values (use their own data) and compere graph outputs of different scenarios. The CHPM Self-Assessment Tool and the CHPM default scenario can be downloaded from the MinPol website (http://www.minpol.com/references.html).

Objective 7 was achieved by the following deliverables:

- D5.1 Integrated sustainability assessment framework (M24),
- D5.2 Economic feasibility assessment methodology (M32),
- D5.3 Self Assessment Tool (M40).

Objective 8: Develop an integrated feasibility assessment framework for evaluating the environmental and socio-economic impacts of the proposed new technology line.

his objective was dealt with in*Task 5.4, 5.5* and *5.6. Task 5.4* and *5.5* started in M24, *Task 5.6* in M36. Even *Task 2.4* provided input by data collection for the subsequent assessment of the environmental impacts of the system in WP5. *Task 2.4* also defined the parameters that should be measured and collected in order to execute WP5. Emerging phenomena that can have relevance from an environmental point of view, or that could affect system optimisation and performance were also considered in *Task 2.4.* Of particular interest is the role of leaching fluids, by-products of chemical reactions or the level of self-containment. The work in *Task 2.4* is documented in deliverable

- D 2.4 Report on overall systems dynamics (M24).

Objective 8 was achieved by the following deliverables:

- D5.4 Report on policy implications (M42),
- D5.5 Environmental Impact Assessment Framework (M38),
- D5.6 Ethics Assessment Report (M42).

Objective 9: Combine metallogenic models with geothermal datasets to develop a database of suitable areas in selected case-study areas in Europe where such developments could be feasible

Task 1.1 and *1.2* earlier completed, supported the achievement of this objective. Four case-study areas were already selected in the preparation phase of the proposal. Based on literature data, the deep mineral potential of the metallogenic belts of Europe was examined in *Task 1.1*. Within *Task 1.2*, an overview of four study areas in the major ore districts in Europe, namely in SW England, southern Portugal, NW Romania and central and northern Sweden was given. It was completed with a survey of existing boreholes in European countries, where temperatures at depth in access of 100 °C were observed. The geological settings were described, and attempts were made to estimate their geothermal potential.

The work in the mentioned two tasks was detailed in the following deliverables:

- D 1.1 EGS-relevant review of metallogenesis (M6),
- D 1.2 Report on data availability – compiled from 5 reports (M10).

Objective 9 was achieved by the work done in *Tasks 6.1* and *6.2,* which started in M24. *Task 6.1* involved a technology visioning process for the development of the CHPM concept against the backdrop of different socio-economical-technological scenarios and expected policy developments. *Task 6.2* aimed to support the development of technology and economic feasibility plans for pilot implementation of a CHPM plant.

Task 6.1 focused on the long-term planning and included different foresight elements for different purposes: 1) Horizon Scanning, 2) Delphi survey and 3) Visioning process. Horizon scanning provided the present technological baseline for CHPM today. The Delphi survey, with 133 participants from the geothermal and the mineral sectors worldwide, informed on what the future may be at important but uncertain areas. The visioning process pointed out what the desired destinations are in the future for the CHPM technology. An important element of the visioning process was the CHPM2030 Visioning Workshop which brought together consortium partners and external experts from both the geothermal and the mineral sectors *(Figure 1.7).*

Figure 1.7: Visioning workshop participants in Las Palmas, on 04.12.2018.

Task 6.2 aimed to support the development of technological and economic feasibility plans for the pilot implementation of the CHPM systems. This work was carried out with the involvement of the geological surveys representing the study areas and the EFG LTPs who assessed the CHPM potential at a national level throughout Europe. Related to this work, two fieldtrips were organised for the partners involved in WP6, one in SW England and one in Romania,.
The work in *Task 6.2* was presented in an extensive study with 907 pages (D6.2). In this study, an evaluation framework was presented that facilitated the examination of the study areas for CHPM technology. The same methodological approach was applied on five areas (South West England, Portuguese Iberian Pyrite Belt, Beius Basin & Bihor Mountains in Romania, and two mining districts in Sweden: Nautanen and Kristineberg), evaluating their CHPM potential and characteristics. A European outlook for CHPM prospective locations was also carried out, covering 24 countries.

Objective 9 was completely achieved by he following deliverables:

- D6.1 Report on Emerging and Converging Technologies (M42),
- D6.2 Report on Pilots – compiled from 5 reports (M40).

Objective 10: Develop a roadmap in support of the pilot implementation of such system before 2030, and the full-scale commercial implementation before 2050.

This objective was achieved by Task 6.3, which started in M33. The CHPM roadmap for 2030 and 2050 used the synergetic combination of three future-oriented layers of studies: 1) CHPM component roadmap, 2) Preparation for future pilots and 3) Overall CHPM concept.

In the CHPM component roadmap, for each technological component, the state-of-the-art, an immediate research plan (2025), a pilot research plan (2030), and the long term objectives (2050) were described. The technological components are visualised in *Figure 1.8*. In the Preparation for pilots, pathways were recommended to the pilot implementation by 2030, by providing a detailed description of the 5 study areas in Europe. In the overall CHPM concept, the feasibility of combining geothermal energy with mineral extraction with the use of foresight tools was examined. Using the synergetic combination of these three layers, a timeline was constructed, including milestones, objectives and targets to be achieved in order to arrive to pilots by 2030 and full-scale application by 2050.

The objective was achieved by the following deliverable:

- D6.3 Roadmap for 2030 and 2050 (M42).

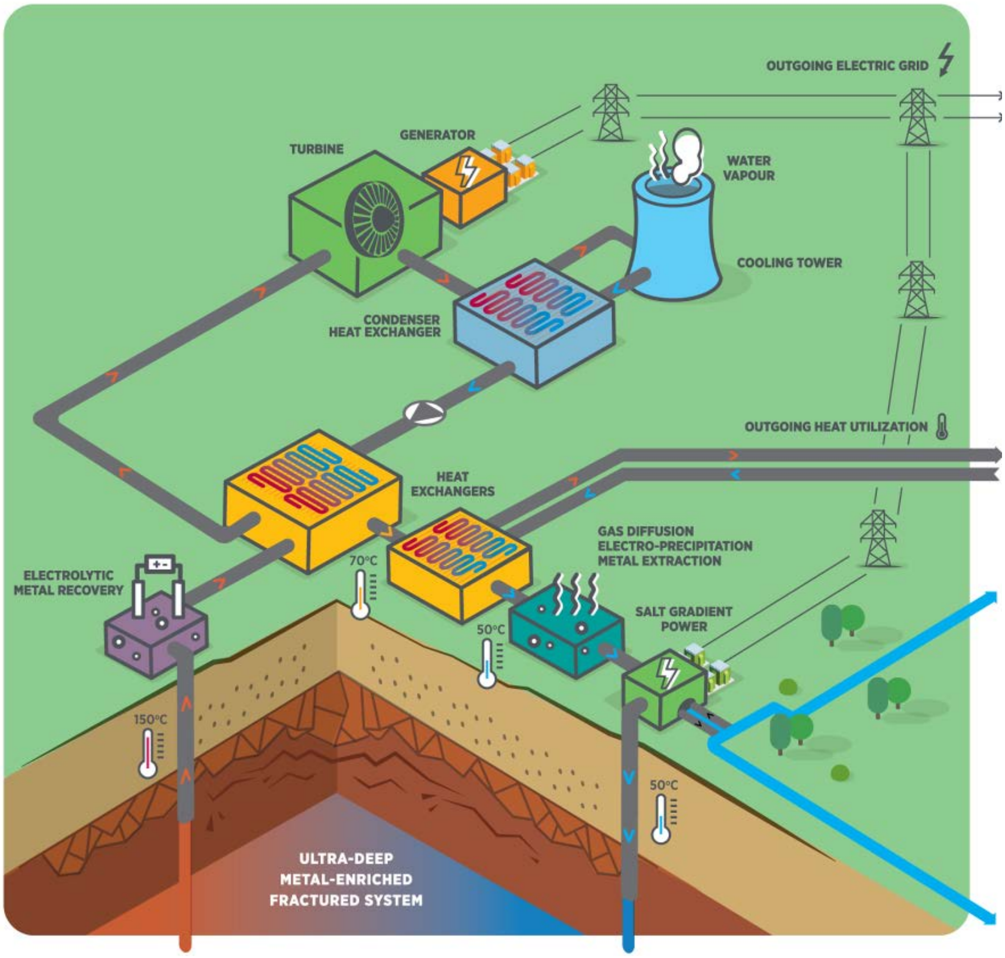

Figure 1.8: Visualisation of a future CHPM plant.

1.2 Explanation of the work carried out per WP in the reporting period

1.2.1 Work Package 3

WP title	**Metal recovery and electrochemical power generation**		
Lead beneficiary:	VITO	Participants:	KU Leuven
Start date:	01.10.2016	End date:	31.12.2018

Objectives of the WP

The dissolved metal content of geothermal fluids (naturally present or leached within the proposed closed EGS concept) would be removed ex-situ (ex-reservoir) by electrochemical methods, to:

- enable the exploitation of the residual salinity gradient power and reduce the environmental impact,
- tailor higher quality geothermal fluids for reinjection into the borehole (i.e., for reduced scale formation and corrosion), and
- unlock the value of the metal resources contained.

The electrochemical routes envisioned by CHPM2030 to accomplish this purpose included:

- salinity gradient power by reverse electrodialysis,
- high-temperature and high-pressure electrolysis, and
- gas-diffusion electroprecipitation and electrocrystallization.

The objective of WP3 was to validate these technologies with modern geothermal fluids as well as with real geothermal fluids (industrially relevant environment) using laboratory experiments and computational simulations, reaching and exceeding TRL-4.

The hypotheses that were tested in this WP included:

- Strategic metals can be recovered from geothermal fluids in relevant concentrations that may substantially influence the economics of EGS.
- The metal content of geothermal fluids can be significantly reduced to an extent that may substantially influence the technological performance of EGS by reducing the possibilities of scaling and corrosion over time and thus extend the overall process lifetime.
- The salinity gradient of the residual geothermal fluids can be tapped to increase the power output of EGS.

WP3 implemented these processes with model fluids and raw geothermal fluids and evaluated. It was not possible to evaluate them with leachate streams produced in WP2, as their volume was insufficient for running the corresponding experiments. It was also not possible to evaluate the applicability of the functionalized carbon particles as flowable electrode materials, as originally anticipated, as the particle sizes used in WP2 did not have the technical specifications amenable for this purpose. Work in WP3 strongly depended on knowing the composition of real geothermal brines, as well as on the availability to obtain samples of sufficient quantity of them.

Synthesis of work done and results achieved

The work in this WP was organised in 3 tasks. A summary of the work carried out by the beneficiaries involved in each of them, for the reporting period, is presented below. Progress within this WP was in-line with what was anticipated and the corresponding deliverables (D3.1, D3.2, and D3.3) were completed and submitted on time *(Figure 1.9).*

Figure 1.9: Deliverables of Work Package 3.

Task 3.1 *Recovery of the metal content by high-temperature, high-pressure geothermal fluid electrolysis*

For the present reporting period, investigations of the effect of temperature and pressure on the recovery of copper using a stationary electrode reactor were continued. The construction and testing of the High Pressure High temperature Rotating Electrode Reactor was completed. The effect of the initial concentration of copper, reduction potential, reduction time, and silica content on the recovery of copper at HTHP conditions were studied.

Details of the results can be found in Deliverable 3.1. Mesoporous platinum deposits on a Pt disk, with pore size ranging between 5 nm and 10 nm, were achieved on Pt. The electrodes showed a rapid and stable potential response. Additionally, the stability of the electrode with temperature was confirmed. The mPt quasi-reference electrode was calibrated with the help of Fe(II)/Fe(III) redox couple *(Figure 1.10).*

The equilibrium potential of the mPt electrode was found to vary linearly with temperature according to the expression:

$$E_{mPt}(\text{vs SHE}) = 0.6108 - 2.5 \times 10^{-3}(T - 298)$$

where, E_{mPt} is the equilibrium potential of the mPt quasi-reference electrode expressed in V vs SHE, and T is the temperature in K.

The cyclic voltammograms indicate that the electroreduction of Cu^{2+} ions and subsequent electrooxidation of Cu in aqueous medium at elevated pressures exhibits no significant difference when compared to that at atmospheric pressure. However, SEM images indicate that the electrodeposits at elevated pressures are more dense and closely packed. As expected, at temperatures greater than the 373 K (100 °C) and elevated pressures, the cyclic voltammograms exhibited currents that were at least 10 times higher than that obtained at room temperatures. Additionally, the deposit morphology at 373 K (100 °C) does not exhibit a crystalline-type deposit as observed at room temperature, and showed layered deposit which was rather scattered and porous. The porous nature of this deposit can be attributed to the Cu dissolution due to the increased rate of comproportionation reaction at higher temperatures, resulting in the formation of Cu^{+} ions, which has been shown to be a primary reason behind a uniform conformal coating. A 'one factor at a time' (OFAT) study was performed to understand the independent impact of temperature, pressure, initial copper concentration, deposition times, and electrodeposition potential on the Faradaic efficiency, yield, recovery rate, and energy required to recover copper was performed. From the study, it can be concluded that the maximum efficiency and minimum energy required to was obtained for both solutions at elevated pressure and solutions at ETEP, indicating that it could be a potential technology that can be used for metal recovery from geothermal fluids.

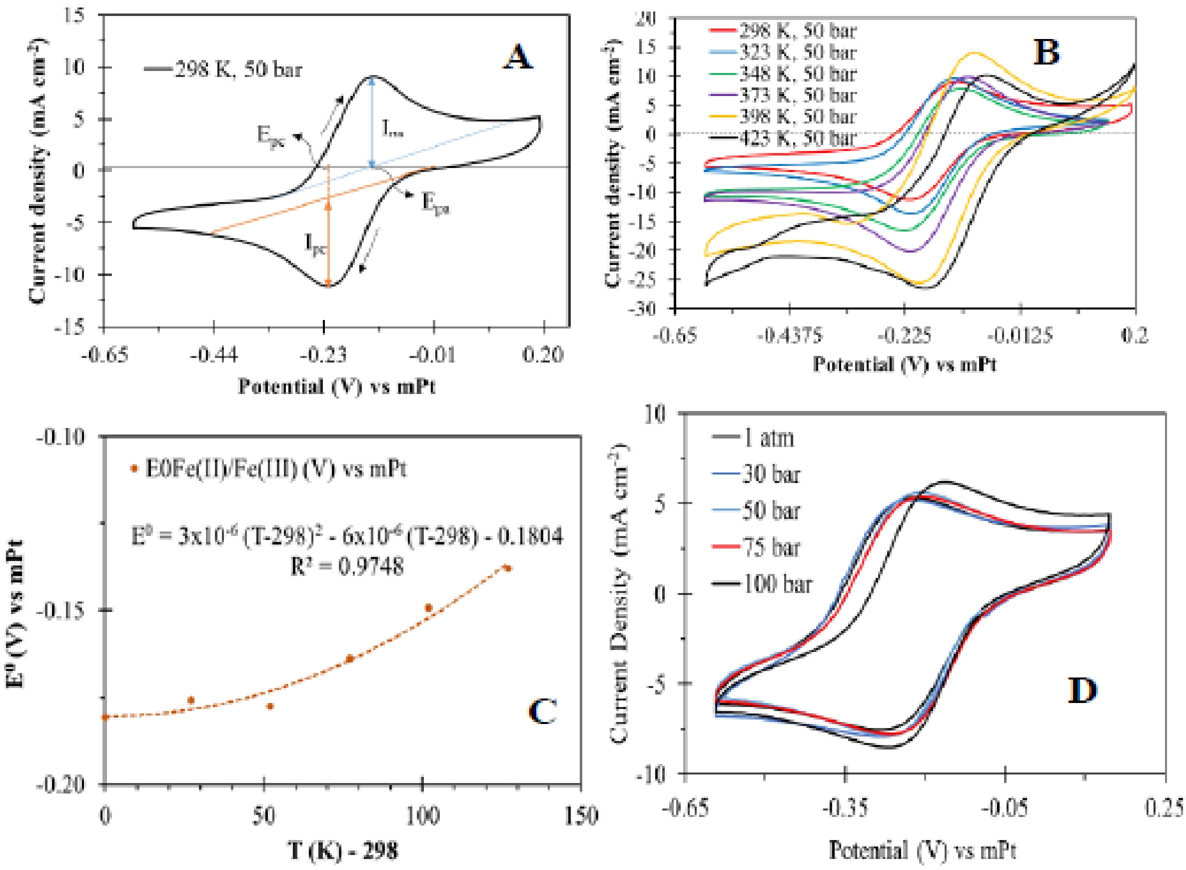

Figure 1.10: (A) Typical cyclic voltammogram for the Fe(II)/Fe(III) redox couple. The CV was performed on a glassy carbon working electrode in a solution of 1 M PBS solution containing 10 mM K4Fe(CN)6 with mPt quasireference electrode, and a Pt foil counter electrode at 100 mV s-1. (B) CV's Fe(II)/Fe(III) redox couple performed at temperatures ranging from 298 K to 423 K, and a pressure of 50 bar. (C) The standard potential of Fe(II)/Fe(III) for the redox couple plotted as a function of temperature.

The following conclusions are also made from the work conducted in Task 3.1:

- High temperature and high pressure electrolytic metal recovery results in comparable efficiencies, yields and rates vs. ambient temperature and pressure electrolytic recovery, yet it has a very positive impact on the energy required for recovery.
- Lower initial concentrations tend to reduce the efficiency, % of metal recovered, yield, and recovery rates, and increase energy consumption, as anticipated.
- The influence of Pb and silica was also investigated. Pb co-deposition with copper occurred in predominant amounts at elevated temperatures and pressures. Minimal amount of silica was co-deposited with Cu and Pb.
- High temperature and high pressure electrodeposition from model samples was successful, although there is still a lot to investigate and optimize to reach conclusions towards the ultimate feasibility of this approach for metal recovery from real geothermal brines.

High temperature and high pressure electrodeposition only works for a limited number of metals like Cu, Ag, Ni, Pb, Sn, Fe, and PGM.

Task 3.2 *Recovery of the metal content of geothermal fluids by gas-diffusion electroprecipitation and electrocrystallization*

During this reporting period, experiments were conducted using CO_2 as the oxidizing gas, as opposed to air (for O_2 reduction) used in previous experiments. An extended screening of the recovery achievable for different individual metals in model solutions was made. Finally, up-scaled experiments with real geothermal brines were conducted, successfully recovering part of the metal content of the geothermal brine. A schematic representation of the technological setup is shown in *Figure 1.11.*

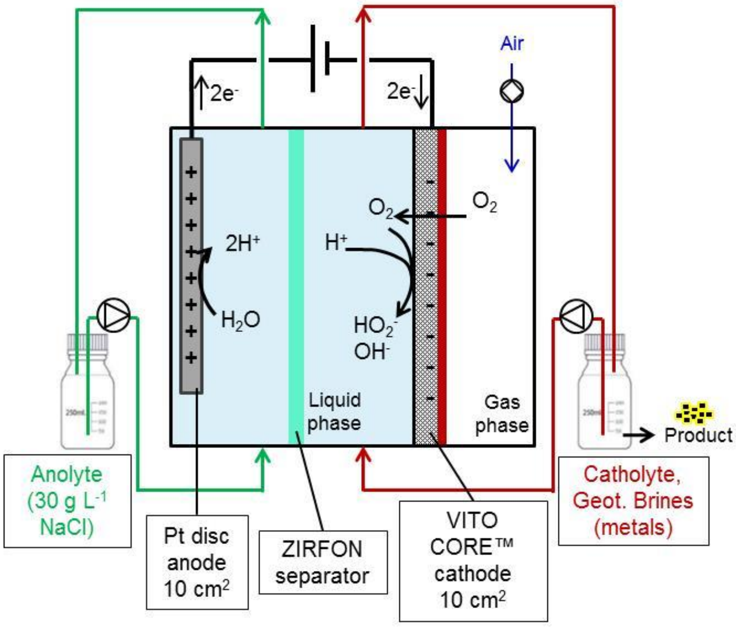

Figure 1.11: Schematic diagram of the GDEX technology for the treatment of geothermal brines.

Via experiments carried out within the previous reporting periods, it was observed that when using O_2 as the oxidant gas for the GDEx process, oxides, hydroxides and mixed metal hydroxide could be recovered from model solutions and real geothermal brines. Additional experiments conducted during the present reporting period, used CO_2 instead of O_2 (in air), with adequate modifications on the operational parameters to achieve the electrochemical reduction of this gas. It was found that instead of producing an oxidizing agent (i.e., H_2O_2) the process generated a reducing agent (nature still not clear, but two options are most feasible: CO or formic acid), which in turn allowed the recovery of elemental forms of the metals contained in model solutions. So far, this route has proven feasible to recover noble metals (i.e., Pt, Pd, Rh, Au).

Based on additional experiments with model solutions, it was found that the following metals (and metalloids) are recoverable (sometimes individually and sometimes in the presence of other metals) via the GDEx process (under different operational conditions, relevant to geothermal brines): Li, Al, Cr, Mn, Fe, Co, Ni, Cu, Zn, B, As, Si, Y, Rh, Pd, Pt, Au, La, Ce, Pr, Nd, Sm, Eu, and Er. No additional metals were tested, but it is possible that others are also potentially recoverable.

Up-scaled experiments with real geothermal brines were also conducted, successfully recovering part of the metal content of the geothermal brine. In total, 400 litre of geothermal brine were processed for this purpose. Sr, Mg, Ca, Mn, Ni, Zn, Pb, Si, and B were recoverable. Ca was so abundant, that it predominated on the composition of the recovered samples, opaquing the detection of the composition of other products present. Crystalline Ca(CO)3 was formed. The recovery of Mn, Zn and Pb was outstanding and it is possible that by reaching lower pH magnitudes (i.e., by applying less current), these three metals could be selectively separated from the aqueous brine.

Table 1.1: Initial concentration of metals in the brine and the % of metal removal after processing the brine with GDEx in the up-scaled experiments at different flow circulation and at different currents.

Metal	Initial concentration (mg/L)	% of metal removal							
		300 mL / min				600 mL/min			
		- 3 A	-6 A	-9 A	-12 A	- 3 A	-6 A	-9 A	-12 A
Sr	463 ± 11	0.4	1.0	0.0	0.0	2.3	0.6	2.3	0.7
Rb	29 ± 0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Li	190 ± 5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Fe	0.039 ± 0.01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mg	102 ± 2	0.0	0.0	5.3	16.4	0.0	0.9	1.6	5.3
Ca	7919 ± 389	1.5	8.1	8.0	15.0	8.6	3.9	3.0	4.1
Al	0.191 ± 0.07	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mn	28 ± 0.6	8.9	18.7	53.0	99.8	0.8	5.7	16.0	50.0
Ni	0.013 ± 0.001	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Zn	7 ± 0.4	79.0	95.1	99.8	99.8	8.8	51.1	93.4	99.7
Pb	0.31 ± 0.03	88.0	93.6	96.7	96.7	24.6	63.9	90.9	96.7
Si	53 ± 2	13.7	20.4	37.4	62.1	3.3	9.0	18.5	37.4
B	47 ± 1	1.6	1.6	0.5	3.7	1.6	1.6	1.6	1.6

The following conclusions are also made from the work conducted in Task 3.2:

- GDEx is a novel way to recover metals from dilute solutions. The patent of the process has now been granted in Europe.
- GDEx allows nearly full recovery of the relevant metals present, selectivity can be achieved in the cases tested (i.e., real and simulated brines)
- Energy consumption is competitive vs other existing alternatives.
- It is up-scalable, although conditions to upscale in the context of geothermal industry high flow rates need to be further explored.
- It works for most of critical raw materials and other industrially interesting materials.
- First economic feasibility calculations show it as a promising option.

Task 3.3 *Salinity gradient power from pre-treated geothermal fluids*

During the recent reporting period, pilot scale experiments with pure NaCl solutions, artificial brine and a real brine were conducted. The first pilot-scale experiment with real geothermal brine and surface water at elevated temperature (50 °C) was successfully executed.

First a stack with 50 cell pairs (approx. 1 m²) was constructed. This is considered to be a first step in the piloting of the technology. Thin (20 µm) Fumatech membranes (FAS-20 and FKS-20) were used to construct the stack, together with Nafion membranes to shield the electrode compartments. Thin, woven spacers (260 µm) were used to optimize the internal resistance of the stack. The stack integrity was tested by checking the internal and external leakages. Although some leakages were detected, this was within the acceptable ranges for operation (approximately 5%). The stack was tested with pure NaCl solution as a reference, followed by a test with an artificial brine and finally a test with a real brine. The results are summarized in *Table 1.2* and *Figure 1.12.*

Table 1.2: Main results of pilot SGP-RE experiments.

High salinity	Low salinity	T (°C)	Type	Max power density	OCV	Observations
2M NaCl	0,01M NaCl	25	Pure NaCl	5.0 W/m²	7.7V	
2M NaCl	0,01M NaCl	50	Pure NaCl	7.9 W/m²	8.2V	
Artificial brine	0,01M NaCl	50	Mixed salts	1.7 W/m²	6.0V	Issues with fouling
Landau brine	Surface water	50	Real feed stream	4.4 W/m²	7.3V	No fouling problems

From *Table 1.2* it is clear that temperature has a very strong influence on the power output of the SGP-RE process. The power density increased with 60% by increasing the temperature from 25 °C to 50 °C. However, during the experiment with the artificial brine the performance dropped dramatically(-75% compared to the pure NaCl at 50°C). This was largely due to the presence of multivalent ions.

Fouling problems also occurred. The artificial brine had a tendency to precipitate inside the stack, causing clogging of the spacers and fouling of the membranes. Hence, a realistic estimate of the intrinsic performance is difficult to make. For the final experiment with the Landau brine a surface water was used as low salinity source. During this experiment, the power density increased to 4.4 W/m². No operational problems occurred during this test.

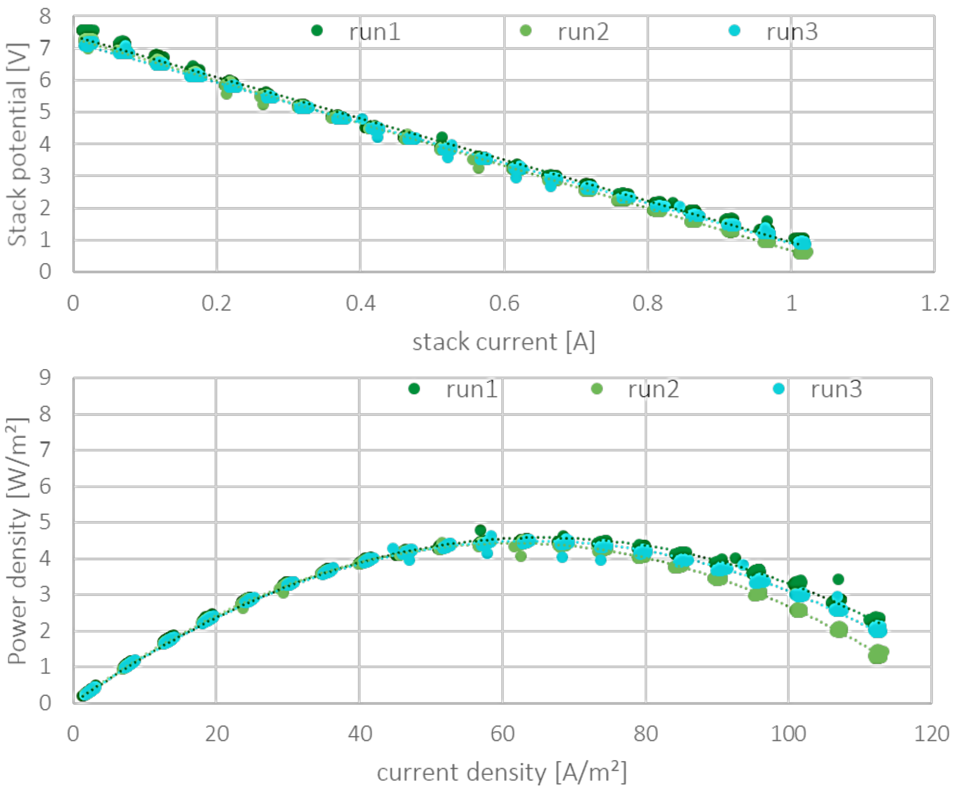

Figure 1.12: Performance results of the experiment with the Landau Brine and surface water as respectively the high and low salinity feed streams at 50°C. During the potentiometric experiment a certain (forward) current (0-1000 mA, 50 mA steps) is applied to the stack and the resulting stack potential is measured. This is repeated three times (runs 1, 2 and 3) to ensure stable operation and representative values. In the top graph the stack potential is plotted vs the applied current. The value where the current is zero represents the open circuit voltage (OCV). The slope of the slope of this graph is opposite to the stack resistance. The bottom graph shows the calculated power density (W/m² cell pair) as function of the applied current density (A/m²).

WP3 deliverables

Deliverable no. and name:	**D3.1 Report on performance and design criteria for high- temperature and high-pressure electrolysis**	
Due date:	31.08.2018	Delivered to the EC on 01.09.2018
Responsible:	KU Leuven	
Summary:	This deliverable was produced in the framework of the activities in WP3 related to surface technologies for the CHPM2030 concept. It covers the experimental work carried out in view of demonstrating the technical feasibility of applying electrodeposition at high pressure and high temperature as means to recovery valuable metals from geothermal brines. It contains the design of the lab setup developed by the team at KU Leuven to carry out the proposed study, results of an extensive lab study.	
Deliverable no. and name:	**D3.2 Report on performance, mass and energy balances and design criteria for gas- diffusion and electroprecipitation and electrocrystalization**	
Due date:	31.08.2018	Delivered to the EC on 06.09.2018
Responsible:	VITO	
Summary:	As temperature can affect the performance of the system, and since the brine treated by the GDEx technology can be within 20-60 °C (as defined by the CHPM proposal), this parameter was evaluated in the system, first using simulated brines. The most important effects of temperature within this range concerned the formation of different products, variations on the system resistance, processing time, level of current, and process efficiency. The long term performance under these conditions was also assessed. Based on the relevant brine compositions obtained from the literature study, experiments with simulated Li-Al brines were conducted, as well as with real brines containing these metals (i.e., Romanian geothermal brines). The formation of mixed metal hydroxides was obtained, which have ample commercial relevance. Finally, the feasibility of employing microbial-electrochemical systems (i.e., bioanodes coupled to GDEx cathodes) was tested, proving that the GDEx system could be operated with lower or negligible power consumption, as well as it could even be used for the co-generation of electricity. Overall, the GDEx process is 2-3 fold more economical than classical mineral processing at the metal concentrations of geothermal brines and its potential to be upscaled is feasible.	
Deliverable no. and name:	**D3.3 Report on performance, mass and energy balances and design criteria for salt gradient power reverse electrodialysis**	
Due date:	31.08.2018	Delivered to the EC on 31.08.2018
Responsible:	VITO	
Summary:	This deliverable covers the experimental work carried out in view of demonstrating the technical feasibility of applying reverse electrodialysis to extract electrical energy from the geothermal brine. It contains the results of an extensive lab study and subsequent pilot test with both artificial and real brines.	

1.2.2 Work Package 4

WP title	**Systems integration**		
Lead beneficiary:	ISOR	**Participants:**	UNIM, USZ, VITO, KU Leuven
Start date:	01.04.2018	**End date:**	30.06.2019

Objectives of the WP

The aim of WP4 is to integrate downstream and upstream processes into a single system and develop optimisation strategies for energy and metals production. This task combined the past experience of the consortium members with the design of medium and high-enthalpy geothermal systems and the outcomes of WP2 and WP3 to create a novel technology line that produces energy and valuable metals in a single, interlinked process. This knowledge was utilised to adapt contemporary power plant design to the expected temperature and extreme salinity conditions that will occur under the CHPM2030 scheme.

Synthesis of work done and results achieved

The work in this WP involved 3 tasks. Below the activities and the results are listed by tasks.

Task 4.1 *Conceptual framework(s) for CHPM power plant*

The main objective of this task was to develop a conceptual framework to convert outputs of WP1-WP3 into an overall architecture design of the envisioned CHPM facility by creating a model framework based on component level models which enables linking downstream and upstream geothermal engineering subsystems. The components in the system are: (1) Underground heat exchanger, (2) Production wells, (3) Electrolytic metal recovery, (4) Geothermal binary power plant, (5) Gas diffusion electro-precipitation, (6) Salt gradient power generation and (7) Injection wells. A schematic diagram of the overall CHPM system, shown in Figure 1.13.

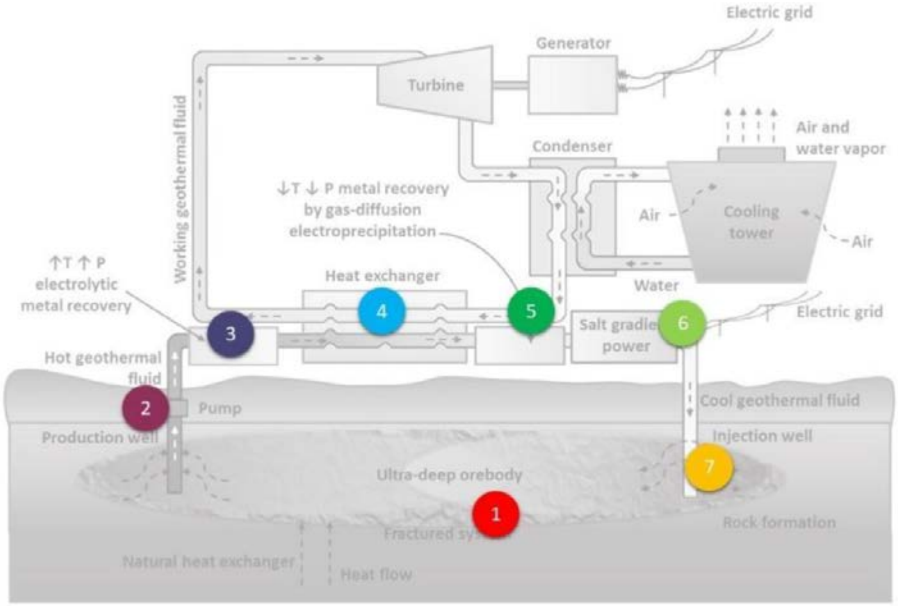

Figure 1.13: Schematic diagram of the overall CHPM system showing the links between the different components.

It was decided to focus on a few specific scenarios regarding site location in the CHPM2030 project. Thus, limited emphasis was placed on the geothermal reservoir and the wells (components No. 1, 2 and 7) in the overall system description since the reservoir conditions will be known (or estimated) for the specific sites. Thus, the overall system description focused on the surface components No. 3, 4, 5 and 6.

A model framework was created based on component level models, which enables linking downstream and upstream geothermal engineering subsystems. The different system components were integrated into a single system by a mathematical model. This model is used to develop optimisation strategies for heat, energy and metal production. The work on the model framework was led by ISOR with input from other WP4 partners and contributions from project partners through discussions at consortium meetings.

A brief overview of the approach is given below:

- The main task is to develop a mathematical model of the overall system.
- The overall model is made up of elements or sub-models describing the behaviour of each component (component models).
- Each component has an input from the previous component in the chain and an output that feeds the following component.
- The overall simulation model is used to study different scenarios, find optimal solutions and perform sensitivity analysis.
- The most important design parameters have already been identified.

Sub-models within the components describe the behaviour of each component and these are combined in one overall mathematical model. Each component has an input from the previous component in the chain and an output to the following component. Based on the component models, a computer model has been developed to describe the integrated CHPM2030 metal extraction and electricity generation system. The model is programmed in the Python programming language. A probabilistic approach is used to estimate the input parameters as well as the simulation results, based on Monte Carlo simulation. It consists of a loop that runs a series of functions that model each of the surface components.

The results of the work on Task 4.1 were presented in D4.1 Conceptual framework for CHPM power plant.

Task 4.2 *Process optimisation and simulations*

In principle, the geothermal reservoir (component 1 in Figure 1) as well as the production (component 2) and reinjection well (component 2) are components that could be described mathematically in similar way as other components in the system. In the development of the current integrated system the focus has been on the surface components and therefore the reservoir and the wells are not described by separates component models. This is a separate task that must consider the complexity of these components. They can be added in further studies if desired by building on already existing research and modelling of reservoirs and geothermal wells. The current system model uses fluid properties at the production wellhead as input. These are based on reservoir properties from known geothermal fields.

Component model for electrolytic metal recovery

An analytical model was created at VITO for electrolytic metal recovery from geothermal brines. The model is based on Faraday's laws assuming a concentration depend recovery rate and energetic efficiency. The electric power consumption is calculated from the amount of metal recovered and the energetic efficiency. The model is valid for noble metals, i.e., metals that have a standard reduction potential equal or above +0.34 V (for Cu).

The model was validated against the experimental data obtained in WP3. The experimental data reveals recoveries of 80-90%. The recovery tends to correlate with the initial concentration: high initial concentrations reveal slightly lover recovery (Table 1.3). It should be noted that batch experiments were used to evaluate metal recovery from brines. In a CHPM plant, flow through technologies will be used. In this case, recovery will depend on the contact time between the brine and the electrodes. It hence can be expected that the recovery will be a function of flow rate: with lower flow rates resulting in higher recoveries.

The energy consumption depends on the initial concentration of the ion. For high initial concentrations, the energy consumption approaches the theoretical value calculated by Faraday's laws. The electrical efficiency decreases with decreasing initial concentration.

Table 1.3: Recovery of Cu and energy consumption at 150°C, 50 bar and a potential of 500 mV vs Pt as a function of initial concentration (C_{in}).

C_{in} (ppm)	C_{end} (ppm)	Recovery	E (kWh/kg)
690	131	81.0%	0.4
345	40	88.4%	1.1
165	22.5	86.4%	2.1

The component model calculates the mass of metal recovery from the flow rate and the intial concentration:

$$m = Q \times C_{in} \times R$$

With Q the brine flow rate in l/s, C_{in} the initial metal concentration in g/l and R the recovery rate. R is calculated by an exponential function fitted to the experimental data:

$$a = 1 - e^{(-80./Q)}$$

'a' is used to calculate R using the numpy.random.normal function.

The corresponding energy consumption is derived from Faraday's laws:

$$I = m \times F_c \times \left| \frac{z \times e_{elec}}{mm} \right|$$

Component model for combined heat and power production

An analytical model for combined heat and power production (CHP) was developed by VITO in Python and integrated in the CHPM-system model. The model is based on the results of thermodynamic optimization of low-temperature (100-150°C) geothermal binary systems and binary CHP plants. The model was validated against reported efficiencies for geothermal binary plants. The model makes it possible to select a specific configuration to combine heat and electricity production from a single source. For simplicity of the calculation, a parallel configuration is assumed for high temperature heat supply and a series configuration for low temperature heat supply. The difference between high and low temperature heat supply is made based on the estimated outlet temperature of the binary cycle.

In case of a series configuration, the brine mass flow over the evaporator of the binary system is equal to the mass flow rate of the geothermal source. In case of a parallel configuration, the mass flow rate over the binary cycle is equal to:

$$\dot{m}_{orc} = \dot{m}_b - \dot{m}_{DH}$$

Where $\dot{m}_b$ is the mass flow rate from the production well(s) and $\dot{m}_{DH}$ is the mass flow rate over the heat exchanger of the district heating system. The $\dot{m}_{DH}$ is calculated based on the heat demand for district heating:

$$\dot{m}_{DH} = \frac{P_{DH}}{cp_b \times \left(T_{b,i} - T_{b,hto} - T_{pitch}\right)}$$

With P_{DH} the heat demand for the high temperature district heating system/heating application covered by geothermal [kW], cp_b the specific heat capacity of the brine [J/kg x °C], $T_{b,hto}$ the output temperature of the high temperature branch of the geothermal CHP installation [°C] and T_{pitch} the pinch temperature of the high temperature/parallel heat exchanger [°C]. $T_{b,hto}$ is calculated as the mixing temperature of the brine derived from the output of the ORC and from the high temperature/parallel heat exchanger for high temperature heat supply.

The net power output of the CHP module is calculated using the following equation:

$$kW_e^{net} = \frac{cp_b \times \left(T_{b,i} - T_{b,orco}\right) \times \dot{m}_{orc} \times \gamma_{en}^{cycle}}{1000 \times 100}$$

With $T_{b,i}$ the production temperature of the geothermal well(s) [°C], $T_{b,orco}$ the brine outlet temperature of the binary installation [°C], the $\dot{m}_{orc}$ the mass flow rate over the binary system [kg/s] and γ_{en}^{cycle} the net energy efficiency of the cycle.

c_{pb} is calculated from the brine temperature and salinity using a formula given by Batzle & Wang.

The net efficiency and brine outlet temperature of the binary system are calculated based on correlations of the results from a thermodynamic optimisation of binary cycles. Distinction is made between air cooled and water-cooled systems.

For air cooled systems, the net efficiency is calculated using the following correlation:

$$\gamma_{en}^{cycle} = \left(-5{,}182 \times 10^{-4} \times T_{b,i}^2 + 0{,}2307 \times T_{b,i} - 10{,}71\right) \times c\_T_0$$

With c_T_0 a term to correct for changes in the dead-state temperature:

$$c\_T_0 = \frac{\left(T_{b,i} - T_0\right) \times \left(556.6 + T_{b,i}\right)}{\left(546.3 + T_{b,i} + T_0\right)}$$

For water cooled system, the following correlations are used:

$$\gamma_{en}^{cycle} = \left(8{,}434 \times 10^{-2} \times T_{b,i} - 0{,}4457\right) \times c\_T_0$$

Component model for the gas diffusion electro-crystallisation metal extraction (GDEx)

The main contributor to the development of a mathematical model for the component Gas Diffusion Electro-Precipitation and Electro-crystallisation (GDEx) was ÍSOR. The model is based on laboratory test data presented in deliverable D3.2. The work included also cooperation with other project partners, especially VITO.

The calibration of the model for the gas-diffusion electro-crystallization component (GDEx) is based on data presented in deliverable D3.2. In the report the energy usage and ratios of recovered metals from brine is measured for different values of Mg and Ca concentrations, salinity (S), working electrode potential (Ewe), temperature (T), and pH. Most of these samples where simulated in the lab. The simulated samples can be divided into two groups: simulated samples that are based on real brine samples from England, Belgium, and Iceland and simulated samples where emphasis was put on studying Li and Al recovery for different parameters and brine compositions. The latter group make up the bulk of the lab simulated samples. Also, a few samples where composed of real brine from Romania.

The energy input used per kg of recovered metals and ratios of metal recovery are modelled via linear regression analysis using the StatsModel package in Python. For the model of energy per kg of recovered metals the logarithm is taken of the energy values. This is done to ensure that the model gives positive energy results and catches any power relations that connect the energy values to the input parameters. The resulting model is described by the following equation:

$$E_{inn} = \exp(\mathrm{A} + \mathrm{B} \cdot \mathrm{Mg} + \mathrm{C} \cdot \mathrm{Ca} + \mathrm{D} \cdot \mathrm{Ph} + \mathrm{E} \cdot \mathrm{S} + \mathrm{F} \cdot \mathrm{T} + \mathrm{G} \cdot \mathrm{Ewe})$$

where A, B, C, D, E, F, and G are the model parameters that are estimated from the regression analysis. The regression analysis was performed on the simulated brine samples that were used to study Al and Li extraction which we will call the lab samples. The reason for restricting the regression to the lab samples is that they compose the largest share of the samples. Furthermore, the other sample types, the simulated Iceland samples (samples 1 and 2), the simulated Belgium samples (samples 3 and 4), the simulated England samples (samples 5 and 6), and the real Romanian brine samples (samples 76 to 79) can be used to test the robustness of the model.

Two types of models were constructed: one where the model parameters are assigned the values produced from the linear regression analysis and another where model parameters are randomly assigned from normal distributions constructed from the values and standard deviations produced by the linear regression analysis.

Table 1.4: Model parameters for the energy input per kg of extracted metal found in Equation 1 according to the linear regression analysis.

	A	B	C	D	E	F	G
	[-]	$[(\mathrm{mg/L})^{-1}]$	$[(\mathrm{mg/L})^{-1}]$	[-]	$[(\mathrm{g/L})^{-1}]$	$[^{\circ}\mathrm{C}^{-1}]$	$[\mathrm{V}^{-1}]$
Value	1.35	1.64×10^{-3}	-0.82×10^{-5}	7.56×10^{-2}	4.99×10^{-3}	0.12×10^{-4}	1.71
Std.	0.35	0.18×10^{-3}	1.57×10^{-5}	2.24×10^{-2}	2.22×10^{-3}	6.56×10^{-4}	0.41

It is important to note that the flow rate of the experiments that are used to calibrate the model was 40 ml/min or around 6.6×10^{-4} L/s. The flow that a standard geothermal power plant consumes is on the order of 100 L/s or nearly five orders of magnitude larger. Therefore, in the final system model the model output based on current experimental results is extrapolated linearly by a factor on the order of magnitude of 10^5.

Component model for salinity gradient power (SGP-RE)

A mathematical model was constructed by VITO and converted to Python-code for predicting the performance of the salinity gradient power (SGP-RE) production. The model was validated and several cases were calculated with different salinities and temperatures. Afterwards, this model was implemented by ISOR in the overall CHPM2030 process model.

The SGP-RE process is modelled by using an approach described in Tedesco et al. in 2012 on the modelling of the reverse electrodialysis process with seawater and concentrated brines, combined with the 2-D approach described in Tedesco et al. in 2014.

The model uses the basic Nernst equation to solve the concentration profiles across the ion-exchange membranes of the dilute and concentrate compartments, resp. LOW and HIGH. The Nernst equation determines the membrane potential as a function of the concentration difference between dilute and concentrate. Applied to a cell pair (one AEM, one CEM, one dilute compartment, one concentrate compartment) the cell potential can be expressed as the sum of the two Nernst potentials across the respective membranes:

$$E_{\text{cell}}(x) = \alpha_{\text{CEM}} \frac{RT}{F} \ln \frac{\gamma_{\text{b}}^{\text{Na}}(x) C_{\text{b}}(x)}{\gamma_{\text{s}}^{\text{Na}}(x) C_{\text{s}}(x)} + \alpha_{\text{AEM}} \frac{RT}{F} \times \ln \frac{\gamma_{\text{b}}^{\text{Cl}}(x) C_{\text{b}}(x)}{\gamma_{\text{s}}^{Cl}(x) C_{\text{s}}(x)}$$

With subscripts ‘b’ referring to the HIGH and subscripts ‘s’ referring to the LOW. The concentration of the salt in the brine and surface water is mentioned (Cb and Cs) since equimolar amounts of Na and Cl will be present in the same solution. Concentrations and activity coefficients are expressed as function of the position along the path length of the stack (Cb(x)). Furthermore, the cell potential of a half-cell will be ‘tined’ by adding a tuning parameters to the equation above. The cell pair resistance consists of the resistance of the two membranes and the resistance of both HIGH and LOW compartments. Expressed as function of the position x along the pathlength axis this becomes:

$$R_{\text{cell}}(x) = R_{\text{b}}(x) + R_{\text{s}}(x) + R_{\text{CEM}} + R_{\text{AEM}}$$

This model for a single cell pair can be used to develop a higher scale model for a stack, consisting of n cell pairs, combining the first two equations in this section to determine the stack potential and internal resistance, hence the power output in combination with a given external load.

CHPM model results

In order to test the impact of the geological conditions on the energetic performance and metal recovery of a CHPM-plant, 5 scenarios were defined:

- The Reykjanes geothermal field (IS);
- The Landau geothermal plant (DE);
- The Balmatt geothermal plant (BE);
- The United Down geothermal project (Cornwall) (UK);
- The Beius geothermal field (Romania) (RO).

The scenarios cover different types of geothermal resources, ranges from high-temperature, volcanic fields to low-temperature sedimentary basins and EGS in granitic rock. The input parameters for the models were derived from measurements on brines from the geothermal fields/project, amended with literature data and the results of the leaching experiments performed in WP2. The geological conditions and information on heat demand was derived from the cases studies elaborated in WP6.

A brief summary of the main results as well as a more detailed results for the Landau field is given in *Table 1.5* and *Figures 1.14* and *1.15.*

Table 1.5: Overview of the main results obtained for the five selected scenarios.

Parameters	**Reykjanes**		**Landau**		**Balmatt**		**Cornwall**		**Romania**	
Q (L/s)	100		40		140		40		55	
T /°C)	150		123		121		175		140	
S (g/L)	35		103		169		10.8		10.8	
Metal extracted	**mg/L**	**kg/h**	**mg/L**	**kg/h**	**mg/L**	**kg/h**	**mg/L**	**kg/h**	**mg/L**	**kg/h**
Cu – Copper	17	6.12	0.038	0.005	0.017	0.009	0.4	0.058	0.2	0.04
As – Arsenic	0.11	0.039	9.7	1.4						
Ag –Silver	0.06	0.022								
Sb – Antimony	0.013	0.005								
Fe- Iron	40	14.4	40	5.8	300	151			0.7	0.14
Br – Bromine	30	10.8	100	14.4	70	35				
Zn – Zink	5	1.8							1.3	0.26
Sr – Strontium			230	33.1	220	111	13	1.9	200	40
Li – Lithium			50	7.2			6	0.86		
Ba – Barium					10	5			5	1
B – Boron							4	0.58		
Mn - Manganese							3.4	0.49		
Total metal extr.	**92.2**	**33.1**	**429**	**61.9**	**600**	**302**	**26.8**	**3.9**	**207**	**41.4**
El. generation MW_e										
Binary plant	3.64		1.3		2.3		2.3		1.6	
Salt gradient plant	0.083		0.084		0.6		0.008		0.01	
Electrolysis comp.			-0.12		-0.00016		-0.005		-0.003	
Gas diffusion comp.	-0.3		-0.6		-3		-0.08		-6	
Net el. generation	**3.4**		**0.7**		**-0.1**		**2.2**		**-4.4**	
Heat generation	**8.4**		**3.4**		**11.8**		**3.4**		**4.6**	

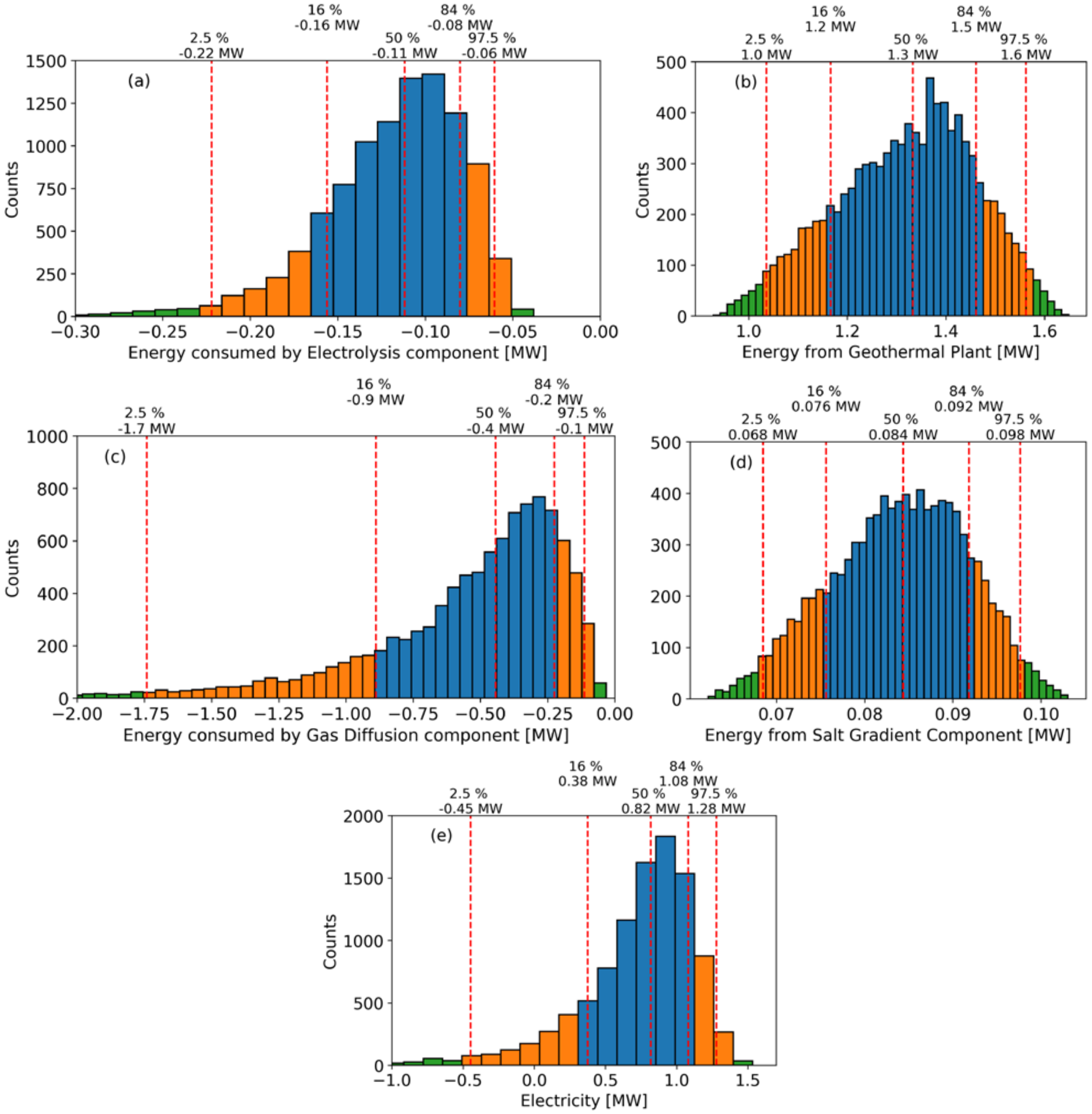

Figure 1.14: Resulting distributions for the Landau site: (a) the power input for the electrolysis component, (b) the power output of the geothermal power plant, (c) the power input for the gas diffusion component, (d) the power output of the salt gradient power component, and (e) the net electric power balance of the whole CHPM system.

Via the Monte Carlo method a rudimentary sensitivity analysis was performed for each scenario in the following way. For each scenario a fixed input parameter list is chosen where the average value is used for each of the parameters. This list of fixed parameters is then iterated and in each iteration the parameter in question is given a constant distribution that ranges ±10% from the average value while the other parameters remain fixed. For this new version of the parameter list we run the Monte Carlo model. We thereby can estimate the range of change in electric power generation or usage that results in varying each parameter in the parameter list, i.e. estimate the sensitivity of the model results to variation of each parameter.

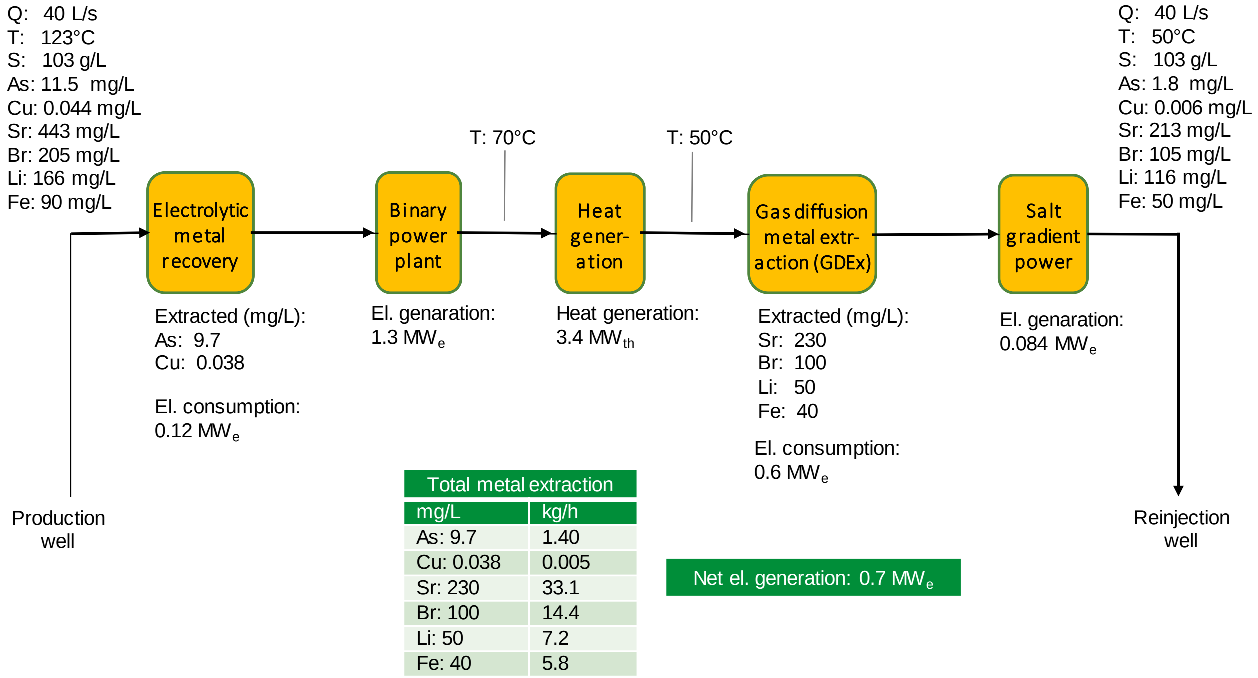

Figure 1.15: Model results for the Landau scenario

Task 4.3 CHPM schematics and blueprints

At this stage of the development of the technology for building and operating a CHPM pilot plant the consortium finds it impossible to provide detailed technical specifications or drawings of such an integrated system. Therefore, an emphasis has been put on preparing drawings and schematics of the laboratory equipment and other instruments that have been used in the project as well as relevant process schemes for the different CHPM technologies. These are presented in D4.3 CHPM schematics and blueprints.

WP4 deliverables

Deliverable no. and name:	**D4.1 Conceptual Framework for CHPM power plant**	
Due date:	30.09.2018	Delivered to the EC on 28.09.2018
Responsible:	ISOR	
Summary:	This deliverable describes a model framework for a CHPM facility and the approach that was used to develop a mathematical model that links the different components of the system in an overall system. The model can be used to simulate and optimise a CHPM plant.	
Deliverable no. and name:	**D4.2 Report on CHPM Process optimisation**	
Due date:	31.05.2019	Delivered to the EC on 30.06.2019, resubmitted in August 2019
Responsible:	VITO	
Summary:	This deliverable describes the computer model that has been developed to describe the integrated CHPM2030 metal extraction and electricity generation system. The individual technical components are described as well as the methodology to develop mathematical description of their performance and how they are combined in an integrated system. A probabilistic approach is	

	used to estimate the input parameters as well as the simulation results. The model is used on several scenarios to evaluate the performance of selected geothermal sites in Europe. The performance of each of these sites is simulated and sensitivity analysis presented.	
Deliverable no. and name:	**D4.3 CHPM schematics and blueprints**	
Due date:	30.06.2019	Delivered to the EC on 30.06.2019, resubmitted in Auguast 2019
Responsible:	ISOR	
Summary:	This deliverable contains drawings and schematics of the laboratory equipment and other instruments that have been used in the project as well as relevant process schemes for the different CHPM technological components.	

1.2.3 Work Package 5

WP title	**Integrated sustainability assessment**		
Lead beneficiary:	USZ	**Participants:**	UNIM, EFG, ISOR, NERC-BGS, LNEG, LPRC, MINPOL, IGR, SGU
Start date:	01.06.2017	**End date:**	30.06.2019

Objectives of the WP

Work package 5 assessed the expected environmental and socio-economic impacts for each component of the proposed CHPM technology followed by an overall systems-level performance assessment. This included a preliminary investigations concerning the environmental footprint of the envisioned technology scenarios. Comparison was then made with existing systems (both for power generation and mineral extraction) to have a good understanding of the relation of CHPM2030 to existing solutions from an environmental and economic performance point of view. Performance indicators considered the fact that CHPM envisions the integration of two, currently independent, processes for improved economics: the production of energy and the production of metals. Work was focused on the socio-economics, environmental and life-cycle issues, risks, risk ownership and possible risk mitigation, performance and cost targets together with relevant key performance indicators and expected impacts.

Synthesis of work done and results achieved

The work in this WP was organised in 6 tasks. Task 5.1 started in M18, Tasks 5.2, 5.4 and 5.5 in M24, Task 5.3 in M28, and Task 5.6 in M36. Six deliverables were submitted related to this work package, five of them in the recent reporting period *(Figure 1.16).*

***Task 5.1** Integrated sustainability assessment framework*

Work on this task was performed and completed in the former reporting period.

Figure 1.16: Deliverables of Work Package 5 in the reporting period.

Task 5.2 *Baseline economics for energy and mineral raw materials*

Task D5.2 was led by MinPol with major contribution from USZ. The task included the characterisation of Enhanced Geothermal Systems (EGS) the most similar energy infrastructure to the proposed CHPM technology. The description focused on the economy and financial issues of EGS projects. As for the metal recovery component, economic issues of the most similar mining method, in-situ leaching were also considered. This method is currently widely used in uranium industry. The CHPM technology was compared with other conventional and non-conventional energy sources and mining methods considering economic, financial and investment aspects. With an overview of the energy and raw material market, the proposed CHPM technology was positioned. Financial implications (investment, operating costs) of the CHPM technology were drafted and its economic feasibility was assessed.

The energy level of the CHPM technology is based on an unconventional geothermal energy source, which can be utilized by EGS power plants. Concepts and types of EGS power plants are quite well defined from a technological point of view. Many research projects, including CHPM2030, are aiming at the development of novel technologies, which would help EGS to become a more common and more effective source of energy. However, current levelised costs of energy (LCOE) for EGS scenarios are higher or at the same level as the current price of electricity for non-household consumers in the EU-28.

Task 5.3 *Decision support for economic feasibility assessment*

This task was also led by MinPol, and the main contributor was USZ. An economic simulation for CHPM facilities was carried out, and a tool using a system dynamics approach and Vensim simulation software was created. Data from other WPs as well as information gathered in Task 5.2 were used for the specification and updating of the model.

Vensim has a graphical modelling environment which allows the user to insert all the system dynamics elements and conceptualize, document, simulate, analyse, and optimize models of dynamic systems. All these elements can be manipulated using an equation editor, and the other functions within Vensim are for setting up the model, several user interface options and displaying the results of simulations *(Figure 1.17).*

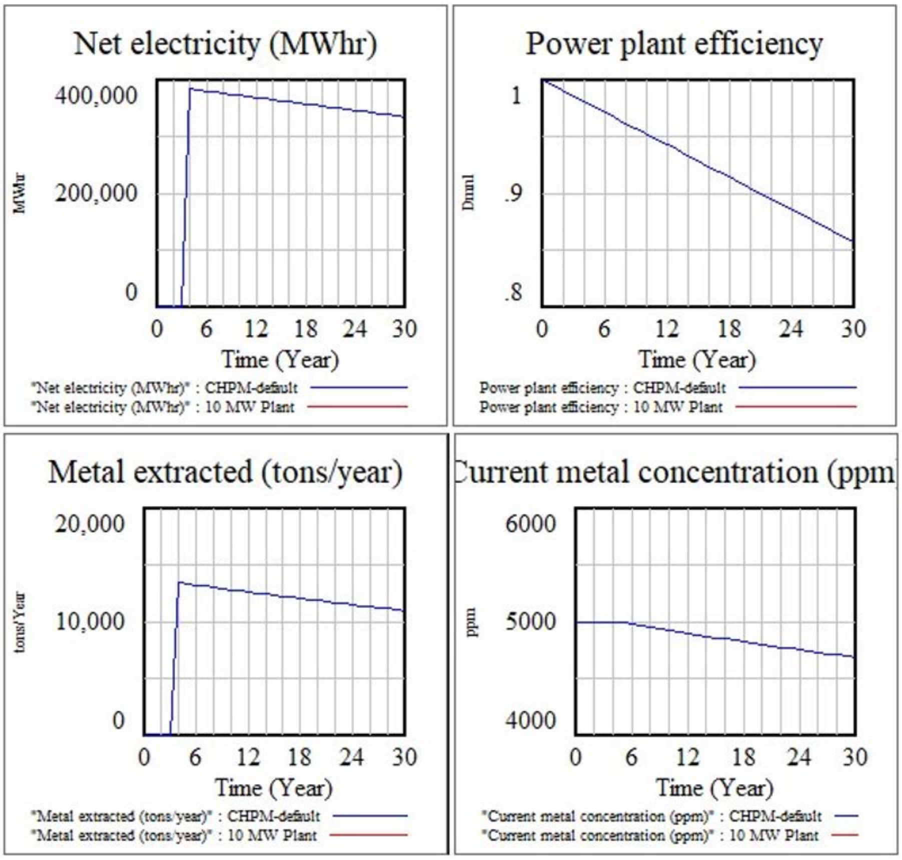

Figure 1.17: A graphical output of the CHPM Self-assessment tool

The CHPM Self-Assessment Tool allows users to simulate revenue stream from both energy and metal extraction levels. The tool also shows how it is influenced by costs, taxes, metal market, economic growth and other aspects. Users can modify values (use their own data) and compere graph outputs of different scenarios. The CHPM Self-Assessment Tool and CHPM default scenario can be downloaded from the MinPol website (http://www.minpol.com/references.html) and remain accessible after the project lifetime.

Task 5.4 *Social impact assessment and policy considerations*

MinPol was the responsible partner for this task with the major contribution of USZ. MinPol worked on policy implications and USZ assessed the social impact of the CHPM technology. These two sub-tasks may be seen as two different issues for the future of CHPM technology – social impacts at one side and policies, legislative or other related regulations on the other side. However, the social impacts are very sensitive topics that politicians (and relevant government institutions) turn into various policy strategies or regulatory frameworks. These policy frameworks will influence directly or indirectly the future development of CHPM projects.

The social impact assessment is focused on describing and suggesting the ‘best practises’ that future companies planning to run CHPM plants should develop to minimize social impacts on affected communities. The methodology was introduced based on criteria set by the International Association on Impact Assessment (IAIA). A great emphasis was put on stakeholder engagement into the CHPM project via the proposed Stakeholder Engagement Plan and the methods of stakeholder engagement *(Figure 1.18)*.

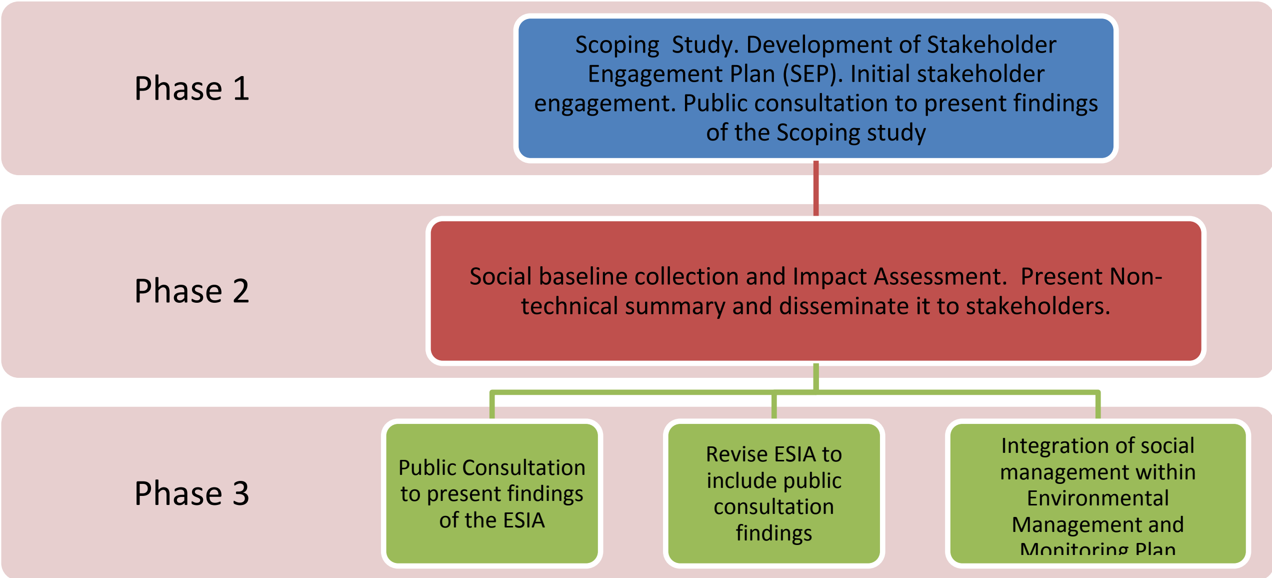

Figure 1.18: Social and community stages in an environmental-social impact assessment.

During the work on policy implications, the EU policy framework that could have direct or indirect effect on the development of the CHPM technology was reviewed. In a general sense, the EU policy framework (including funding schemes) is very supportive for deployment of clean, non-carbon energy solutions and also for innovative low-impact mining methods aiming to secure raw materials for sustainable grow. The EU directives related to the protection of the environment, water, groundwater established strict rules set out to minimise the impacts of CHPM technology and are in agreement with geothermal energy development. More challenging would be the clear definition of CHPM technology as it is ambiguous whether it would be regulated by Waste/Mining Waste or Industry Emission directives on a European scale, and such contradictions are even more pronounced in national legislations.

The EU policy framework in 'climate action' sets a suitable environment for the development of renewable sources such as geothermal. However, deep-geothermal energy, especially capital intensive EGS will need an even more supportive legislative context on both EU and national levels. CHPM will need similar actions, especially to introduce the EGS-orebody concept to legislative texts. The combined innovative energy and raw materials nature of the CHPM technology is much ahead of the relevant policies and legislative frameworks which would regulate this technology and business sector. Unifying deep-geothermal (EGS) and innovative metal extraction methods developed in a CHPM project under one licensing authority (ideally the respective member state's mining authority) and single resource ownership will be key aspects for development of the CHPM technology.

Task 5.5 *Environmental Impact Assessment*

The responsible partner for this task was USZ. The work concept was discussed with the Advisory Board. Following that, companies and experts with relevant experience were contacted for further co-operation and in order to gain access to the environmental impact assessment of an actual European EGS project. The work focused on the development of a methodology framework with recommendations on how an environmental impact assessment should be carried out for a CHPM facility. The ultimate objective of this task was to provide a comprehensive guideline for the future adopters of the CHPM concept to deliver a well-structured and detailed environmental impact assessment that meets the relevant standards and legislative framework of the host country, where the project is going to be developed. The goal was to compile a rather general approach with certain specific details corresponding to the applied technologies, instead of coming up with a made-up site and specifying all aspects accordingly. By doing so, flexibility was granted to the future environmental impact assessment practitioners to adjust this approach to their corresponding project.

Task 5.6 *Ethics Assessment*

Identifying what is 'ethically acceptable', required a detailed assessment of the environmental and social impacts from a proposed development, considered in the context of project alternatives and the broader need to supply energy and minerals. An ethical matrix which would help project stakeholders make informed decisions and choices in this context was developed.

It is essential to find solutions to avoid ethical impacts at each proposed development. Open communication must occur with stakeholders throughout all stages of a project, prior to exploration work commencing through to decommissioning. This will help people understand what is actually going on and how impacts from a development will be managed. At the same time, it is essential that the process of engaging stakeholders also helps to provide a broader education on supply and security or energy and minerals in Europe. As part of the ethical assessment, an ethical matrix should be developed at each proposed CHPM site. This process will help stakeholders make informed decisions about a development, providing an understanding of the likely environmental and social impacts, and how these impacts will be managed. Furthermore, an ethical assessment should also integrate with the ESIA (Environmental and Social Impact Assessment) project description and alternatives, outlining 'choices' relating to how energy and minerals are supplied and what the pros and cons are with different production and supply methods.

WP5 deliverables

Deliverable no. and name:	**D5.1 Integrated sustainability assessment framework**	
Due date:	31.12.2017	Delivered to the EC on 27.12.2017
Responsible:	USZ	
Summary:	This deliverable was submitted in the 2nd reporting period.	
Deliverable no. and name:	**D5.2 Economic feasibility assessment methodology**	
Due date:	31.08.2018	Delivered to the EC on 28.08.2018
Responsible:	MINPOL	
Summary:	This deliverable is focused on the description of economic related issues of two levels of the CHPM technology. Energy level, represented by enhanced geothermal system (EGS), is not a current rival to other conventional energy sources due to very high capital and operational costs. Simulations predict competitiveness of EGS in time framework of CHPM development. Extraction of metals from geothermal fluid is a commercially untested technology, which has no clearly defined operation costs. This makes the economic feasibility assessment difficult. Theoretical models suggest that positive economic feasibility can be achieved only on sites with higher concentrations of dissolved metals in brines and/or higher fluid flow.	
Deliverable no. and name:	**D5.3 Self-Assessment Tool**	
Due date:	30.04.2019	Delivered to the EC on 02.05.2019
Responsible:	MINPOL	

Summary:	This deliverable serves as a user guide for the installation and work-flow of the CHPM Self-Assessment Tool. This tool is based on a system dynamics approach and uses the free software Vensim Model Reader. The CHPM Self-Assessment Tool allows simulation of a revenue stream from both energy and metal extraction, and shows how it is influenced by costs, taxes, metal market, economic growth and other aspects. Users can modify values and comp are graph outputs of different scenarios.	
Deliverable no. and name:	**D5.4 Report on policy implications**	
Due date:	30.06.2019	Delivered to the EC on 29.06.2019
Responsible:	MINPOL	
Summary:	D5.4 is focused on social impact assessment and policy implications of the CHPM technology. A key aspect ensuring public acceptance of CHPM technology is the stakeholder engagement from the very beginning of a future CHPM project development. EU policy framework is very supportive for development of renewable energy sources and innovative low-impact mining methods. A combined innovative energy and raw materials target of CHPM technology comes before policies and legislative frameworks. Definitions of specific terms (EGS, EGS-orebody, etc.) and legislative unifying of both CHPM levels under one government authority will be key for CHPM development fro m a policy perspective.	
Deliverable no. and name:	**D5.5 Environmental Impact Assessment Framework**	
Due date:	29.02.2019	Delivered to the EC on 08.03.2019
Responsible:	USZ	
Summary:	The ultimate objective of this deliverable is to provide a comprehensive guideline for the future adopters of the CHPM concept to deliver a well-structured and detailed Environmental Impact Assessment that meets the relevant standards and legislative framework of the hosting country, where the project is going to be developed. Our goal was to compile a rather general approach with some specific details corresponding to the applied technologies, instead of coming up with a 'theoretical site' and specifying all aspects accordingly. By doing so we believe that we granted the future EIA practitioners the flexibility to adjust this approach to their corresponding project.	
Deliverable no. and name:	**D5.6 Ethics Assessment Report**	
Due date:	30.06.2019	Delivered to the EC on 29.06.2019
Responsible:	USZ	
Summary:	Undertaking an ethical assessment at each proposed development should be considered a part of the ESIA (Environmental and Social Impact Assessment) process. Identifying what is 'ethically acceptable', requires a detailed assessment of the environmental and social impacts from a proposed development, considered in the context of project alternatives and the broader need to supply energy and minerals. Developing an ethical matrix will help project stakeholders make informed decisions and choices in this context.	

1.2.4 *Work Package 6*

WP title	**Roadmapping and Preparation for Pilots**		
Lead beneficiary:	LPRC	**Participants:**	UNIM, USZ, EFG (with LTPs), ISOR, NERC-BGS, LNEG, VITO, IGR, KU Leuven, SGU
Start date:	01.12.2017	**End date:**	30.06.2019

Objectives of WP6

The CHPM technology is a low-TRL, novel, disruptive but fragile idea, which needs further nurturing and future oriented thinking. WP6 represents these forward-looking efforts and aims to set the ground for subsequent pilot implementation by working on three interlinked areas:

- mapping convergent technology areas (linked to CHPM exploration, development, operation and market),
- studying potential pilot areas,
- developing future research roadmaps.

These three areas were grouped under the WP6 tasks: Task 6.1 Horizon scanning & Visions; Task 6.2 Preparation for pilots; Task 6.3 Roadmapping.

Synthesis of work done and results achieved

The work in WP6, was implemented by the coordination and facilitation of LPRC, with the involvement of all partners, Advisory Board members and external experts. The outcomes from this work package are summarised in three deliverables *(Figure 1.19).*

Figure 1.19: Deliverables of Work Package 6.

***Task 6.1** Horizon Scanning and Visions*

This task involved two main activity areas in the 3rd reporting period: the 2nd round of the [CHPM2030 Delphi survey] and the [Visioning workshop].

The CHPM Delphi survey was a two-round expert input using a foresight tool, and it was completed with 133 participants from the minerals and the geothermal sectors worldwide. All project partners completed both rounds. Partners, especially EFG and UNIM, used their professional network and channels (website, social media, newsletters) to invite participants. The survey was built on the results of Horizon Scanning, and the 2nd round incorporated the results from the 1st one, so participants could re-evaluate their feedback. The survey provided insight about important, but uncertain areas in the future, while mapping convergent technology areas and emerging issues. The results have been processed by LPRC, and was used to define discussion topics and issues for the Visioning workshop.

The main outcome from this task is the definition of a wide array of convergent technologies and relevant issues that can support the implementation of the technologically challenging CHPM scheme by 2030/2050. Each theme included a range of subtopics that were used during the roadmapping process to define actions and targets. The 2nd round CHPM Delphi survey was successfully completed in the recent reporting period and integrated into the Deliverable 6.1. The survey reached 1120 Experts, and led to 133 completed surveys.

Task 6.2 *Preparation for pilots*

This task had three fields of activities in the present reporting period: 1) finalising the evaluation template for the study areas, 2) evaluating study areas, and 3) creating an EU spatial database on prospective locations.

The risk of not having enough data to show the potential of the CHPM2030 technology at the areas was pointed out, and mitigation measures were set up: developing a study area evaluation template and framework, online meetings and workshops, multiphase internal submissions and review process of the study area reports, identification of remaining gaps and recommendations.

The first step was the creation of the evaluation template (with the help of BGS, LNEG, IGR, SGU, UNIM, facilitated by LPRC) through online meetings, email communication, field trips and a workshop. This served as a 'checklist' for important characteristics to consider when looking into the CHPM potential. During the creation of the evaluation strategy, a field trip in Romania *(Figure 1.20)* was organised by IGR (BGS, UNIM, LPRC participated), following the previous Cornwall field trip (22-24th of May 2018) organised by BGS. A strong emphasis was given to 3D modelling and to compile all available geological information at one place for reinterpretation.

Figure 1.20: Participants of the Romania field trip (25-26 July 2018)

The 5 study areas from 4 countries have been evaluated according to this new strategy, investigating the CHPM potential. With the help of the reports on the study areas and the European outlook, the following items have been clarified:

- The information is available at each area,
- The CHPM potential based on the geoscientific data,
- Remaining gaps to be overcome in the future.

The evaluated areas are:
- Cornwall in South West England by BGS,
- The Portuguese Iberian Pyrite Belt by LNEG,
- Beius Basin and Bihor Mountains in Romania by IGR *(Figure 1.21)*,
- Two mining districts, Nautanen and Kristineberg in Sweden by SGU.

BGS staff produced a c. 160 page detailed report on SW England as part of T6.2.1. This worked with information sources reported in WP1, and also new information coming out of the ongoing geothermal investigations in SW England (e.g. the United Downs Deep Geothermal Power project, and also the GWatt project). A detailed reappraisal of the data was undertaken. In summary, the report considered the availability of geoscience information, the geological environment, geothermal characteristics, potential for deep metal enrichment, and technical, environmental, social and regulatory factors that could influence the future development of CHPM extraction technology in the region. Preliminary modelling of the Cornubian Batholith has been undertaken to improve understanding of its properties relevant to geothermal energy development. A regional model was constructed to understand the spatial relationship of key geological parameters. These data were used for the development of two site-scale models that aimed to improve understanding of the fracture network and flow pathways at the reservoir-scale. South-west England, and specifically Cornwall, is an excellent location for a pilot-scale CHPM system.

WP6 have provided BGS with an excellent springboard to be involved with EGS projects being funded as part of work within south-west England. These include the industry-led United Downs Deep Geothermal Power project, and the science-driven GWatt project. Being part of the CHPM2030 project was crucial in getting BGS involved in other work centred around SW England, and in the case of the GWatt project, was crucial to winning funding. As such, some of the findings from the CHPM2030 project (such as fracture models and potential for metal leaching) will have direct and immediate use in these ongoing UK projects – though it is more difficult to quantify at this time exactly the form this will take or the impact they will have. However, several of the protocols developed within the CHPM2030 project will be taken forward in these new projects, allowing us to continue to populate datasets relevant to the CHPM concept.

The report on the Portuguese Iberian Pyrite Belt (80 pages) provided by LNEG evaluated the Variscan metallogenic province, massive sulphides deposits, prospect for deep mineralization for CHPM potential. The study area report provided an update on the geoscientific data and information on SW IPB, 3D modelling (focused on the Neves-Corvo Mine), geophysical data. The future research programmes should investigate the deeper ore deposits, with 3D/4D modelling, new deep seismic studies, 3D electromagnetic forward modelling, 3D inversion. The Lombador orebody, is present at 2-3 km, and has the potential to extend the lifetime of the mine with CHPM technology. Strong cooperation with the mining company and government is recommended.

IGR contributed with the report from Romania (80 pages) providing information about the CHPM potential of Beius Basin (up and running geothermal heating system, Mg skarns, high geothermal potential), and Bihor Mountains (granodiorite-granite plutonic body related, skarns (Fe, Bo, Bi, Mo, W), and veins (Cu, Zn, Pb, sulphides). IGR has also developed a new 3D geological model, compiling all available geoscientific information of the study area. The future recommendations on this area describe new geothermal models (150 °C); refraction seismic for the plutonic body and mineral indications; fracture network modelling for understanding reservoir characteristics.

SGU assembled geological/geophysical data in two specific areas of Sweden, the Kristineberg and Nautanen mining districts. Discussions and visits with mining companies were carried out that provided unpublished data. As a result, the Swedish report (72 pages) described 2 ore provinces: Kristineberg area (Skellefte district, volcanogenic massive sulphide deposits, Zn, Cu, Au), and Nautanen area (Northern Norrbotten district, IOCG, Cu, Fe, Au). The challenges here are the low geothermal gradient, limited information at 5-7 km depth, low permeability and hydraulic conductivity, lack of information about deep-seated fluids. It is recommended that future exploration includes identification of metal bearing formation at crustal depths (seismic velocities, electrical resistivity), 3D/4D modelling, stimulation, involvement of the mining industry and ER regional development funds, achieving public acceptance, etc.

Beside evaluating concrete study areas, EFG led the European outlook for prospective locations, with the help of the its National Associations that are involved in the project as Linked Third Parties. In total, there were 24 countries covered: Belgium, Czech Republic, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Netherlands, Poland, Portugal, Serbia, Slovenia, Spain, Switzerland, Ukraine, Austria, Croatia, Cyprus, Luxembourg, Slovakia, Sweden, the United Kingdom. Each National Association had 3 tasks: 1) Area selection: definition of areas most likely to be a future CHPM candidate; 2) Basic area evaluation: the task continued with the evaluation of the basic characteristics of the selected areas; 3) CHPM characteristics: this task considered a deeper investigation and data evaluation of the most likely CHPM sites. EFG and LPRC provided instructions and templates for the LTPs and organised an orientation workshop, so they were fully informed about the task. Through continuous communication with the LTPs, EFG collected the 3 reports for most countries, describing the 3 tasks. The result is a selection of areas that have potential for future CHPM application, which has been uploaded to a publicly available spatial database: http://bit.ly/CHPMinfoplatform *(Figure 1.21).*

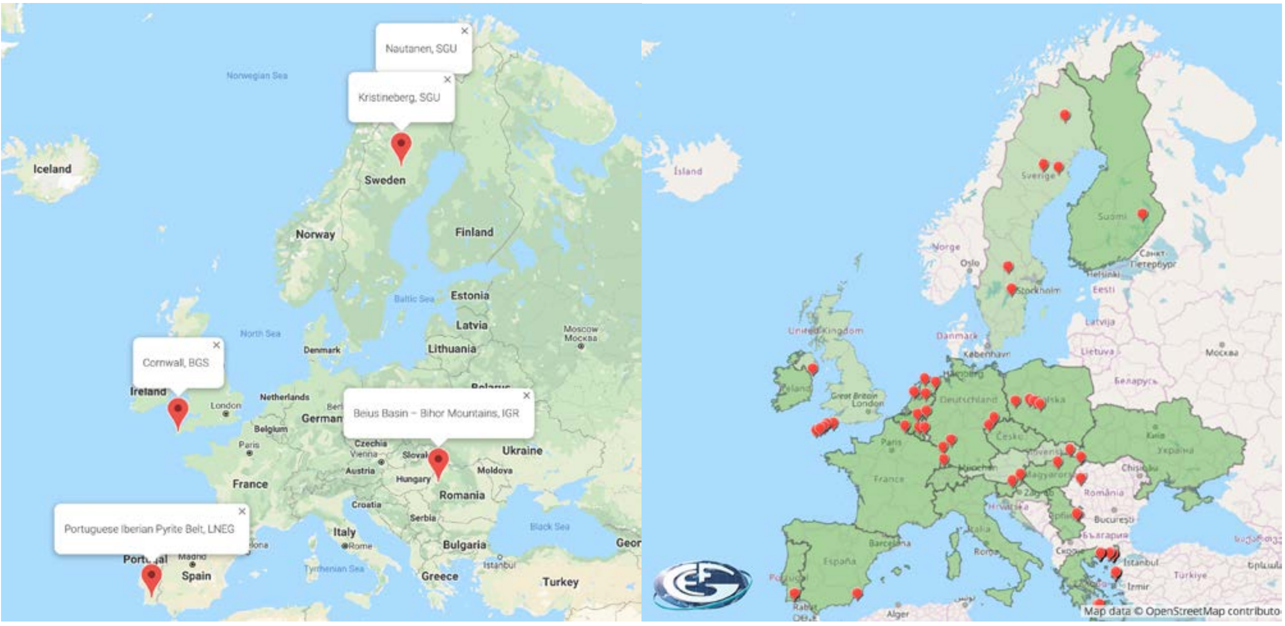

Figure 1.21: The 5 study areas (left) and the CHPM information platform (right)

Based on a previously identified risk, and since the report was expected to result in a considerable amount of pages, a multiphase internal submission was implemented: partners (BGS, LNEG, IGR, SGU) sent their reports in three stages: end of December, February, and March. The remaining differences in the study area reports, even after having the evaluation template, continuous communication, internal submission, and external reviewer, was largely due to the difference in data availability and readiness levels of the different areas.

The D6.2 Report on Pilots was submitted with contribution from partners: LPRC 1-59 pp, BGS 60-217 pp, LNEG 218-270 pp, IGR 271-349 pp, SGU 350-422 pp, EFG & LTPs 423-904). Reviewer of the deliverable 6.2 was ISOR.

Task 6.3 *Roadmapping*

This task had three future-oriented activities related to the 2030 and 2050 time horizons, building different layers of the CHPM roadmap: 1) CHPM component roadmap, 2) Preparation for future Pilots, 3) Overall concept of CHPM. The objective of Task 6.3 is to provide a timeline and direct support for the implementation of CHPM projects and support breakthrough research. These activities were built on the results of Task 6.1 and 6.2 and the contribution by all partners, AB members and external experts who were involved in this process. Each layer provided recommendations about how to advance the area and support future pilot implementation.

The 'CHPM component roadmap' provides a direct follow-up of all technological components, by describing the

- State-of-the-art (2019: current state of the component, achievements, results from the project, referenced to the relevant deliverable),
- Immediate research plan (2025: next actions, targets to continue the research on the technological component after the project),
- Pilot research plan (2030: requirements of the component before integrating it into a CHPM pilot application), and
- Long term objectives (2050: requirements of the component before integrating it into a CHPM commercial application) *(Figure 1.22)*.

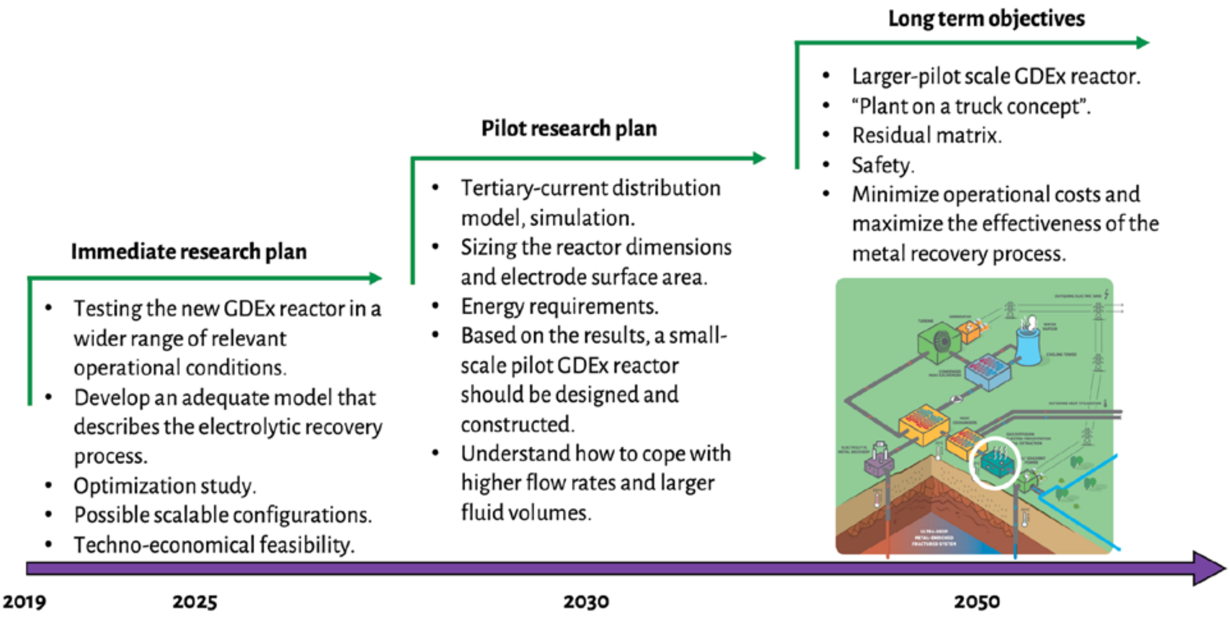

Figure 1.22: CHPM component roadmap for the GDEx (metal recovery via gas-diffusion electrocrystallization) component.

The following technological components were considered in the roadmapping process (in brackets the researchers participating in the process):

- Integrated reservoir management (Szanyi János, Máté Osvald, Tamás Medgyes, USZ);
- Metal content mobilisation using mild leaching (Chris Rochelle, Andrew Kilpatrick, BGS);
- Metal content mobilisation with nanoparticles (Steven Mullens, VITO);
- High-temperature and high-pressure (HTHP) electrolytic metal recovery (Ramasamy Palaniappan, Jan Fransaer, KU Leuven, Xochitl Dominguez-Benetton, VITO);

- Metal recovery via gas-diffusion electrocrystallization (GDEx), (Xochitl Dominguez-Benetton, VITO);
- Salinity-gradient power by reverse electrodialysis (SGP-RE) (Joost Helsen, VITO);
- System integration (Árni Ragnarsson, ISOR).

The 'Preparation for future pilots' study investigated the pathway to pilot implementation by 2030, by providing a detailed area description and future recommendations. This task was completed at five areas in Europe by their representing partner (Cornwall by BGS, Iberian Pyrite Belt by LNEG, Beius Basin/Bihor Mountains by IGR, Kristineberg and Nautanen by SGU). The recommendations covered

- Future exploration plans for the technological components (getting new geoscientific information, exploration methods and tools to obtain relevant information regarding the technological components (outlined in the evaluation template),
- Funding opportunities (EU funds projects, PPP, private investors, other financing),
- Stakeholder engagement (involved parties, end users, stakeholders, policy and regulatory issues).

The 'Overall concept of CHPM' study investigated the feasibility of combining geothermal energy with mineral extraction with the use of foresight tools such as Horizon Scanning, Delphi survey and Expert workshops. The emerging issues were split into four main themes (CHPM exploration, development, operation, market). These topics and their subtopics were delivered and refined through the foresight exercises in WP6.

The Roadmapping workshop was the continuation of the Visioning workshop with the involvement of the consortium partners (ISOR, VITO, UNIM, EFG, LPRC /host/, BGS) and external experts. The main task of the group work was the validation of previously identified targets (vision) and the backcasting exercise itself (actions). After the workshop, the LPRC team processed the results, and presented the findings in D6.3 about the recommendations on targets, actions, signposts, wildcards linked to exploration, development, operation, and market, including a visualisation for each theme *(Figure 1.23).*

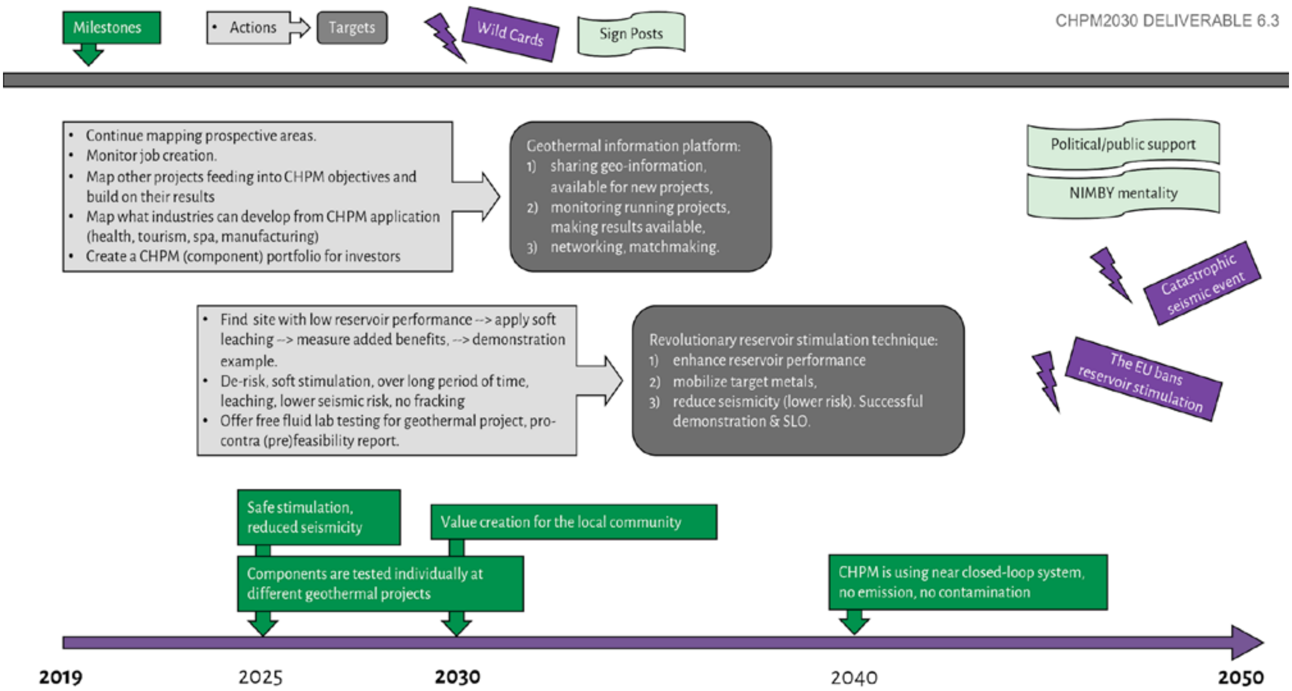

Figure 1.23: Milestones, actions, targets, wild cards, and signposts for CHPM development.

WP6 deliverables

Deliverable no. and name:	**D6.1 Report on Emerging and Converging Technologies**	
Due date:	30.04.2019	Delivered to the EC on 29.04.2019
Responsible:	LPRC	
Summary:	This report summarises the methodology and results of the three foresight tools (Horizon Scanning, Delphi survey, Visioning process) deployed during the CHPM2030 foresight exercise, outlines future emerging and converging technologies that can help the realization of the CHPM scheme, and ultimately, it presents a vision, an ambitious future state that will be used by the upcoming CHPM roadmap 2030 and 2050.	
Deliverable no. and name:	**D6.2 Reports on Pilots – compiled from 5 reports**	
Due date:	30.04.2019	Delivered to the EC on 20.05.2019
Contributors:	LPRC (responsible), EFG (with LTPs), UKRI-BGS, LNEG, IGR , SGU	
Summary:	This report presents an evaluation framework that facilitates the investigation of study areas for CHPM technology. The same methodology was applied to five areas (South West England, Portuguese Iberian Pyrite Belt, Romania Beius basin and Bihor mountains, Nautanen and Kristineberg in Sweden) evaluating their CHPM potential and characteristics. A European outlook for CHPM prospective locations has also been prepared, covering 24 countries.	
Deliverable no. and name:	**D6.3 Roadmap for 2030 and 2050**	
Due date:	30.06.2019	Delivered to the EC on 30.06.2019
Responsible:	LPRC	
Summary:	The CHPM roadmap for 2030 and 2050 has been developed using the synergetic combination of three future-oriented layers of studies: 1) The "CHPM component roadmap" study provides a direct follow-up of the current technological components (e.g. metal mobilization/recovery), by describing the state-of-the-art, immediate research plan (2025), pilot research plan (2030), and long term objectives (2050); 2) The "Preparation for future pilots" study investigates the pathway to pilot implementation by 2030, by providing a detailed description of the 5 areas in Europe (Cornwall, Iberian Pyrite Belt, Beius Basin/Bihor Mountains, Kristineberg and Nautanen) for CHPM potential with recommendation for future exploration, stakeholder engagement and funding opportunities. 3) The "Overall concept of CHPM" study investigates the feasibility of combining geothermal energy with mineral extraction with the use of foresight tools such as Horizon Scanning, Delphi survey and Expert workshops. Targets and actions have been identified related to exploration, development, operation, and market, all related to CHPM technology. A timeline has been constructed, including milestones, objectives and target to be achieved in order to arrive to pilots by 2030 and full-scale application by 2050.	

1.2.5 Work Package 7

WP title	**Dissemination and stakeholder involvement**		
Lead beneficiary:	EFG	**Participants:**	UNIM, USZ, ISOR, NERC-BGS, LNEG, VITO, LPRC, MINPOL, IGR, KU Leuven, SGU
Start date:	01.01.2016	**End date:**	30.06.2019

Objectives of the WP

Objectives of the WP

This Work Package sought dialogue and engagement as well as dissemination of thematic WP outputs towards the stakeholder communities, research organisations, universities, SMEs and large companies, investors, R&D funding organizations, relevant technology platforms, NGOs, professional associations and the general public.

Synthesis of work done and results achieved

Within this Work Package, the work was organised in 3 tasks, which lasted from the beginning to the end of the project.

Task 7.1 *Dissemination management*

During the first months of the project, a Communication and Dissemination Plan has been developed by EFG and presented to the consortium for approval. The communication and dissemination plan defined and prioritised key objectives for the dissemination of CHPM2030. Furthermore, it detailed the steps to be taken during the project's lifetime to achieve maximum impact and reach relevant audiences, combining timing and different media supports with consistent message content, structure and format. It also sets the framework to facilitate communications among the consortium members, between the consortium and stakeholders or the general public. The Communication and Dissemination Plan was reviewed in autumn 2018 to ensure that the project objectives and outcomes were communicated with optimum results until the end of the funding period. This review comprised an update of the stakeholder classification and led in the following months to a significant enlargement of the database of stakeholders interested in the future economic development of the CHPM technology. The update of the stakeholder database concerned especially the following categories of stakeholders: national, regional and local authorities; venture capitalists; environmental groups; the energy sector; and the raw materials sector.

Task 7.2 *Dissemination support services*

Most of the activities in this task were implemented by EFG, but the other partners and the linked third parties also contributed.

To help raise awareness to a broad range of stakeholders, both within the partner countries and in other EU countries, the consortium committed to generating at least four **newsletters** during the project's duration. These newsletters were produced by EFG in June 2016, June 2017, August 2018 and June 2019 with the aim of providing information about the project objectives and the current status of work. The newsletters were disseminated to the project's mailing list. EFG has also disseminated the newsletters via its own communication channels, reaching approximately 50,000 geoscientists all over Europe.

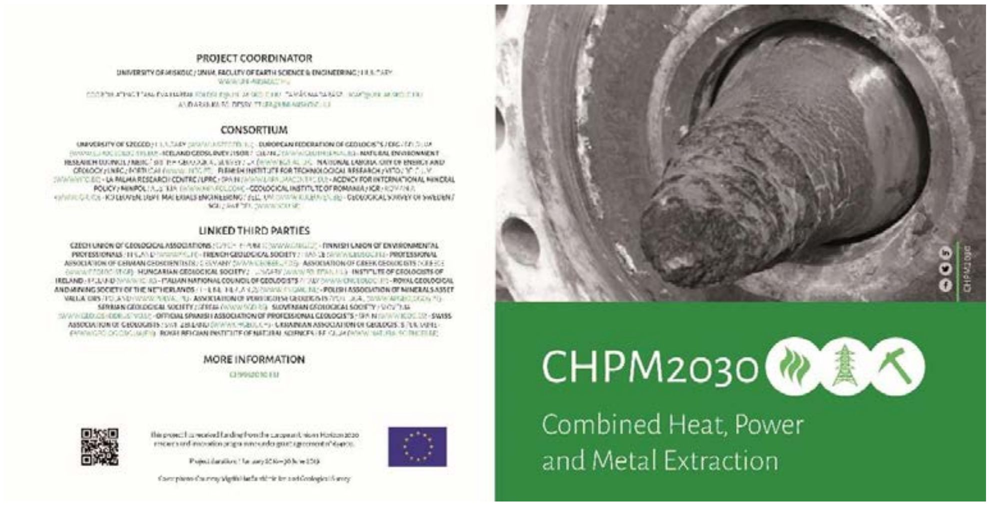

Figure 1.24: Cover and back pages of brochure 3.

In total, three project **brochures** have been designed by EFG and disseminated by all project partners. The text of these brochures was prepared by UNIM. The first version was designed to provide a general overview of the project objectives; the second one introduced interim project results and provided an overview of the current status of work. The third version, which was produced within the recent reporting period (M32), contained an overview of the project aims and a timeline displaying completed, ongoing and upcoming activities *(Figure 1.24)*. All brochure versions have been translated by the EFG Linked Third Parties into 14 European languages in total (Czech, Dutch, Finish, French, German, Greek, Hungarian, Italian, Polish, Portuguese, Romanian, Serbian, Slovenian, Spanish) and made available on the project website.

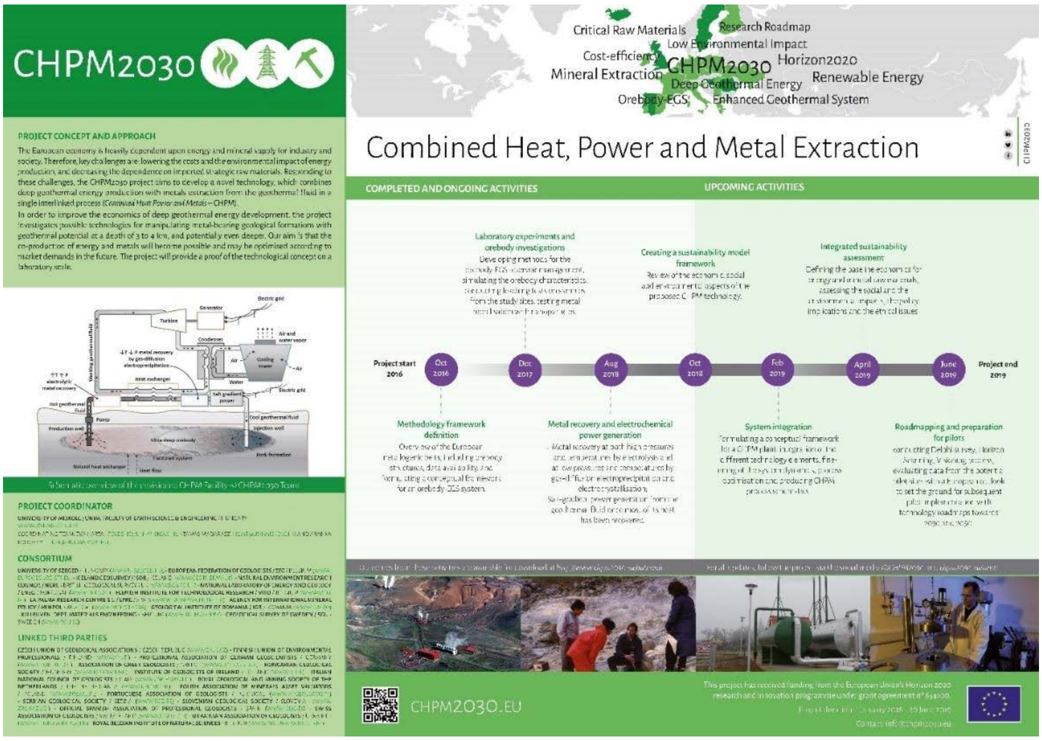

Figure 1.25: New version of the CHPM2030 poster.

In October 2018 EFG designed a new **poster**, providing general information about the project and a timeline displaying completed, ongoing and upcoming activities *(Figure 1.25)*. The poster was displayed at the EU Raw Materials Week in November 2018 and during the project's international conference in Delft, in May 2019.

All promotional material is made available to the project partners via the internal Google drive.

In total, two project **videos** have been produced by EFG. In January 2018 an animation video was released and broadly disseminated through social media. It can be accessed via the following link: https://youtu.be/GrZ3cmGFUf4. As of 28 June 2019, the video has been viewed 457 times on YouTube, 229 times on Twitter and 345 times on Facebook. In January 2019, a longer video (6:48 minutes) was released *(Figure 1.26)*. It presents the project's different work packages in detail from a technical point of view, combining animations and interviews with the Work Package leaders. As of 28 June 2019, it has been viewed 368 times on YouTube. It can be accessed here: https://youtu.be/KycincLt9FQ

Figure 1.26: Screenshots from the second CHPM2030 video in which the work package leaders are interviewed.

Since the project beginning, several **press releases** have been produced whenever a critical step was completed. In this reporting period, two press releases have been published: the first one in January 2019 to announce the project's work programme for 2019, the release of the second video and the organisation of the international conference. The second one was published in June 2019, shortly after the international conference which was held on 23 May 2019 in Delft.

In combination with the publication of the January 2019 press release, a **media kit** for journalists and other interested parties was produced *(Figure 1.27)*. The media kit included the press release, the factsheets and a promotional ad for the final conference. The kit has been disseminated broadly towards the CHPM2030 database of media outlets and journalists to increase general awareness of the project's objectives and launch the promotion of the international conference in Delft.

Since the early beginning of CHPM2030, **social media** have been used as a powerful tool to disseminate project aims and results on a regular basis, Twitter being the channel with the highest number of followers. The posts on the CHPM2030 twitter account have for instance received approximately 225,000 impressions since the start of project year 2 *(Figure 1.28)*.

Figure 1.27: Media kit produced at the beginning of 2019.

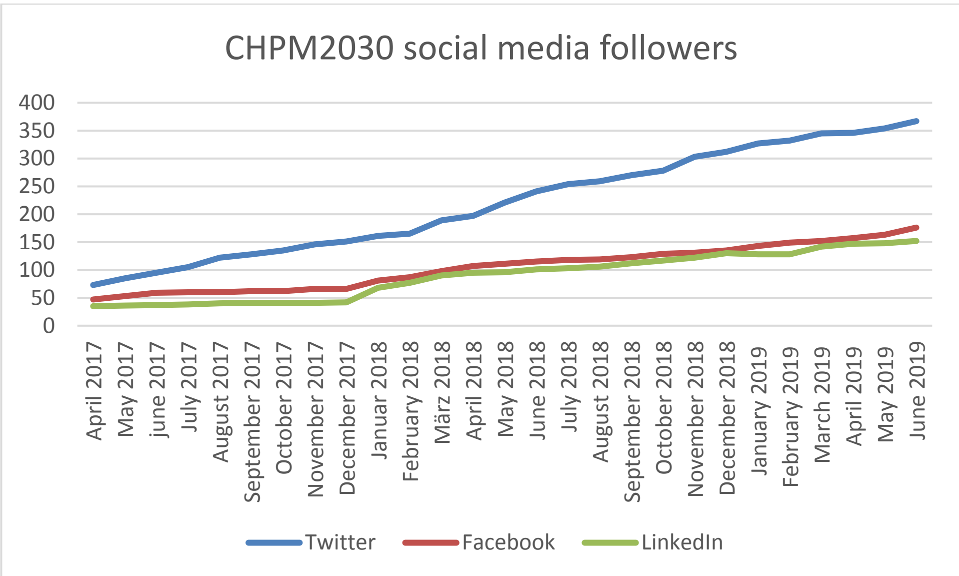

Figure 1.28: Number of CHPM2030 followers on Twitter, Facebook and LinkedIn.

In total, until the end of June 2019, around 450 social media posts relating to CHPM2030 have been published on both the project's and EFG's Twitter, Facebook and LinkedIn accounts. To boost dissemination towards the end of the project, dedicated social media campaigns about *D6.2 Report on pilots* and *D6.3 Roadmapping* were designed in collaboration with LPRC. The campaign on D6.2 was implemented at the end of June and well followed across all channels *(Figure 1.29)*. As of 28 June, it led to 491 downloads of the deliverable *6.2 Report on pilots* and its different annexes. The campaign on D6.3 is planned to be launched around mid-July to ensure a continuing news feed around the CHPM technology development after the EU-funding period.

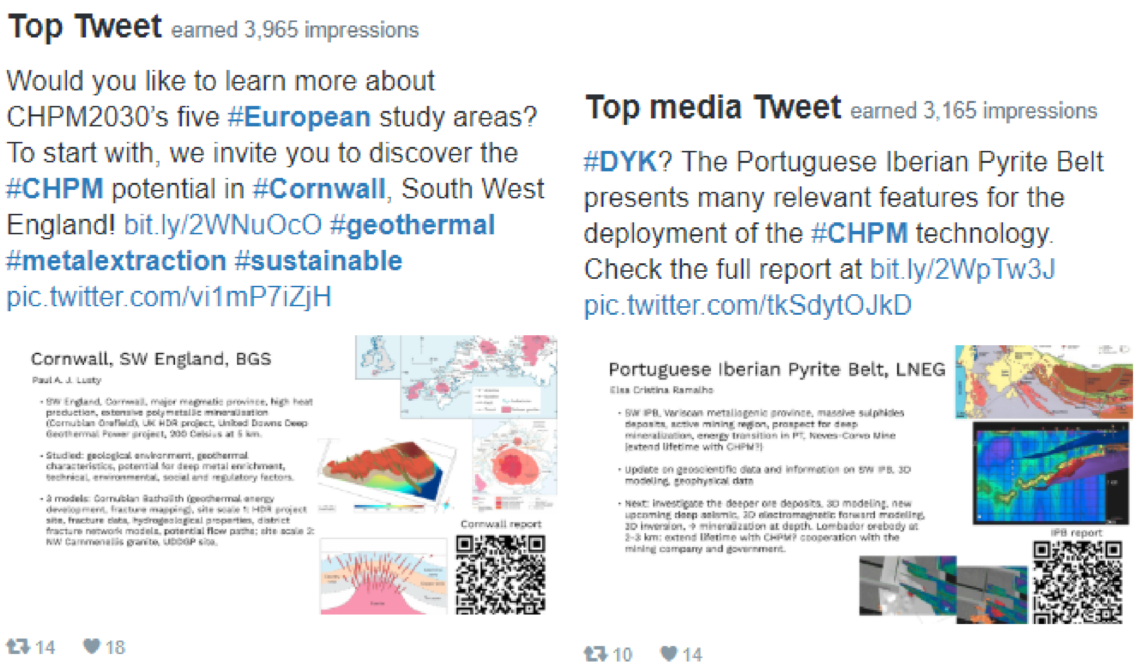

Figure 1.29: The June top tweets were linked to the social media campaign around D6.2.

The **CHPM2030 website** has been used all along the project duration as a major platform to spread news about the project development and outcomes. All promotional material is available through the website's outreach section (https://www.chpm2030.eu/outreach/) and the news section (https://www.chpm2030.eu/news/) has been fed with project updates on a regular basis. Since the website has been set up, 95,488 different persons have visited it. In total it has received 250,353 visits (as of 28 June 2019), meaning that each visitor returned to the website two to three times on average.

Throughout the project duration, the social media and website **statistics** have been monitored on a monthly basis to identify visitor trends and optimise the communication strategy.

As part of WP7, **EFG** has also disseminated project news using its inhouse communication channels which include among others the weekly EFGeoWeek news compilation, and the monthly GeoNews. Several short articles were published in the news section of the EFG website and the bi-annual European Geologist Journal. The approximate audience size of these online and print publications reached through EFG's national member associations amounts to ~50,000 persons covering mainly geoscience professionals, scientists and policy makers.

EFG's efforts in disseminating the project towards the European geoscientists' community have been supported by the **Linked Third Parties (LTPs)**, which are national member associations of EFG. They have disseminated the results of the CHPM2030 project at the national level in web portals, newsletters, magazines, articles, or during conferences, workshops, educational activities, exhibitions or any other relevant means. Seven EFG member associations did not take part in the project, but they also disseminated the project results at a basic level in their own countries (newsletter, website) as a part of the usual communication channel between EFG and the national professionals. One of the LTPs, the Royal Belgian Institute of Natural Sciences (RBINS), was focused on data collection only (WP1 and WP6) and did not take part in the dissemination. In this reporting period, the LTPs activities have led to 25 presentations or brochure distributions at conferences or workshops, and 298 web based promotional activities, including more than 100 reported social media posts. A complete summary of the outreach at national level is included in the attached table.

The other project partners contributed to the implementation of Task 7.2 as follows:

ISOR has participated in the review of dissemination materials.

IGR: The project brochures were distributed to the public during activities carried out within the Romanian National Museum of Geology, such as the European Museum Night (http://noapteamuzeelor.org/muzeu/muzeul-geologic/).

LPRC has developed a new infographic presentation of the CHPM schematics in collaboration with the technology developers and a graphic designer, with the aim of communicating the CHPM technology towards the industry and science community, but also to the general public and policy makers (see figure 1.8). In addition, LPRC has published several website posts about CHPM2030 (https://www.lapalmacentre.eu/tag/chpm2030/ and also actively disseminated the project via its social media channels (Twitter, LinkedIn, Facebook).

MINPOL has linked its website to the website of the CHPM2030 project, and the CHPM2030 system dynamic model and the Self-Assessment Tool – created as D5.3 - were uploaded on the MINPOL website as a permanent link for download.

UNIM has reviewed the reports on the interviews with the AB members. In addition, UNIM has contributed to and reviewed brochure 3, contributed to the preparation of the second CHPM2030 video, and participated in the preparation of newsletter 3 and 4.

SGU has participated in the review of dissemination materials.

Task 7.3 *Leveraging dissemination and dialogue*

During the reporting period, **EFG** has presented the project and disseminated promotional material at the following **conferences and workshops**:

- 4th Meggen Days of natural resources, September 2018, Germany;
- Horizon Geoscience: overcoming societal challenges, creating change dinner debate, September 2018, Belgium;
- EU Raw Materials Week, November 2018, Belgium *(Figure 1.30)*;
- CHPM2030 international conference, May 2019, Belgium.

Figure 1.30: CHPM2030 poster displayed at the EU Raw Materials Week 2018.

The project's final **international conference** (D7.14) was organised on 23 May 2019 in Delft, the Netherlands. To ensure broad dissemination and outreach, the event was organised back-to-back with the EuroWorkshop "Geology and the energy transition", in collaboration with the European Federation of Geologists (EFG) and the Royal Geological and Mining Society of the Netherlands (KNGMG).

Since January 2019, the event has been promoted actively through the CHPM2030, EFG and KNGMG websites. In total three circulars were sent to the CHPM2030 and the EFG mailing lists *(Figure 1.31).* The event was also broadly advertised through the social media channels of both EFG and CHPM2030. According to the CHPM2030 dissemination and communication plan, different stakeholder categories have been identified (policymakers; national, regional and local authorities; environmental groups; academic sector; venture capitalists; energy sector; raw materials sector; journalists and influencers). A dedicated invitation was prepared and disseminated for each of these target groups in spring 2019. In addition, the EFG LTPs have promoted the conference actively at a national level. For all promotional efforts, a common visual identity, closely aligned with the CHPM2030 style guide, was used.

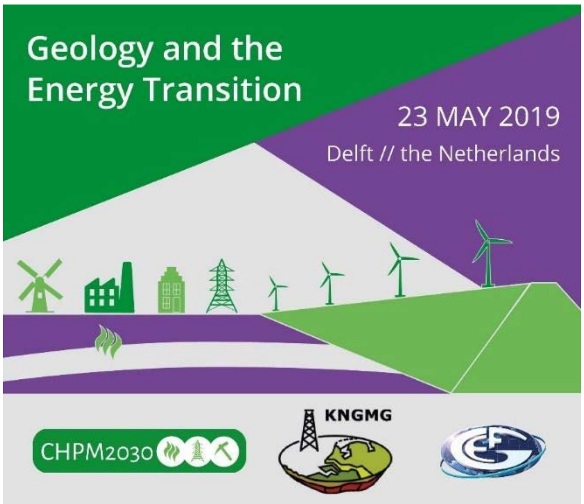

Figure 1.31: Banner of the CHPM2030 international conference and EFG's workshop on energy transition.

In total, 96 persons registered for the final Conference, and approximately 90% of them attended the event. There was a single morning session and two parallel technical sessions in the afternoon. As the CHPM2030 session was in the afternoon, it was attended by approximately half of the participants, e.g. 40 persons.

The overall aim of the event was to provide insights into the energy transition and how it affects geosciences. The morning session ("Policy discussed by policymakers") debated the policies that have been adopted to encourage the energy transition to gain an understanding of how these policies will provide directions for future developments. The aim for the afternoon was to present actual projects where geosciences play a crucial role in the implementation of the energy transition: "Projects presented by geologists for geologists". Furthermore, it was the aim of the organisers that the information provided and knowledge gained would improve the understanding of the future role geoscientists have to play in the energy transition, facilitating cross-fertilisation between different scientific areas and contributing to bring our society a step closer to reaching the goal of zero CO_2 emissions.

Accordingly, two parallel sessions were organised in the afternoon to present concrete examples of projects where geosciences play a key role in the implementation of the energy transition. The first session was dedicated to the CHPM2030 project, with the aim to present preliminary project outcomes, and the second session presented several other examples of projects where geoscientists are actively involved in the energy transition (e.g. deep underground storage of CO_2).

The session dedicated to the CHPM2030 project aimed at providing a complete overview of the work carried out during the project lifetime and presented an outlook on the future development of CHPM technology *(Figure 1.32).* The following presentations were delivered by the project partners:

- ‘Overview of the CHPM2030 project results’ by Éva Hartai and Tamás Madarász (CHPM2030 project coordinators, UNIM);
- ‘Metal content mobilisation from deep ore bodies’ by Chris Rochelle (BGS);
- ‘Metal recovery from geothermal fluids’ by Xochitl Dominguez and Jan Fransaer (VITO);
- ‘Salt gradient power generation by reverse electrodialysis’ by Joost Helsen (VITO);
- ‘System integration and conceptual framework for the CHPM plant’ by Árni Ragnarsson (ISOR);
- ‘Economic and environmental aspects of the CHPM technology’ by Wojtech Wertich (MinPol) and Máté Osvald (USZ);
- ‘2030 and 2050 Roadmaps for the CHPM technology’ by Tamás Miklovicz (LPRC).

Figure 1.32: the CHPM2030 partners presenting the project during the final conference.

After the event, a press release was issued and disseminated broadly within the network of EFG, its Linked Third Parties, and the CHPM2030 project. The presentations given were made available through the conference website.

Besides EFG, the other project partners contributed to Task 7.3 in the recent reporting period according to the followings:

BGS has been working towards paper and conference outputs/presentations (mainly resulting from outputs from WP2). It prepared the following papers and presentations:

- M. Osvald, A.D. Kilpatrick, C.A. Rochelle, J. Szanyi, T. Medgyes and B. Kóbor (2018). Laboratory Leaching Tests to Investigate Mobilisation and Recovery of Metals from Geothermal Reservoirs. In ‘Geothermal Systems: Interdisciplinary Approaches for an Effective Exploration’, special volume of Geofluids, vol. 2018, Article ID 6509420, 24 pages, 2018. https://doi.org/10.1155/2018/6509420.
- M. Osvald, A.D. Kilpatrick, C.A. Rochelle, J. Szanyi, T. Medgyes and B. Kóbor (2019). Batch and flow-through leaching of different metallic rocks under geothermal reservoir circumstances. Abstract presented at the EGU General Assembly 2019, and submitted to

ITS2.7/HS11.71/BG1.37/ERE6.8/GMPV3.6 – Interacting Geofluid Systems – Research and Innovation.
- Presentation of a summary of findings from WP2 at the Euroworkshop "Geology and the Energy Transition', Delft, 23 May 2019.
- C. Rochelle, A. Kilpatrick, M. Osvald, J. Szanyi, T. Medgyes and B. Kóbor (accepted). Laboratory leaching tests to investigate mobilisation of metals within engineered geothermal reservoirs. Submitted to 16th International Symposium on Water-Rock Interaction, Tomsk, Russia (on July 21-26, 2019).

BGS has also distributed CHPM2030 outputs as part of engaging with ongoing or planned EGS projects in SW England - the United Downs Deep Geothermal Power project, and the GWatt project. BGS staff (Lusty and Haslam) presented some of the SW England outputs from WP6 of the CHPM2030 project at the GWatt project startup meeting.

Finally, BGS has ensured integration, and compatibility, with tasks in a new UK-funded, 3.5-year project called 'GWatt', which started in January 2019. This science-led project will also focus on the geothermal potential of SW England. It will focus on fractures and fluid movement in the granitic basement and will extend site-specific studies to a more regional scale. A short overlap between the CHPM2030 and GWatt projects effectively allows a 'handover' of data, which can be continued to be gathered and datasets extended during the GWatt project. In particular gathering key data on fracture networks and deep geothermal fluid compositions.

ISOR participated in the CHPM2030 International Conference in Delft, and provided a presentation on the CHPM system integration.

LNEG has disseminated the project at the following events:
- VIII Jornadas APG "O paradigma energético" (22.02.2019, FCUL, Lisboa, Portugal
- 27th Colloquium of African Geology &17th Conference of the Geological Society of Africa, Aveiro, Portugal, 21-28.07.2018).

An article on the assessment of the Neves-Corvo characteristics to introduce CHPM technology is under preparation by Ramalho, E. C., Carvalho, J. and Matos, J.

IGR has participated in the 'EGU General Assembly 2019' in Vienna with the poster '3D Structural Model in Beius, Basin and its adjacent areas, Romania; a study to propose a potential location for the installation of a CHPM system' (authors: Catalin Simion and Stefan Marincea). Costs of these activities were supported from other sources than the project budget.

LPRC has presented and/or promoted CHPM2030 at several events:
- IEA - International Workshop on Geothermal Energy (8-9 of April 2019, Gran Canaria), presentation by Adrienn Cseko + project brochures.
- Turku Futures conference CHPM roadmap presentation and abstract, Tamas Miklovicz;
- Participation in the geothermal conference: the impact of EU R&D funding (09/20/2018) and distribution of project brochures.
- Participation in the ETIP-DG 7th Stakeholders Meeting (09/01/2019), Tamas Miklovicz;
- Participation in the CHPM2030 International Conference - Tamas Miklovicz.
- Organisation of Visioning and Roadmapping workshops with external experts: Tamas Miklovicz; Marco Konrat and Ariadna Ortega.

In addition, LPRC has carried out a Delphi survey (2nd round) reaching out to external experts (see D6.1 page 93, Table 5); Tamas Miklovicz, Balazs Bodo and Marco Konrat.

MINPOL participated in the CHPM2030 International Conference in Delft, and provided a presentation on the economic and environmental aspects of the CHPM technology.

UNIM participated in the following events and promoted the project by presentations:
- ETIP-DG Annual Conference 2018, 19.06.2018, Brussels (Tamás Madarász).
- EuroWorkshop: Geology and Energy transition, 23.05.2019, Delft (Éva Hartai Tamás, Madarász)
- European Geothermal Congress, 12.06.2019, the Hague (Tamás Madarász, Péter Szucs)

UNIM also published the following article:
- Éva Hartai, Tamás Madarász & the CHPM2030 Team: Co-production of clean energy and metals – the CHPM concept. European Geologist, vol. 47, 10-15, DOI: 10.5281/zenodo.2673784

USZ promoted the project by presentations and posters at the following events:
- 10th European Geothermal PhD Day, Postdam, 25-27.02.2019 (Máté Osvald)
- EGU General Assembly 2019, Vienna, 7-12.04.2019 (Máté Osvald)
- European Geothermal Congress, The Hague, 11-14.06.2019 (Máté Osvald)
- 16th International Symposium on Water-Rock Interaction, Tomsk, Russia, 21-26.07.2019 (Máté Osvald)

SGU has presented the project at the following events:
- GeoTherm, Baltic Sea Symposium, 13.02.2019, Offenburg, Germany (Gerhard Schwarz).
- International Ground Source Heat Pump Association (IGSHPA) workshop, 18-20.2018, Stockholm, Sweden (Gerhard Schwarz).
- Innovation cluster warm & cold workshop, 15.05.2019, Stockholm, Sweden (Gerhard Schwarz).

VITO participated in the CHPM2030 International Conference in Delft with two presentations: results of the GDEx experiments and the additional power generation by SGP-RE.

Other presentation related to WP3 by VITO:
- Americas International Meeting on Electrochemistry and Solid State Science, 2018, Mexico (X. Dominguez-Benetton, G Pozo, R Prato Modestino, P De la Presa, P Marin, J Fransaer)

VITO also submitted the following scientific articles:
- X. Dominguez, J.C. Varia, G. Pozo, O. Modin, A.T. Heijne, J. Fransaer, K. Rabaey (2018): Metal recovery by microbial electro-metallurgy. Progress in Materials Science, 94, 435-461, DOI: 10.1016/j.matsci.2018.01.007
- B. C. Rutely C., Fontmorin Jean-M., Tang W. Z., Dominguez-Benetton X. and Sillanpaa M. (2018): Towards reliable quantification of hydroxyl radicals in the Fenton reaction using chemical probes. RSC Advances, 2018, 8, 5321–5330, DOI: 10.1039/c7ra13209c

In summary, the main achievements from WP7 in the present reporting period are as follows:

The consortium has produced additional **electronic and printed deliverables** that support the efforts made by all partners to promote the project:
- Brochure 3 has been produced (M32), translated by LTPs into 14 languages and disseminated at national and international level;
- Newsletter 3 and 4 have been produced (M32 and M42) and broadly distributed;
- A second project video has been created and disseminated (M37);

- A press release about the project's work plan for 2018 and a media kit for journalists have been released in parallel with the second video (M37);
- A press release about the international conference has been produced and disseminated broadly (M42);
- Social media campaigns have been conducted to promote D6.2 and D6.3 (M42).

Consequently, an extensive list of **outreach** activities has been achieved, including:
- 44 presentations (oral and posters) were made at conferences and workshops both at national and international level;
- The project's final international conference has been organised (M41) and increased the awareness about CHPM2030 both through the event promotion and the press release published as a follow-up action;
- 7 articles were submitted to peer reviewed journals and conference proceedings;
- More than 350 news articles were published on websites and in newsletters;
- More than 600 social media posts were made.

The full list of dissemination activities is attached to this report.

WP7 deliverables

Deliverable no. and name:	**D7.1 Basic project website**		
Due date:	01.02.2016	Delivered to the EC on 01.02.2016	Status: approved
Responsible:	EFG		
Summary:	This deliverable was completed in the first reporting period.		
Deliverable no. and name:	**D7.2 Final project website**		
Due date:	30.06.2016	Delivered to the EC on 28.06.2016	Status: approved
Contributors:	EFG		
Summary:	This deliverable was completed in the first reporting period.		
Deliverable no. and name:	**D7.3 Project image and stylebook**		
Due date:	30.04.2016	Delivered to the EC on 20.04.2016	Status: approved
Responsible:	EFG		
Summary:	This deliverable was completed in the first reporting period.		
Deliverable no. and name:	**D7.4 Communication and Dissemination Plan**		
Due date:	30.06.2016	Delivered to the EC on 28.06.2016	Status: approved
Responsible:	EFG		
Summary:	This deliverable was completed in the first reporting period.		
Deliverable no. and name:	**D7.5 Brochure First edition**		
Due date:	30.06.2016	Delivered to the EC on 28.06.2016	Status: approved
Responsible:	EFG		
Summary:	This deliverable was completed in the first reporting period.		
Deliverable no. and name:	**D7.6 Brochure Update 1**		
Due date:	30.06.2017	Delivered to the EC on 17.06.2017	Status: approved
Responsible:	EFG		
Summary:	This deliverable was completed in the first reporting period.		
Deliverable no. and name:	**D7.7 Brochure Update 2**		

Due date:	31.08.2018	Delivered to the EC on 16.08.2018	
Responsible:	EFG		
Summary:	The third version of the brochure contains an overview of the project aims and a timeline displaying completed, ongoing and upcoming activities. It has also been translated by EFG's Linked Third Parties to facilitate promotion at national level.		
Deliverable no. and name:	**D7.8 Newsletter 1**		
Due date:	30.06.2016	Delivered to the EC on 28.06.2016	Status: approved
Responsible:	EFG		
Summary:	This deliverable was completed in the first reporting period.		
Deliverable no. and name:	**D7.9 Newsletter 2**		
Due date:	30.06.2017	Delivered to the EC on 19.06.2017	Approved
Responsible:	EFG		
Summary:	This deliverable was completed in the first reporting period.		
Deliverable no. and name:	**D7.10 Newsletter 3**		
Due date:	31.08.2018	Delivered to the EC on 16.08.2018	
Responsible:	EFG		
Summary:	The third version of the newsletter provides updated information on the current status of the project. It has been disseminated to the project's mailing list and via the EFG communication channels reaching approximately 50,000 geoscientists all over Europe.		
Deliverable no. and name:	**D7.11 Newsletter 4**		
Due date:	30.06.2019	Delivered to the EC on 29.06.2019	
Responsible:	EFG		
Summary:	The fourth version of the newsletter provides updated information on the current status of the project. It has been disseminated to the project's mailing list and via the EFG communication channels reaching approximately 50,000 geoscientists all over Europe.		
Deliverable no. and name:	**D7.12 Press-releases and media-kits related to CHPM2030 initiatives and outcomes**		
Due date:	30.06.2016	Delivered to the EC on 28.06.2016	Status: approved
Responsible:	EFG		
Summary:	This deliverable was completed in the first reporting period.		
Deliverable no. and name:	**D7.13 Fact sheets on the CHPM technology**		
Due date:	31.12.2017	Delivered to the EC on 28.06.2016	Status: approved
Responsible:	EFG		
Summary:	This deliverable was completed in the first reporting period.		
Deliverable no. and name:	**D7.14 International Conference**		
Due date:	31.05.2019	Delivered to the EC on 29.06.2019	
Responsible:	EFG		
Summary:	The international conference was organised on 23 May 2019 in Delft, the Netherlands. To ensure broad dissemination and outreach, the event was held back-to-back with the EuroWorkshop "Geology and the energy transition", in collaboration with the European Federation of Geologists (EFG) and the Royal Geological and Mining Society of the Netherlands (KNGMG). The event has been attended by approximately 100 participants.		

1.2.6 Work Package 8

WP title	**Project management**		
Lead beneficiary:	UNIM	**Participants:**	USZ, EFG, ISOR, NERC-BGS, LNEG, VITO, LPRC, MINPOL, IGR, KU Leuven, SGU
Start date:	01.01.2016	**End date:**	30.06.2019

Objectives of the WP

The objective of WP8 is to ensure a smooth and on-time execution of the project for the entire consortium, based on the description of work and in accordance with the European regulations. Work includes project planning, monitoring of the project progress, maintenance of effective communication and exchange of relevant information within the consortium and with the European Commission. The coordination work is shared among the three members of the Coordinating Team.

Synthesis of work done and results achieved

The work in this WP is organised in 6 tasks. Below the activities and the results are listed by tasks.

Task 8.1 *Coordination and supervision of project activities*

University of Miskolc set up the project coordination team during the GA preparation phase. The team includes the Project Coordinator (Éva Hartai), the Project manager (Tamás Madarász) and the Financial and Technical Assistant (Aranka Földessy).

The Coordinator maintains contact with the Project Officer and the consortium members. In order to facilitate internal communication a Google Groups Forum was established for changing e-mails and used from the beginning to the end of the project. The group (chpmpartners@googlegroups.com) involves all project participants (research and administrative). The mailing list has been continuously updated. The Coordinator regularly informs the consortium members about any project related news and events, controls and harmonises the project implementation, checks the financial completion and the deadlines, and monitors the duties of partners and the submission of deliverables. No major deviations related to the deliverables and the financial completion occurred in the recent reporting period. The Project Manager is responsible for the planning and implementation of the tasks at University of Miskolc, and supervises all administrative and financial matters at the institution. The Financial and Technical Assistant controls the financial matters at institutional and project levels, and provides technical assistance to the Coordinator and the Manager.

A Google Drive Account was created in the early phase of the project in order to share project related documents. The uploaded documents are organised in folders and they are continuously updated. A special folder is dedicated to the Advisory Board where all information and documents they may need are uploaded. The main folders are shown in *Figure 1.33*. Within the main folders, the documents are organised in subfolders.

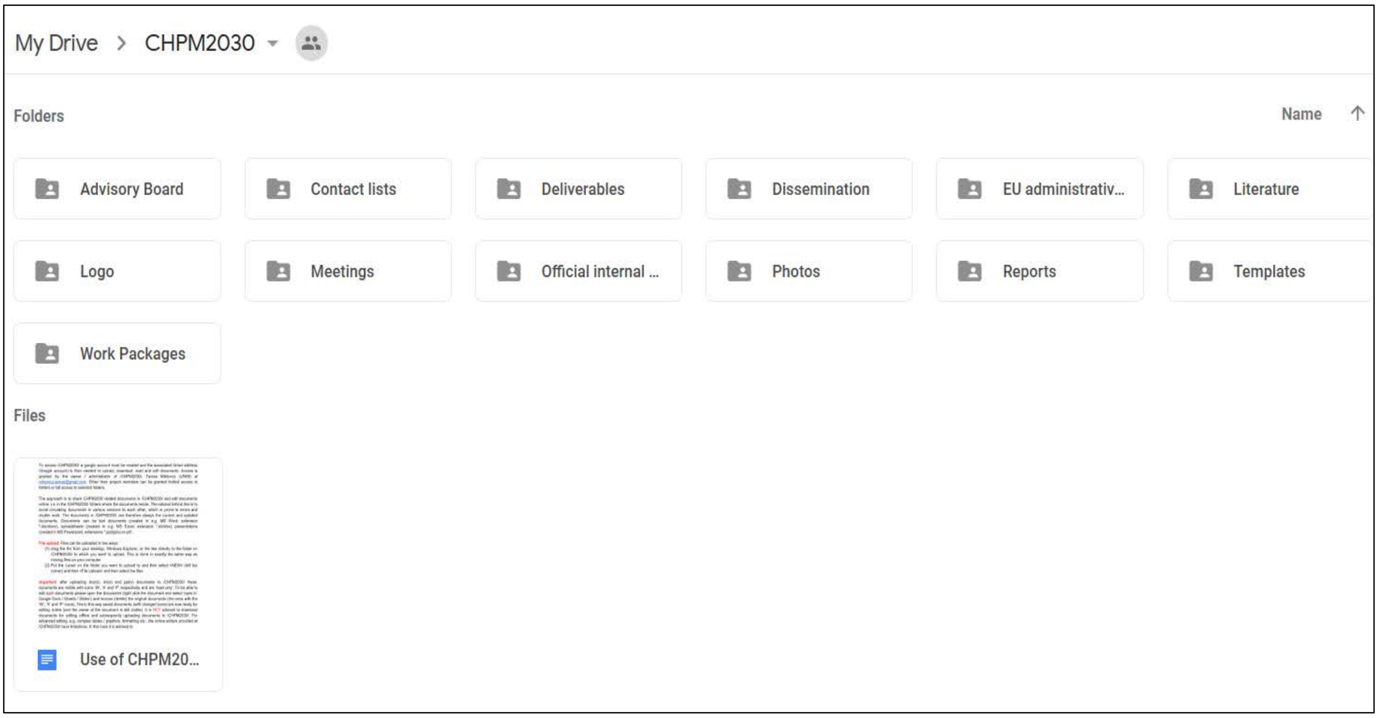

Figure 1.33: Main folders of the CHPM2030 Google Drive.

The project activities are arranged into work packages, and all major activities of the project are managed through this structure. The Coordinator continuously monitors activities through email communication, consortium meetings and monthly online meetings. Minutes of the consortium meetings and the online meetings are circulated among the partners and uploaded to the Google Drive. In the minutes, the due actions, the responsible partners and the deadlines are indicated.

***Task 8.2** Administrative project management*

This Task involves the administrative actions covering the following fields:

- Ensuring the implementation of the Grant Agreement and the Consortium Agreement,
- Controlling the completion of tasks by the partners,
- Controlling finances and budgets,
- Monitoring and managing the deadlines, milestones, deliverables and emerging risks,
- Keeping contact with the Project Officer and informing her about any issues,
- Organising project meetings and workshops,
- Uploading the deliverables to Sygma and submitting them to the EC,
- Assessing the internal reports,
- Preparing and submitting the Periodic Reports.

In the reporting period, an amendment process was carried out. The amendment was about the termination of IGR. The reason was that there had been an existing recovery order by the European Commission on IGR. During the project implementation, IGR debt was offset twice, in the first and in the second interim payment. The pre-payment, which was transferred to IGR at the beginning of the project, has been deducted from the second interim payment. IGR declared not to be willing to return the pre-payment to the coordinator. This resulted in a deficit in the overall project budget and in the high risk that also at the end of the project the beneficiary would not return to the consortium budget meant for other beneficiaries. Therefore, an amendment was initiated to terminate IGR participation in the Grant Agreement. The process was closed on 18.06.2019.

Task 8.3 Administrative project reporting

The reporting system is composed of two main components:

- Internal reports to the Coordinator,
- Periodic reports to the EC.

Internal reports

It was agreed at the kick-off meeting that the Consortium would submit internal reports to the Coordinator at the half of each reporting period. The internal reports cover both the professional and the financial aspects of the reporting period. The Coordinator provided a template for these reports. In the report, the partners were asked to describe the activities carried out in the reporting period, and they also indicate the resource consumption both in terms of person-months and personnel costs. They also reported the other costs incurred in the reporting period.

The first and the second internal reports were submitted and assessed in the former reporting periods. In the recent reporting period, the third internal reports covered M31-M36 (July-December 2018).

In the assessment of the partners' report, the use of PMs was summarised by partner and by WP. Minor deviations (both underuse and overuse) were identified and it was discussed with the partners. It was also pointed out that a few partners had underspending in personnel and other costs *(Figure 34).* This was discussed with the relevant partners and they were asked to compensate the deviations before the end of the project.

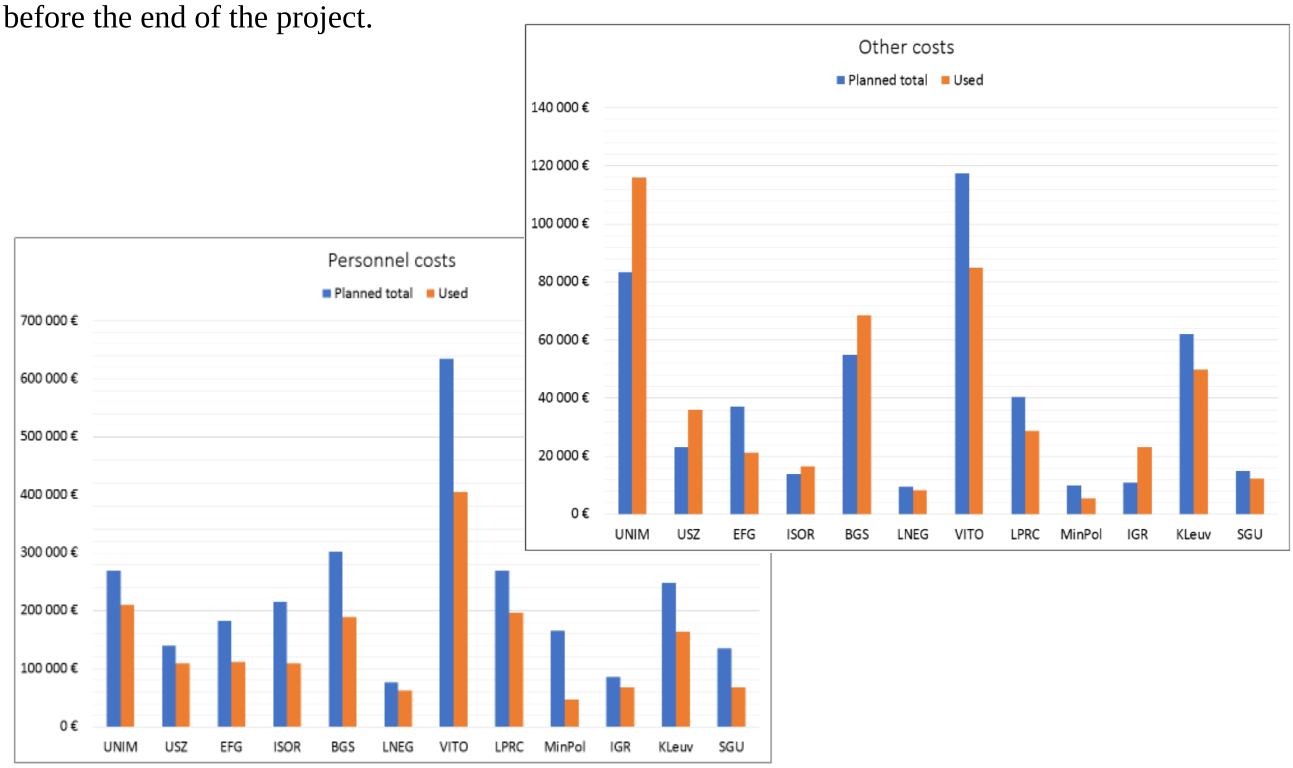

Figure 1.34: Use of personnel and other costs until the end of the internal reporting period M31-M36.

Periodic Reports

The first Periodic Report covered M1-M18 (January 2016-June 2017), the second one covered M19-M30 (July 2017-June 2018). The reports were submitted on time and reviewed and assessed by the Project Officer. The first Review Meeting was on 13th September is Brussels, the second review meeting on 04.10.2018. The Project Officer found the status of the projects satisfactory overall, however recommendations were made in order to improve the implementation.

Preparation for the recent report started in May 2019. Templates for gathering data for both Part A and Part B of the Technical Report, as well as template for the Financial Report were prepared by the coordinator and sent to the partners. Deadlines for preparing each type of reports were set up.

First, the consortium members sent their Partner Reports to the WP Leaders. Based on these inputs, the WP Leaders prepared the WP reports and submitted them to the Coordinator. The Coordinator summarised the WP reports and inserted them to Part B of the Technical Report. Partners were also asked to provide data for Part A.

A template for the internal financial report was also sent to the partners. They provided the requested data, and the coordinator assessed them before submitting the Financial Statements through Sygma.

Task 8.4 *Organisation of project meetings*

CHPM2030 related events organised by the project partners are grouped into three types:

- Consortium meetings
- Online project meetings
- Other project related events.

Consortium meetings
A draft schedule of project consortium meetings was agreed by the Consortium during the kick-off meeting. With some minor modifications, the meetings were organised according to this schedule in compliance with the proposal. All meetings were co-organised by the coordinator and the hosting partner institution. The meeting agenda was prepared/initiated by the coordinator carefully observing contractual obligations and project progress actualities, however logistics, venues, other events were recommended and arranged mainly by the hosting partner. The preliminary agenda was circulated among partners about 2 months before the meetings, and all partners (but specially WP leaders) had their active contribution in the content of the working programme of the events.

All partners were requested to be represented at all project meetings. Special attention was paid to provide reasonable solutions in terms of logistics and costs. Minutes of the meetings were prepared by the coordinator and were distributed within the partnership for approval. Attendance lists of meetings were signed by all participants and the original documents are filed in the project archive.

From the beginning of the project, the following personal consortium meetings have been organised:

- 28-29 January 2016: Kick-off Meeting, Miskolc, Hungary
- 11-14 October 2016: 2nd Consortium Meeting and 1st Advisory Board Workshop, Älvkarleby, Sweden
- 28-29 March 2017: 3rd Consortium Meeting, Nottingham, UK
- 11-14 September 2017: 4th Consortium Meeting, 2nd Advisory Board Workshop and 1st Review Meeting, Brussels, Belgium
- 21-23 March 2018: 5th Consortium Meeting, Lanzarote, Spain
- 04-07 September 2018: 6th Consortium Meeting and 3rd Advisory Board Workshop
- 18-19 June 2019: 7th Consortium Meeting, Miskolc, Hungary

Online project meetings
UNIM purchased the GoToMeeting software in order to use it for regular online meetings. It was agreed by the Consortium that these online meetings would be held in every month (except the months when there are personal consortium meetings). These were usually one hour long meetings, where the project progress, the status of the ongoing Tasks, the due deliverables and other topics were discussed. The online meetings were recorded. The minutes of the meetings with the due actions and

the deadlines were circulated within the partnership and also uploaded to the Google Drive together with the recording.

Dates of online project meetings in the recent reporting period:

- 23 October 2018
- 11 December 2018
- 29 January 2019
- 18 March 2019
- 24 April 2019

Several WP-focused online meetings were also organised related to WP4 and WP6 with the participation of the partners involved in the given WP.

Other project related events in the reporting period

Several other project-related meetings and workshops were organised by the partners in the reporting period. In timing order, these are as follows:

- 22-24 May, 2018: Fieldtrip related to WP6 in SW England for studying: the geology, fractures, mineralisation and mining history, water treatment to remove metals from minewater, and the geothermal potential of the area (organised by the BGS).
- 24-27 July, 2018: Fieldtrip related to WP6 in the Beius area and the Bihor Mountains, Romania for studying the mineralisation and geothermal potential of the area (organised by IGR)
- 04-05 December, 2018: Visioning workshop related to WP6, with the participation of the project partners and external experts (organised by LPRC in Gran Canaria, Spain)
- 07-08 March, 2019: Roadmapping workshop related to WP6, with the participation of the project partners and external experts (organised by LPRC in Gran Canaria, Spain) *(Figure 1.35)*
- 23 May 2019: International CHPM2030 Conference (organised by EFG and UNIM in Delft, the Netherlands)

Figure 1.35: Participants of the roadmapping Workshop in Las Palmas, on 07.03.2019

Upcoming event under organisation

- 28 August 2019: 3rd Review Meeting in Brussels

Task 8.5 *Risk management and conflict resolution*

Risk management and conflict resolution protocols were worked out in details in the first reporting period, in Deliverable 8.1. The protocols were approved by the consortium. The approach for the risk management was as follows:

- Identification of risk,
- Risk assessment,
- Response to issues.

The identification of risks was the duty of each partner within the consortium with their responsibility to inform their WP leader. The risk identification represents a proactive task for the Coordinator for the entire project and for the WP-leaders within the framework of their WP activities.

In the recent reporting period only one risk emerged. This was related to the fact that the IGR's pre-payment was deducted by the EC from the second interim payment, and because of that, the partners' reported costs could not be fully covered. The problem was solved by the termination of IGR and the missing sum will be financed from the guarantee fund.

Task 8.6 *Technology exploitation, innovation management and IPR.*

Related to WP3, Task 3.2, four patents have been filed (relating also to other projects). The first three are filed and pending, the fourth is granted for all PCT countries, Denmark and Spain (other countries still pending).

- Patent family: An electrochemical process for producing nanoparticles of cuprate hydroxychlorides (Priority: 2018)
  - Assignee: VITO
  - Inventors: G Pozo Zamora, X Dominguez-Benetton
  - EP18248090, Pending
- Patent family: A method for precipitating arsenic from solution (Priority: 2018)
  - Assignee: VITO
  - Inventors: X Dominguez-Benetton, G Pozo Zamora, K Vanbroekhoven, D Van Houtven
  - EP18248215, Pending
- Patent family: An electrochemical process for producing iron oxide nanoparticles (Priority: 2018)
  - Assignees: VITO, KU Leuven
  - Inventors: R Prato Modestino, X Dominguez-Benetton, J Fransaer
  - EP18248064, Pending
- Patent family: An electrochemical process for preparing a compound comprising a metal or metalloid and a peroxide, ionic or radical species (Priority: 2015)
  - Assignee: VITO
  - Inventors: X Dominguez-Benetton, Y Alvarez-Gallego, C Porto-Carrero, K Gijbels, S Rajamani
  - EP3242963B1, Granted
  - ES2702082T3, Granted
  - DK3242963T3, Granted
  - US2018023201A1, Pending
  - CN107532309A, Pending

- MX2017009005A, Pending
- CA2973289A1, Pending
- WO2016110597A1, Pending
- JP2018508659A, Pending

WP8 deliverables

Deliverable no. and name:	**D8.1 Risk Management Strategy**		
Due date:	30.06.2016	Delivered to the EC on 28.06.2016	Status: approved
Responsible:	UNIM		
Summary:	This document was submitted in the first reporting period.		
Deliverable no. and name:	**D8.2 Data Management Plan**		
Due date:	30.06.2016	Delivered to the EC on 28.06.2016	Status: approved
Responsible:	UNIM		
Summary:	This document was submitted in the first reporting period.		
Deliverable no. and name:	**D8.3 Project report 1**		
Due date:	30.06.2017 (31.08.2017)	Delivered to the EC on 20th August 2017	Status: approved
Responsible:	UNIM		
Summary:	This document was submitted in the second reporting period.		
Deliverable no. and name:	**D8.4 Project report 2**		
Due date:	30.06.2018	Delivered to the EC on 25th August 2018	Status: approved
Responsible:	UNIM		
Summary:	Project Report 2 includes the technical and financial report of the whole consortium for the period 01.07.2017-30.06.2018. The report was prepared and submitted according to schedule.		
Deliverable no. and name:	**D8.5 Project report 3**		
Due date:	30.06.2019	Delivered to the EC on 19th August 2019	Status: submitted
Responsible:	UNIM		
Summary:	Project Report 3 includes the technical and financial report of the whole consortium for the period 01.07.2018-30.06.2019. The report has been prepared and submitted according to schedule.		

1.2.7 Work Package 9

WP title	**Ethics requirements**		
Lead beneficiary:	UNIM	**Participants:**	USZ, EFG, ISOR, NERC-BGS, LNEG, VITO, LPRC, MINPOL, IGR, KU Leuven, SGU
Start date:	01.01.2016	**End date:**	30.06.2019

Objectives and implementation of the WP

In this Work Package, the partners and linked third Parties from countries which are not members of the EU, must confirm that the ethical standards and guidelines of Horizon 2020 will be rigorously applied, regardless of the country in which the research is carried out. These declarations were provided by ISOR and the Swiss, the Ukrainian and Serbian LTPs. The Coordinator submitted the declarations to the EC as Deliverable 9.1 on 20th April 2016.

1.3 Impact

In the first reporting period, the focus was on screening Europe's mineralised regions in terms of their EGS potential, identifying data gaps, and with detailed examination of the four study sites. In addition, the EGS-relevant geochemical and rock mechanical properties of the ore bodies were determined and the conceptual framework for the orebody-EGS was developed.

In the second reporting period, more emphasis was placed on laboratory experiments, the technological aspects of the project, creating an integrated feasibility assessment framework, and starting a visioning process for the further development of the CHPM technology. There were also extensive activities to publicise the project and disseminate its initial findings.

In the recent reporting period, the focus was on the assessment of metal recovery, additional power generation experiments, and integrating the technological components into one single system. A complex assessment framework was established considering economic, social, policy, environmental and policy aspects. The technology visioning process was completed and roadmaps were created for the 2030 and 2050 time horizons. Project results were disseminated through several media channels.

The main impacts of the project developed during the recent reporting period are as follows:

- It was proved that metals can be successfully electrodeposited at elevated pressure and temperature (up to 300 °C and 238 bar); elevated pressures and temperatures lead to higher recovery rates.
- It was proved that GDEx is a novel way to recover metals from dilute solutions. The patent of this process has been granted in Europe.
- It was proved that GDEx allows nearly full recovery of the relevant metals present, and selectivity can be achieved. The GDEx experiments are up-scalable and work for most of the critical raw materials. Preliminary economic feasibility calculations show positive results.
- It was proved that the presence of multivalent ions in the geothermal brine does not eliminate the potential for SGP-RE, though a reduction in power was noted. However, the extraction of electrical energy was enhanced significantly by increasing the brine temperature.
- A mathematical model framework was created based on the technology component-level models, which enables linking downstream and upstream geothermal engineering subsystems.

- The overall model can be used to study different scenarios, perform simulations, and develop optimisation and other kinds of system analysis.
- A decision support tool has been developed for the economic feasibility assessment allowing users to simulate revenue streams from both energy and metal extraction levels. The tool will remain accessible after the project lifetime through the MinPol website.
- Best practices have been suggested to companies planning to run CHPM plants for minimising the social and environmental impacts of the technology.
- A wide array of convergent technologies and relevant issues were defined (linked to CHPM exploration, development, operation and market) that can support the implementation of the technologically challenging CHPM scheme by 2030/2050.
- Detailed studies on the potential pilot sites and European-level databases provide the foundations for the implementation of pilot CHPM projects by 2030.
- Roadmaps for the implementation of future CHPM projects have been provided for 2030 and 2050 time horizons, including actions, targets and milestones.
- Due to the extensive dissemination activities by the partners and the EFG's linked third parties, the project concepts and the results have reached about 50 000 scientists and professionals in Europe.
- In the reporting period, 44 presentations (oral and posters) were made at conferences and workshops both at national and international level.
- The project's final international conference increased the awareness about CHPM2030 both through the event promotion and the press release published as a follow-up action.
- 7 articles were submitted to peer reviewed journals and conference proceedings, more than 350 news articles were published on websites and in newsletters;
- More than 600 social media posts were made.
- Participation in CHPM2030 helped BGS secure £1.8M (c. €2M) of research funding from the UK Natural Environment Research Council to better understand fluid movement in fractured granite in SW England, and thus provide enhanced scientific understanding of EGS potential within the UK.

2 Update of the plan for exploitation and dissemination of results

The plan for the exploitation and dissemination of the project results is described in Deliverable 7.4 - Communication and Dissemination Plan, submitted in June 2016. This deliverable defines and prioritises the key objectives of dissemination and communication and details the steps to be taken during the project's lifetime in order to achieve maximum impact and reach relevant audiences. It also sets the framework to facilitate communication among the consortium members, as well as between the consortium and stakeholders or the general public.

In the recent reporting period (autumn 2018), EFG revised the Communication and Dissemination Plan. The aim was to ensure that the project objectives and outcomes were communicated with optimum results until the end of the project lifetime. This revision comprised an update of the stakeholder classification and led in the following months to a significant enlargement of the database of stakeholders interested in the future economic development of the CHPM technology. The update of the stakeholder database concerned especially the following categories of stakeholders:

- National, regional and local authorities,
- Venture capitalists,
- Environmental groups,
- The energy sector, and
- The raw materials sector.

3 Update of the data management plan

The CHPM2030 project has committed itself to the Open Research Data Pilot with the aim of improving and maximising access to and the re-use of data generated by the project. For this purpose the project consortium has prepared Deliverable 8.2 - Data Management Plan (DMP) containing the main elements of the data management policy to be applied by the project partners for handling datasets generated during the project, as well as upon completion. The DMP has been prepared in accordance with the 'Guidelines on Data Management in Horizon 2020' and it defines procedures regarding data quality, sharing and security.

CHPM2030 has generated substantial volume of data especially within WP 1, WP2 and WP3, and WP4, some of them quite unique that could be used to fuel basic/applied research including updates of existing geological models. Partly for confidentiality reasons and partly for better tracking project samples and data, the consortium created the CHPM project data archive in the second reporting period, described in detail in D 2.4.

The main goal of the database was to organise the key information from lab experiments, but it was also needed to be easily handled, and had to be dynamic in such a sense that it accommodated newly generated data types. It was also expected that each partner can have access to the scope and structure of the generated data and could use them for his/her own research tasks. It was not the goal of the data archive however, to collect and archive all lab measurement data and their details – as agreed by the consortium. Each partner was responsible for the orderly and safe maintenance of the generated project data. It is our goal to provide the necessary metadata (link to the data holder) and the key features of previously accomplished lab measurements for parties both inside and outside the CHPM2030 consortium.

Besides the data generated by the methodological and laboratory work packages, substantial information was collected and organised into summary documents of the four project pilot areas and about the relevant European outlook (Tasks 6.2.1-6.2.5). These documents can be important sources of information for potential investors/decision makers active on these sites.

Other types of documents, presentations and public access reports, such as scientific publications, public deliverables related to the implementation of the Action as defined by the GA are stored on the Google Drive account in an organised file structure. Deliverables and public dissemination materials (such as project brochure, introductory video, fact sheets and newsletters) of the project and are published on the website of the CHPM2030 project, under Outreach menu.

The project management guaranties access to public data generated by the CHPM2030 consortium for the scientific community. The data shall be available via the project webpage, even after the closure of the project. Furthermore, keeping in mind that project activities go beyond the funded period, there might be demand for data access and manipulation by the consortium partners. The Research Roadmap activity and the two promised deadlines of pilot plant operation (2030) and full scale operation (2050) shall refer to the data and publications generated by the consortium.

4 Follow-up of recommendations and comments from previous review

The overall assessment of the project implementation after the submission of the 2nd Periodic Report was positive and it was declared that the project had fully achieved its objectives and milestones for the period. However, there were recommendations by the Project Officer in order to improve the level of implementation in the third reporting period. Below these recommendations and the relevant actions are listed.

Recommendation 1:
The risk of not having enough data and detailed and comprehensive information for the preparation of study areas (WP6), to clearly show the potential of the CHPM2030 technological solution and allow for future advances in the TRL building on the results of CHPM2030, has to be addressed and mitigation measures put in place before end of December 2018.

Actions on Recommendation 1
Risks on data availability in the study areas were already identified in the first reporting period (Deliverable 1.2). The amount and types of the available data are different in the four potential pilot areas. The main sources of data (both on geology/geophysics and EGS potential) were the national geological surveys. Where it was needed, local authorities and environmental or other types of institutions were also approached for getting access to their data.

In WP6, the focus was on the detailed evaluation of data. In order to apply the same approach in each area, a harmonised study area evaluation template was developed. This was an iterative process with the involvement of external experts, technology developers and the study area representatives at consortium meetings, workshops, fieldtrips and online meetings for the WP6 participants,. The evaluation template served as a ‘checklist’ for important characteristics to consider when looking into the CHPM potential. As in general, substantial amounts of information were only available for the upper 1 km of the subsurface, the challenge was to extend this understanding to greater depths, run new, preferably 3D surveys, and further advance the predictive 3D models for a downward continuation.

Recommendation 2:
The risk for the different components of the overall geothermal engineering system (WP4) to be insufficiently described has to be addressed and mitigation measures put in place before end of December 2018;

Actions on Recommendation 2:
In order to manage the risk of insufficient description of the technological components, preparation for the development of the mathematical model for system integration started in March 2018. A workshop on WP4 was held, where the components and the programming language for the modelling work were identified. Following that, the input and output parameters for each component were defined. Online meetings dedicated to WP4 and regular exchange of e-mails helped the harmonisation of the participating partners’ work.

The selected approach for the system integration WP is based on mathematical component level models which enable linking of downstream and upstream geothermal subsystems in an overall system model. This approach does rely on successful data collection from the partners that develop the individual components in order to be able to describe mathematically what happens within the components and estimate the relevant uncertainties. In case the results of WP2 and WP3 did not provide satisfactory component level models, an effort was put on collecting available data from the literature and other sources to describe the expected behaviour of the components. Together with the results of the laboratory tests performed within the project, this was in some cases used to demonstrate the overall model. By this, it was ensured that a valuable system integration model had been developed at the end of the project. It can be used and developed further in later research projects with revised and more accurate input data when they are available.

Recommendation 3:
Deliverable D8.4 (Project Report 2) is to be submitted before the end of November 2018.

Actions:
D8.4, Project Report 2 was submitted on 29th November.

Recommendation 4:
According to Art. 33 of the GA, beneficiaries must aim — to the extent possible — for a gender balance at all levels of personnel assigned to the action, including at the supervisory and managerial levels. The improvements registered in the second reporting period are positive, yet the consortium is asked to continue its efforts in putting in place specific measures to support this requirement.

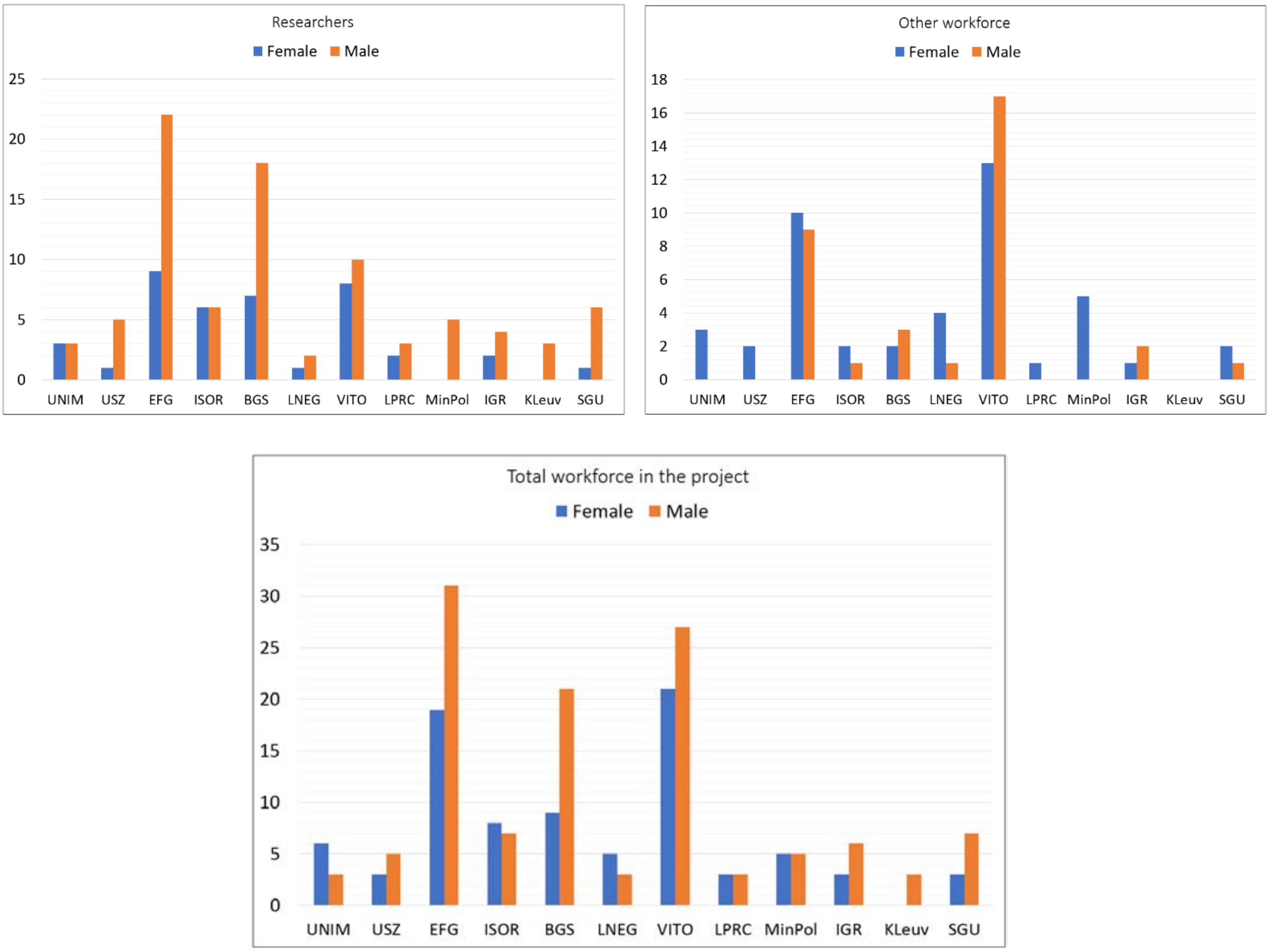

Figure 4.1: Female/male ratio at the partners in the CHPM2030 project. Project participants in the period M31-M42 are considered. Under 'EFG', both the EFG's and the LTPs' staff are indicated.

Actions:
Project partners made efforts to utilise both their female and male staff in an equal and fair way. Traditionally the disciplines represented in the project (earth sciences, chemical engineering) have a higher proportion of males, though there is a progressive trend towards an increasing number of

females. Project staff were selected based on the participants' technical skills and availability. Among the researchers, male participants slightly dominate female ones. However, in the 'other workforce' category, which means mostly administrative staff, females are dominant.

The ratio between the female and the male CHPM2030 participants by partner is shown in *Figure 4.1*. In the figure, the gender distribution of the EFG LTPs is also represented. For the present reporting period, the total number of participating females is 85, the total number of males is 121.

5 Deviations from GA Annex 1

No significant deviations from GA Annex 1 occurred in the reporting period.

An amendment request was submitted in the reporting period. The subject of the amendment was the termination of the Geological Institute of Romania (Institutul Geologic al Romaniei – IGR) from the CHPM2030 project. The reason was that there were an existing recovery order by the European Commission on IGR. IGR debt was offset twice, in the first and the second interim payment. The pre-payment, which was transferred to IGR at the beginning of the project, was deducted from the second interim payment. IGR declared not to be willing to return the pre-payment to the coordinator. This resulted in a deficit in the overall project budget and in the high risk that also at the end of the project the beneficiary would not return to the consortium budget meant for other beneficiaries. Therefore the consortium, in agreement with IGR, decided to terminate IGR participation in the Grant Agreement.

IGR actively contributed to CHPM2030 and they completed all of their tasks in the project as planned in the Grant Agreement. Therefore the termination of IGR did not have any negative consequences on the completion of the project activities and in reaching the project objectives. The amendment was signed by the European Commission and entered into force on 18th June.

5.1 Tasks and deliverables

According to the GA, in the reporting period, deliverables from tasks in WP3, WP4, WP5, WP6, WP7 and WP8 had to be submitted. The submission deadline of three deliverables were extended:

- D3.3 originally was due in M30 (June 2018) but after the request for postponing the submission, the Project Officer approved the extension of the deadline to M32 (August 2018).
- D4.2 originally was due in M41 (May 2019) but after the request for postponing the submission, the Project Officer approved the extension of the deadline to M42 (June 2019).
- D6.2 originally was due in M40 (April 2019) but after the request for postponing the submission, the Project Officer approved the extension of the deadline to M41 (May 2019).

There were no significant deviations in the submission of the other deliverables, all were provided on time or with a minor delay. The deliverables, in the order of their due dates, are listed in *Table 5.1*.

Table 5.1: Due and submission dates of the deliverables in the reporting period.

Deliverable	Due date	Submission date	Comment
D3.1	31.08.2018	01.09.2018	-
D3.2	31.08.2018	06.09.2018	Nine days delay because of the final improvements
D3.3	31.08.2018	31.08.2018	Extension of submission deadline was approved
D5.2	31.08.2018	28.08.2018	-
D7.7	31.08.2018	16.08.2018	-
D7.10	31.08.2018	16.08.2018	-
D4.1	30.09.2018	28.09.2018	-
D5.5	28.02.2019	08.03.2019	Three days delay because of the final improvements
D5.3	30.04.2019	02.05.2019	-
D6.1	30.04.2019	29.04.2019	Extension of submission deadline was approved
D6.2	31.05.2019	20.05.2019	-
D4.2	30.06.2019	28.09.2018	Extension of submission deadline was approved. In agreement with the PO, deliverable was rejected for improvement, improved version submitted on 31st August.
D7.14.	31.05.2019	29.06.2019	A few weeks delay because of the assessment of the conference outcomes

D4.3	30.06.2019	30.06.2019	In agreement with the PO, deliverable was rejected for improvement, improved version submitted on 31st August.
D5.4	30.06.2019	29.06.2019	-
D5.6	30.06.2019	29.06.2019	-
D6.3	30.06.2019	30.06.2019	-
D7.11	30.06.2019	29.06.2019	-
D8.5	30.06.2019	20.06.2019	-

5.2 Use of resources

Use of financial resources

Each beneficiary has a financial statement.

Use of financial resources by the project partners

No significant deviations occurred in the use of financial resources in the reporting period. Spending on personnel and other costs by the partners was proportional to the duration of the period *(Table 5.2, Figures 5.1 and 5.2).*

Table 5.2: Use of direct costs by the partners in the former and the recent reporting periods.

Partner	Planned total budget (€)	Planned total direct costs (€)	Personnel costs						Other costs						Total direct used (€) M1-M42	Total direct used % M1-42
			Planned total (€)	Used (€) M1-M18	Used (€) M19-M30	Used (€) M31-M42	Used (€) M1-M42	Used % M1-M42	Planned total (€)	Used (€) M1-M18	Used (€) M19-M30	Used (€) M31-M42	Used (€) M1-M42	Used % M1-M42		
UNIM	442 000,00	353 600,00	270 100,00	118 592,00	63 176,97	57 163,24	238 932,21	88,46	83 500,00	76 062,00	20 089,50	33 419,91	129 571,41	155,18	368 503,62	104,21
USZ	203 750,00	163 000,00	140 000,00	52 952,36	37 591,79	39 143,81	129 687,96	92,63	23 000,00	9 302,09	18 181,15	8 512,06	35 995,30	156,50	165 683,26	101,65
EFG	275 875,00	220 700,00	183 500,00	31 893,62	43 471,03	98 443,69	173 808,34	94,72	37 200,00	6 777,11	7 400,00	25 701,00	39 878,11	107,20	213 686,45	96,82
ISOR	287 500,00	230 000,00	216 000,00	25 509,86	34 429,10	175 610,98	235 549,94	109,05	14 000,00	7 201,93	3 563,00	14 326,30	25 091,23	179,22	260 641,17	113,32
BGS	447 000,00	357 600,00	302 600,00	81 761,38	70 986,56	91 148,16	243 896,10	80,60	55 000,00	31 264,12	27 631,00	35 753,84	94 648,96	172,09	338 545,06	94,67
LNEG	107 500,00	86 000,00	76 500,00	28 224,73	17 816,05	26 817,62	72 858,40	95,24	9 500,00	3 939,37	1 958,16	3 485,81	9 383,34	98,77	82 241,74	95,63
VITO	940 717,50	752 574,00	635 122,00	110 912,66	294 682,23	243 296,43	648 891,32	102,17	117 452,00	16 728,58	68 345,16	35 079,74	120 153,48	102,30	769 044,80	102,19
LPRC	387 225,00	309 780,00	269 280,00	21 290,86	122 750,90	128 551,01	272 592,77	101,23	40 500,00	8 120,76	10 079,03	22 042,20	40 241,99	99,36	312 834,76	100,99
MinPol	218 750,00	175 000,00	165 000,00	15 780,58	25 476,28	98 878,17	140 135,03	84,93	10 000,00	2 655,95	1 733,09	693,59	5 082,63	50,83	145 217,66	82,98
IGR	121 250,00	97 000,00	86 000,00	49 716,79	15 687,88	9 242,00	74 646,67	86,80	11 000,00	5 683,75	9 954,68	6 714,90	22 353,33	203,21	97 000,00	100,00
KLeuv	388 000,00	310 400,00	248 400,00	50 589,38	90 455,54	116 125,80	257 170,72	103,53	62 000,00	27 580,66	13 977,87	12 743,63	54 302,16	87,58	311 472,88	100,35
SGU	187 500,00	150 000,00	135 000,00	54 409,38	13 823,78	53 657,26	121 890,42	90,29	15 000,00	2 801,74	4 992,56	9 081,14	16 875,44	112,50	138 765,86	92,51

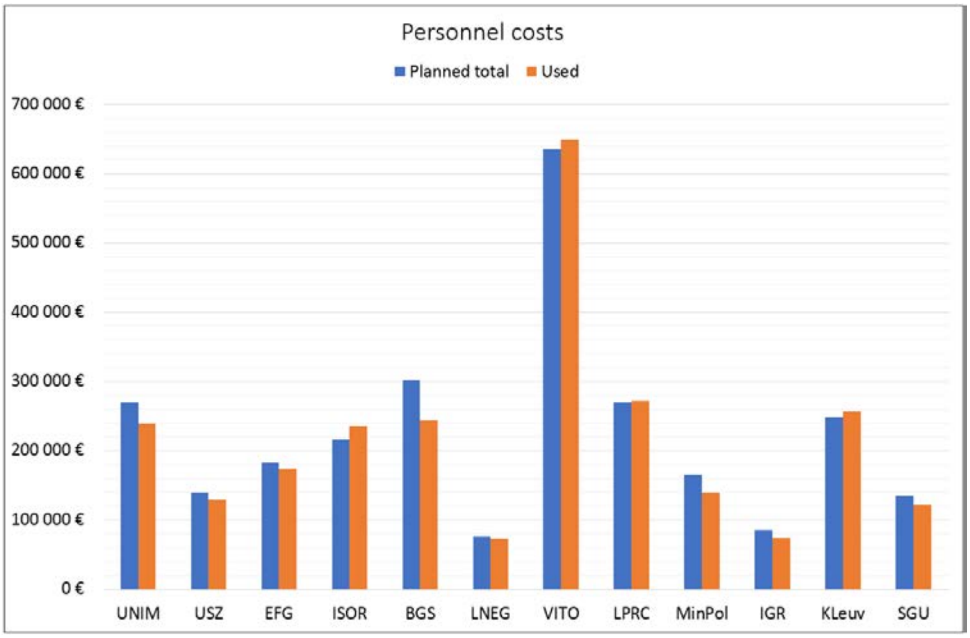

Figure 5.1: Use of personnel costs by the partners during the whole duration of the project.

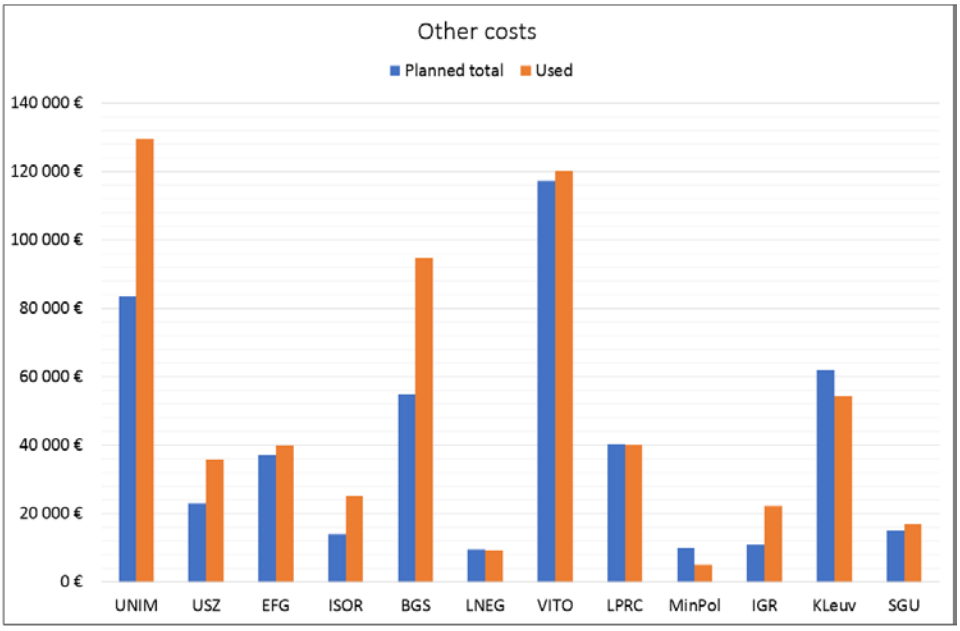

Figure 5.2: Use of other costs by the partners during the whole duration of the project.

The minor deviations are justified below by partners:

<u>UNIM:</u>
UNIM overspent the 'Other costs' budget. The reason is that the coordinator partner had to finance the travel and accommodation costs of the Advisory Board members. During the preparation of the proposal, these costs were underestimated and UNIM had to spend more for their participation in the Advisory Board workshops than expected. In addition, three more members were invited to the AB, as their expertise was needed for the successful implementation of the project. However, this overspending was balanced by the end of the project from the budget which was not used by other partners.

The average personnel costs of UNIM is lower than planned in the original proposal for the following reasons: A) the original budget was planned with the highest personal salaries, as the participation of senior staff was envisaged mainly. However, since the submission of the CHPM2030 proposal the University of Miskolc received funding for several other projects and the participation of the senior staff has been reduced in time and the larger part of the tasks, the operative work is implemented by younger researchers. Therefore the average wage is lower, and the number of person months have increased slightly; B) another reason for lower gross wages is that the percentage of social security contribution decreased from 27% to 19.5%; C) the fluctuation of the exchange rate of the Hungarian forint against the euro has an influence also on the average wages.

<u>USZ:</u>
At USZ, a minor overspending of the 'Other costs' budget occurred. This is due to an underestimation of travel costs associated with attending bilateral meetings, field trips and consortium events. Under-spending of the 'personnel costs' budget line allows for a minor reallocation of funds and covers the excess within the approved budget.

The deviation in average personnel costs per month is due to the level of participation required from the USZ staff in the technical WP's having been somewhat underestimated during the project-planning phase. The need to increase person-months dedicated to the research (most importantly laboratory measurements) became evident very early in the project, and forced both the USZ as the employer, and the staff to settle for lower monthly payments than planned originally. Despite the unforeseen efforts and time-allocation, all activities have been conducted on time, and the budget has neither been exceeded nor does the overall deviation reach the flexibility limit. Overall personnel costs remain largely unchanged, with an estimated ~6% underspending by the end of the project. The unspent amount will cover a slight overspending in the travel costs. The excess in man-power allocation does not alter the activities described in DoA, the changes are consistent with the R&D nature of the project.

BGS

At the beginning of the project, there was an agreement by the PO to adjust the resources allocated between staff and other costs to correct for an inaccuracy in two of the originally submitted costs sub-headings. As such, BGS spent less on staff and more on other costs compared to the very initially submitted costs. This change may explain some of the reasons for the deviations. Deviation in average personnel costs per month appears to also be a function of utilising a relatively higher proportion of lower-graded staff for the reporting period, as some of the higher-graded staff have been tied up in other projects. Exchange rate changes may also be a factor. Deviation in other direct costs appears to be related to the agreed changes in the relative proportion of resources between staff and other costs.

ISOR

ISOR had an overspending in personnel costs of 9.1% (EUR 19,550). This is a consequence of the fact that the work effort exceeded what was originally planned, in total by 21.1%. The largest influence has the work on WP4 (System integration), led by ISOR, since about two third of ISOR's work was done on that WP. The average cost per person-month was lower than expected when the budget was prepared and this has helped with limiting the overspending in personnel costs. The main reason for the overspending in work effort and personnel costs is that the work on developing the mathematical model of the CHPM system was more time consuming than expected. This is mainly related to development of some component models that had to be developed on the basis of rather raw data from experimental results. Also, it was agreed with the project coordinator to do additional work by performing scaling studies on two Icelandic geothermal fields to support work in WP2 and WP3.

ISOR had an overspending in other direct costs of 79.2% (EUR 11,091). They were expected to be only EUR 14,000 so the overspending is large in terms of percentages. There are several reasons for this overspending. First of all, the travel cost to consortium meetings for ISOR's staff is relatively high compared to most other participants. Also, about half of the overspending is related to the cost category “other goods and services”, which was not included in the budget. This includes collection of chemical samples and analysis of them as a part of the scaling studies mentioned before and purchase of a computer program for simulations.

VITO

Due to a shift of the experimental work in WP3 from senior staff to younger, more unexperienced lab technician and researchers, more time was invested in both the execution and follow-up of the work than planned at the start of the project.

MINPOL

The overall budget at MINPOL was undercut. This is due to the SME owner's hourly rate, which is lower than it was originally budgeted for the senior scientist.

Use of financial resources by the EFG’s linked third parties

Similarly to the project partners, no significant deviations occurred in the use of financial resources by the EFG’s linked third parties in the reporting period. Spending on personnel and other costs by the partners was proportional to the duration of the period *(Table 5.3, Figures 5.3 and 5.4).* The Swiss LTP used personnel costs but they did not submit a claim for compensation.

Table 5.3: Use of direct costs by the EFG's linked third parties in the former and the recent reporting periods.

Partner	Planned total budget (€)	Planned total direct costs (€)	Personnel costs						Other costs						Total direct used (€) M1-M42	Total direct used % M1-M42
			Planned total personnel costs	Used (€) M1-M18	Used (€) M19-M30	Used (€) M1-M30	Used (€) M31-M42	Used % M1-M42	Planned total other costs	Used (€) M1-M18	Used (€) M19-M30	Used (€) M1-M30	Used (€) M31-M42	Used % M1-M42		
CAEG	11 500,00	9 200,00	7 500,00	2 988,00	875,00	3 863,00	7 630,00	153,24%	1 700,00	0,00	0,00	0,00	0,00	0,00%	11 493,00	124,92%
YKL	11 500,00	9 200,00	7 500,00	0,00	1 632,00	1 632,00	1 176,00	37,44%	1 700,00	0,00	1 494,89	1 494,89	0,00	87,93%	4 302,89	46,77%
UAG	11 500,00	9 200,00	7 500,00	1 563,00	1 070,00	2 633,00	5 610,00	109,91%	1 700,00	83,86	847,25	931,11	555,00	87,42%	9 729,11	105,75%
APG	11 500,00	9 200,00	7 500,00	547,26	1 345,81	1 893,07	3 003,52	65,29%	1 700,00	0,00	1 132,57	1 132,57	4 816,55	349,95%	10 845,71	117,89%
CNG	11 500,00	9 200,00	7 500,00	3 222,00	1 093,92	4 315,92	2 627,58	92,58%	1 700,00	0,00	899,31	899,31	1 127,58	119,23%	8 970,39	97,50%
MFT	11 500,00	9 200,00	7 500,00	3 003,14	2 130,45	5 133,59	1 756,57	91,87%	1 700,00	0,00	546,97	546,97	1 704,00	132,41%	9 141,13	99,36%
IGI	11 500,00	9 200,00	7 500,00	0,00	4 275,00	4 275,00	2 791,50	94,22%	1 700,00	0,00	0,00	0,00	0,00	0,00%	7 066,50	76,81%
PAMAV	11 500,00	9 200,00	7 500,00	2 720,00	400,00	3 120,00	4 380,00	100,00%	1 700,00	0,00	244,54	244,54	1 503,78	102,84%	9 248,32	100,53%
SGD	11 500,00	9 200,00	7 500,00	2 448,00	3 808,00	6 256,00	2 176,00	112,43%	1 700,00	41,00	848,99	889,99	252,47	67,20%	9 574,46	104,07%
IRSNB	67 500,00	54 000,00	50 000,00	20 114,00	11 069,65	31 183,65	28 200,18	118,77%	4 000,00	0,00	0,00	0,00	0,00	0,00%	59 383,83	109,97%
ICOG	11 500,00	9 200,00	7 500,00	2 012,72	3 565,07	5 577,79	1 907,05	99,80%	1 700,00	0,00	0,00	0,00	0,00	0,00%	7 484,84	81,36%
SGS	11 500,00	9 200,00	7 500,00	2 863,00	2 859,00	5 722,00	1 785,00	100,09%	1 700,00	0,00	1 346,00	1 346,00	445,00	105,35%	9 298,00	101,07%
SEG	11 500,00	9 200,00	7 500,00	2 865,16	2 843,13	5 708,29	1 791,71	100,00%	1 700,00	634,08	635,84	1 269,92	384,75	97,33%	9 154,67	99,51%
CHGEOL	0,00	0,00	0,00	400,00	600,00	1 000,00	450,00		0,00	0,00	0,00	0,00	0,00		1 450,00	
BDG	11 500,00	9 200,00	7 500,00	1 455,36	5 547,02	7 002,38	1 331,21	111,11%	1 700,00	0,00	1 314,03	1 314,03	226,34	90,61%	9 873,96	107,33%
KNGMG	11 500,00	9 200,00	7 500,00	552,12	1 769,28	2 321,40	2 246,11	60,90%	1 700,00	0,00	366,30	366,30	194,40	32,98%	5 128,21	55,74%

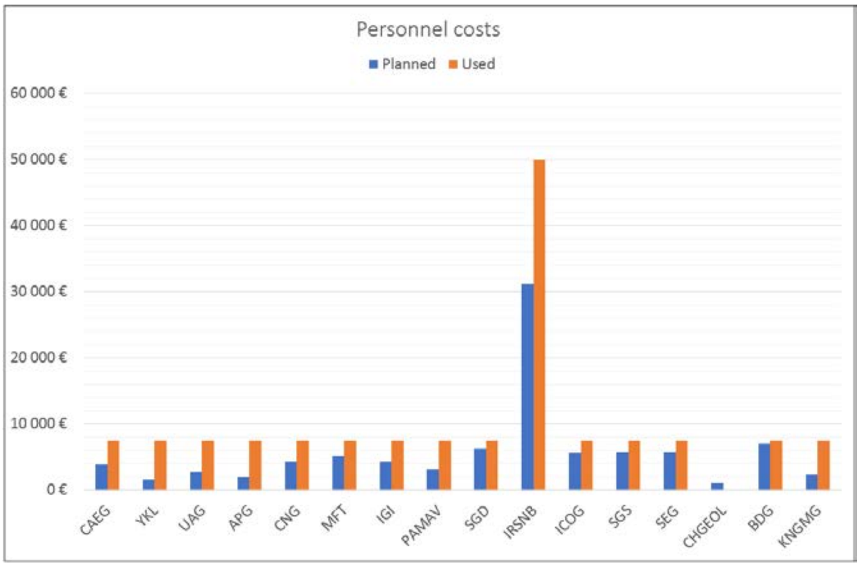

Figure 5.3: Use of personnel costs by the EFG's LTPs during the whole duration of the project.

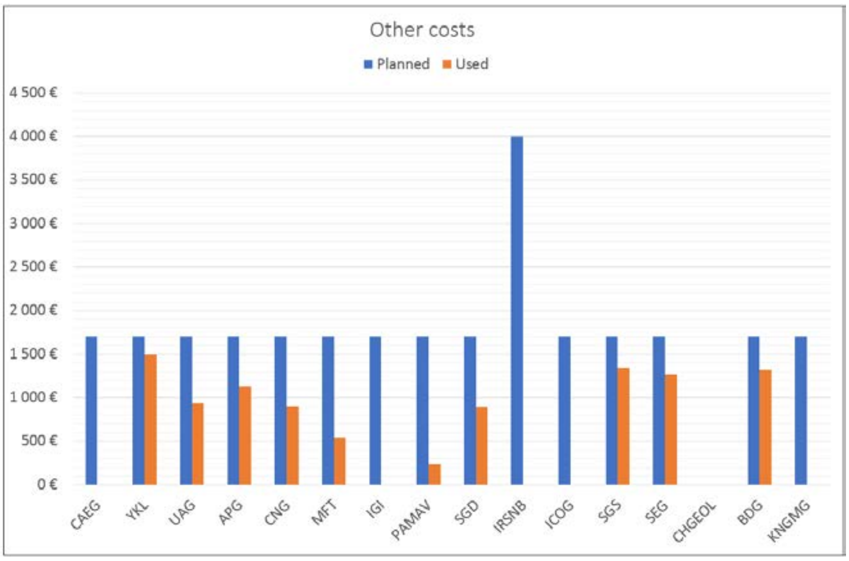

Figure 5.4: Use of other costs by the EFG's LTPs during the whole duration of the project.

Use of person-months by the project partners

There were no major deviations in the spent working hours compared to the planned ones. The numbers are indicated in *Table 5.4* and they are presented in graphs in *Figure 5.4.*

Table 5.4: Use of person-months by the project partners during the whole duration of the project.

Partner	WP1		WP2		WP3				WP4				WP5			
	Planned	Used M1-M42	Planned	Used M1-M42	Planned	Used M1-M30	Used M31-M42	Used M1-M42	Planned	Used M1-M30	Used M31-M42	Used M1-M42	Planned	Used M1-M30	Used M31-M42	Used M1-M42
UNIM	25	27,27	15	15,90					6	4,17	3,01	7,18	5	3,52	2,84	6,36
USZ	10	12,76	15	61,00					2		2,51	2,51	20	21,80	23,15	44,95
EFG	4	1,09											2	0,45	0,07	0,52
ISOR	1	0,96	1	1,04					18	4,07	18,68	22,75	2	0,89	1,90	2,79
BGS	8	7,29	17	17,20									1		0,10	0,10
LNEG	8	8,17											1	0,67	0,43	1,10
VITO			10,60	8,88	28,35	32,10	16,8	48,9	15	4,08	9,30	13,38				
LPRC													6	0,22		0,22
MinPol													16	5,11	5,25	10,36
IGR	9	13,20											1		1,00	
KLeuv					32,00	26,80	21,00	47,80	11		6,00	6,00				
SGU	8	8,70											1	0,15	0,13	0,28

Partner	WP6				WP7				WP8				Total		
	Planned	Used M1-M30	Used M31-M42	Used M1-M42	Planned	Used M1-M30	Used M31-M42	Used M1-M42	Planned	Used M1-M30	Used M31-M42	Used M1-M42	Planned	Used M1-M42	Used %
UNIM	6	3,65	6,27	9,92	4	4,79	1,67	6,46	10	7,63	3,38	11,01	71	84,10	118,45
USZ	2		5,12	5,12	1		2,51	2,51	1		2,79	2,79	51	131,64	258,12
EFG	5	3,13	7,57	10,70	19	11,30	9,89	21,19	2	3,51	4,44	7,95	32	41,45	129,53
ISOR	3	0,02	2,21	2,23	1	0,08	1,77	1,85	1	0,85	0,23	1,08	27	32,70	121,11
BGS	6	7,88	14,82	22,70	1	1,10	1,82	2,92	1	0,93	2,19	3,12	34	53,33	156,85
LNEG	6	2,97	3,92	6,89	1	0,17	0,91	1,08	1	0,98	0,49	1,47	17	18,71	110,06
VITO	1		0,80	0,80	1	1,26	0,7	1,96	1				57	73,92	129,80
LPRC	21	16,00	23,08	39,08	6	4,56	0,44	5,00	3	1,80	1,39	3,19	36	47,49	131,92
MinPol	4	1,70	0,03	1,73	1	0,35		0,35	1	0,65	1,27	1,92	22	14,36	65,27
IGR	8	4,35	2,20	6,55	1	1,35		1,35	1	1,20		1,20	20	22,30	111,50
KLeuv	1	0,01		0,01	1	0,15		0,15	1	0,56		0,56	46	54,52	118,52
SGU	7	1,85	8,06	9,91	1	0,07	0,27	0,34	1	0,20	0,55	0,75	18	19,98	111,00

The justifications for the deviations are as follows:

<u>UNIM</u>

At UNIM, there is an overuse of person-months in WP6 (3.65 PMs planned, 9.92 PMs used). The reason is that UNIM actively contributed to the formulation of the questionnaires for the Delphi surveys, completed the lists of stakeholders who were invited to the survey, and participated in the assessment of the survey report. Two representatives of UNIM attended both the Visioning Workshop and the Roadmapping Workshop, made presentations and actively contributed to the developments. From the UNIM's side, there were two participants in the Cornwall fieldtrip and three participants in the Romania fieldtrip, which were organised in the frame of WP6.

<u>USZ</u>

In W5, 20 PMs were planned for USZ, and 44.95 PMs were used. USZ experts were involved in Tasks 5.1, 5.4, 5.5 and 5.6 from M18 to M42. They participated in the preparation of D5.1, 5.4, 5.5 and 5.6. During the implementation of Task 5.1, USZ developed an integrated sustainability assessment which was used as a methodological framework for all other tasks in WP5. To guarantee oversaw all activities in the WP, USZ held personal and on-line meetings, and reviewed all outputs and deliverables. The efforts dedicated to the implementation of project-related activities in WP5 and coordination efforts of the work package as WP leaders, exceeded the plans and required 25 extra person-months.

In WP6, 2 PMs were planned for USZ, and 5.12 PMs were used. In the reporting period, USZ participated in the planning and implementation of WP6. The main reason for the excess in man-power allocation is that the workshops, surveys and interactive work on WP6 required a greater than expected involvement of USZ. Therefore, 3.12 man-month extra time was used.

Despite the unforeseen effort and extra time allocation necessitated by the coordination of framework-development, the planning and execution of surveys, and the dissemination activities beyond the commitments, USZ successfully conducted all activities on time. Also, regardless of the 24.95 and 3.12 extra man-months allocated to the project under WP5 and WP6 respectively, the budget has only been exceeded with 3000 EUR (travel costs related to partner meetings) and required no contractual modification.

<u>EFG</u>

In WP8, 2PMs were planned for EFG and 7,95 PMs were used. The reason is that EFG was the organiser of the International Conference in Delft in May 2019. The preparation work and the promotion of the conference needed more administrative and management tasks than expected.

In W6, 5 PMs were planned for EFG, and 10.70 PMs were used. The involvement of EFG's LTPs and integrating their contribution to CHPM2030 deliverables required more PM resources than it was originally foreseen in the project. This is partly due to the increased quantity of data that have been delivered by the LTPs. This was anticipated at the start of WP6, therefore an LTP orientation workshop was organised, ensuring that the reported data are already structured. Furthermore, partly the extra PM effort was focused on the creation of a map-based visualisation of the results (http://bit.ly/CHPMinfoplatform). This required further processing and formatting of the LTP's data (numerical, visual, descriptive), and some additional communication with the LTPs. The map has also been integrated into the CHPM2030 website, and was continuously updated. To cope with the additional information and extra commitments, WP6 required more person working for longer period of time than originally planned, while staying within the overall EFG budget.

BGS

In WP6, 6 PMs were planned for BGS and 22.70 PMs were used. BGS was the organiser and leader of the Cornwall fieldtrip, which was not planned in the project proposal. The preparation of the field guide and the organisational work needed a significant amount of workload. BGS also participated in the online meetings for discussing the work on D6.2, and also organised meetings and liaison with relevant external stakeholders operating in SW England.

The work on D6.2.1 needed more working hours than expected. BGS staff produced a 160 page detailed report on SW England. New information coming out of the ongoing geothermal investigations in SW England (e.g. the United Downs Deep Geothermal Power project, and also the GWatt project was included. Preliminary modelling of the Cornubian Batholith has been undertaken to improve understanding of its properties relevant to geothermal energy development. A regional model was constructed to understand the spatial relationship of key geological parameters. This data were used for the development of two site-scale models that aimed to improve understanding of the fracture network and flow pathways at the reservoir-scale.

BGS representatives participated in the Romania fieldtrip and both in the Visioning Workshop and the Roadmapping Workshop in Gran Canaria.

VITO

In WP3, 28,35 PMs were planned and 48,9 were used, and at VITO. The reason of the overuse is that VITO originally planned to involve largely senior researchers and experienced technicians. During the course of the project several personnel shifts caused the efforts to shift more towards younger, less experienced researchers and technicians. This resulted in more time spent on guiding and supervising the experimental work and reporting than initially envisaged. The overspending of time is compensated however by the lower hourly rates of the younger staff.

LPRC

In WP6, LPRC planned 16 PMs and used 39.8. There are two reasons for the overuse of the man-power. One reason is that originally the implementation was planned by senior staff with higher hourly rate but for technical reasons, the task was completed mostly by younger staff, with the supervision of a senior staff member. The other reason is that the workload needed for the perfect implementation of the work packages was underestimated during the planning phase. The completion and assessment of the Delphi surveys, the organisation of the WP-related personal and online meetings and the production of the impressively extensive Deliverable 6.2 needed much more working hours than originally planned.

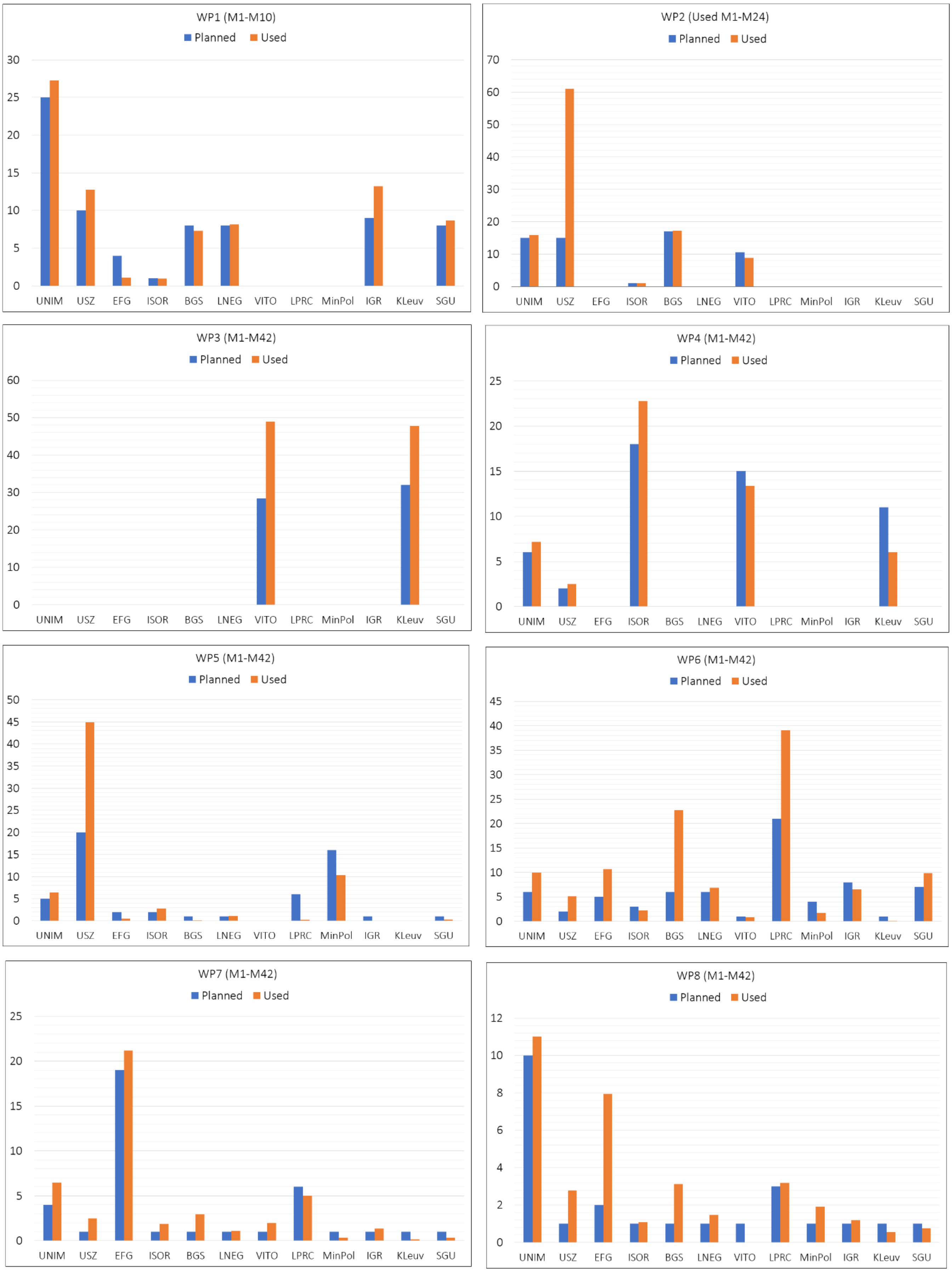

Figure 5.4: Use of person-months by the project partners in the eight work packages during the whole duration of the project.

Use of person-months by the EFG's linked third parties

EFG's LTPs contributed to WP1, WP6 and WP7. In WP1, there was a slight underuse of the planned working hours. Working time inWP6 was more balanced. In WP7, there is a significant overuse, which is due to the fact that the LTPs were very active and made significant efforts in the project dissemination *(Table 5.5, Figure 5.5).*

Table 5.5: Use of person-months by EFG's LTPs during the whole duration of the project.

LTP	WP1		WP6					WP7					Total	Total
	planned	used M1-M18	planned	used M1-M18	used M19-M30	used M31-M42	used M1-M42	planned	used M1-M18	used M19-M30	used M31-M42	used M1-M42	planned	used
CAEG	0,60	0,00	0,60	0,00	0,12	0,00	0,12	0,30	0,58	0,06	1,52	2,16	1,50	2,28
YKL	0,60	0,00	0,60	0,00	0,24	0,03	0,27	0,30	0,00	0,00	0,14	0,14	1,50	0,41
UAG	0,60	0,13	0,60	0,00	0,07	0,09	0,16	0,30	0,60	0,16	1,10	1,86	1,50	2,02
APG	0,60	0,13	0,60	0,00	0,13	0,50	0,63	0,30	0,15	0,52	0,95	1,62	1,50	2,25
CNG	0,60	0,63	0,60	0,00	0,20	0,19	0,39	0,30	0,21	0,03	0,10	0,34	1,50	0,73
MFT	0,60	0,00	0,60	0,00	0,61	1,00	1,61	0,30	2,73	0,00	0,46	3,19	1,50	4,80
IGI	0,60	0,00	0,60	0,00	0,56	0,17	0,73	0,30	0,00	0,24	0,28	0,52	1,50	1,25
PAMAV	0,60	0,95	0,60	0,00	0,07	1,40	1,47	0,30	0,00	0,07	0,13	0,20	1,50	1,67
SGD	0,60	0,17	0,60	0,00	0,61	0,17	0,78	0,30	0,33	0,17	0,28	0,78	1,50	1,56
RSNB	4,00	4,67	4,00	0,00	3,00	7,69	10,69	0,00	0,00	0,00	0,00	0,00	8,00	10,69
ICOG	0,60	0,35	0,60	0,00	0,54	0,00	0,54	0,30	0,17	0,39	0,51	1,07	1,50	1,61
SGS	0,60	1,72	0,60	0,00	1,54	0,00	1,54	0,30	0,94	1,05	1,63	3,62	1,50	5,16
SEG	0,60	2,09	0,60	0,00	0,79	0,61	1,40	0,30	0,70	0,61	0,28	1,59	1,50	2,99
CHGEOL	0,60	0,02	0,60	0,00	0,00	0,00	0,00	0,30	0,02	0,03	0,04	0,09	1,50	0,09
BDG	0,60	0,00	0,60	0,00	0,69	0,25	0,94	0,30	0,34	0,58	0,06	0,98	1,50	1,92
KNGMG	0,60	0,00	0,60	0,00	0,59	0,40	0,99	0,30	0,15	0,25	0,22	0,62	1,50	1,61

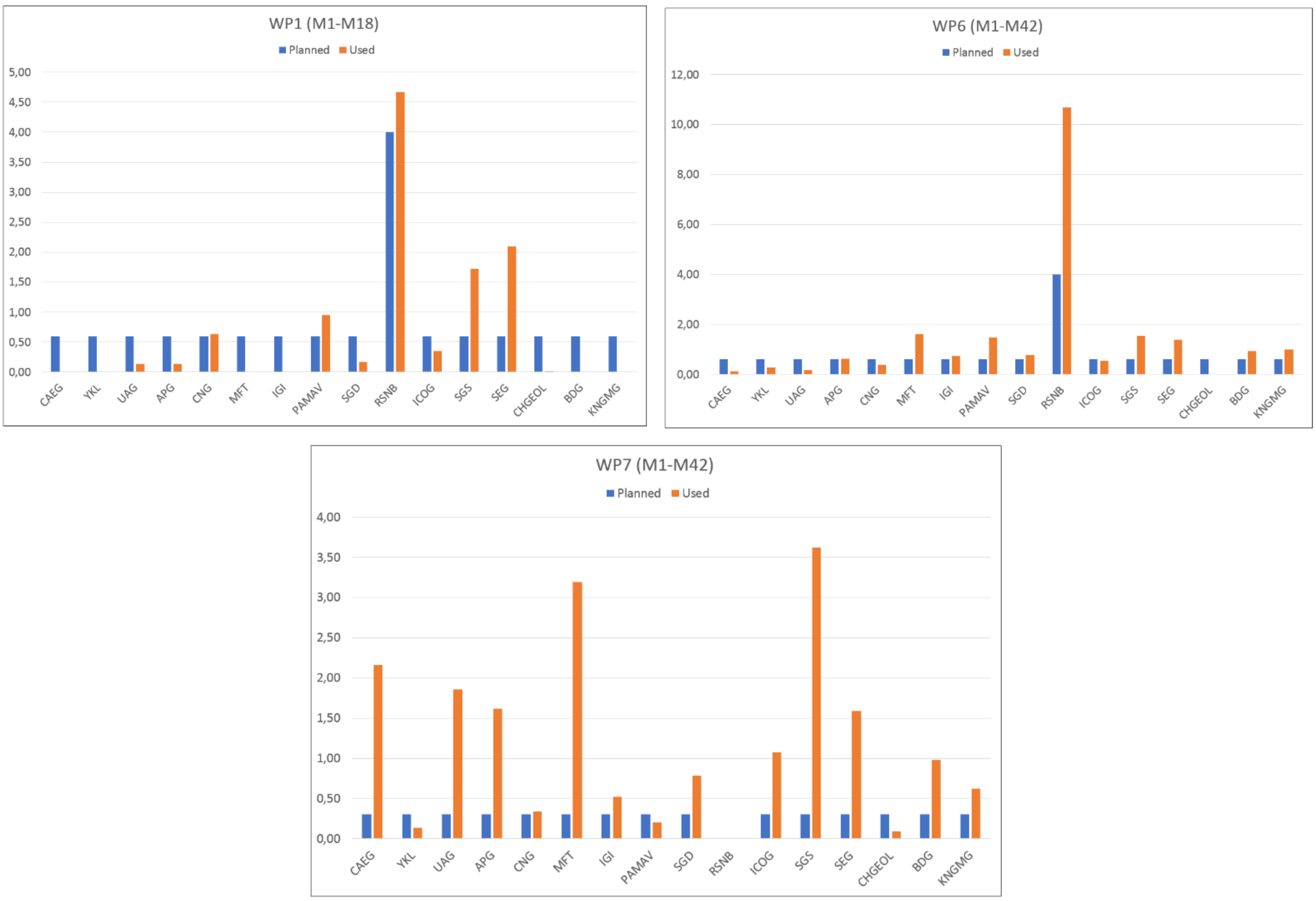

Figure 5.5: Use of person-months by the EFG LTPs during the whole duration of the project.

5.2.1 Unforeseen subcontracting (if applicable)

Not applicable.

5.2.2 Unforeseen use of in kind contribution from third party against payment or free of charges (if applicable)

Not applicable.

Annex 1: Dissemination activities by the project partners and the EFG LTPs in the period M31-M42

International conferences and workshops

Date	Event details (name & place)	Partner(s) involved	Type of dissemination activity Name of person involved	Type of audience	Estimated size of audience	Countries addressed	File name of supporting document
07.06.2018	Upscaling blue energy	LPRC	Multidisciplinary approach for geothermal resources *Tamas Miklovicz*	Industry, academics, policy makers	8	Netherlands, Germany, Belgium, Hungary, Italy	180607_LPRC
07.06.2018	EU Sustainable Energy Week	LPRC, EFG	Multidisciplinary approach for geothermal resources *Tamas Miklovicz, Anita Demény*	Industry, academics, policy makers	100	Mainly EU	180607_LPRC 160607_EFG
18.06.2018	3rd Workshop of H2020 Geothermal Research and Innovation Projects	UNIM	*Tamás Madarász* presented the new results of CHPM2030	Representatives of INEA and the H2020 geothermal projects	30	Various from EU	180818_UNIM
19.06.2018	ETIP-DG Annual Conference 2018	UNIM	*Tamás Madarász* participated in the Roundtable discussion with representatives of geothermal projects	Representatives of the geothermal projects	30	Various from EU	https://www.etip-dg.eu/event/annual-conference-2018/
19.06.2018	ETIP-DG Annual Conference 2018	LPRC	Distribution of brochures *Tamas Miklovicz, Anita Demény*	Representatives of the geothermal projects	30	Various from EU	https://www.etip-dg.eu/event/annual-conference-2018/
12.09.2018	4th Meggen Days of natural resources,	EFG, BDG	Presentation about CHPM2030 foresight activities	Geologists, geoscientists	100	International	https://eurogeologists.eu/4th-meggen-raw-materials-days-international-geologists-conference-of-the-bdg-in-the-galileo-park-lennestadt-meggen/
26.09.2018	Horizon Geoscience	EFG	Overcoming societal challenges, creating change dinner debate	Geologists, geoscientists	60	International	https://eurogeologists.eu/efg-and-egu-establish-dialogue-with-policy-makers-on-how-the-

							geosciences-can-help-overcome-europes-major-societal-challenges/
12-16.10.2018	EU Raw Materials Week	EFG	Poster presentation of the project in Raw Materials week	Geologists, geoscientists	100	International	https://ec.europa.eu/growth/content/raw-materials-week-2018_en
04-05.12.2018	CHPM2030 Visioning workshop (WP6), organised by LPRC	LPRC, UNIM	CHPM workshop to define future targets, *Tamas Miklovicz:* WP6 context, *Marco Konrat*: Visioning methodology	External experts from the mineral and geothermal community	20	Europe	04.12.2018a_LPRC 04.12.2018b_LPRC 04.12.2018_UNIM
09.01.2019	ETIP-DG 7th Stakeholders Meeting	LPRC	Brochure distribution	Researchers, industry	60	Europe	https://www.etip-dg.eu/event/7th-stakeholders-meeting-and-presentation-of-the-strategic-research-and-innovation-agenda/
25-27.02.2019	10th European Geothermal PhD Day Potsdam, Germany	USZ	Short presentation and poster *Máté Osvald*	Geothermal-related PhD students and keynote speakers	70	Mainly EU	25.02.2019_USZ
07-08.03.2019	CHPM2030 Roadmapping workshop (WP6), organised by LPRC	LPRC, UNIM	CHPM workshop to define future actions and recommendations. *Tamas Miklovicz:* WP6 context, *Marco Konrat:* Roadmapping methodology	External experts from the mineral and geothermal community	20	Europe	07.03.2019a_LPRC 07.03.2019b_LPRC 07.03.2019_UNIM
7-12.04.2019	EGU General Assembly 2019 Vienna, Austria	USZ, IGR	Poster *Máté Osvald, Catalin Simion, Stefan Marincea*	Scientists	500	Worldwide	07.04.2019_USZ 07.04.2019_IGR
09.04.2019	IEA - International Workshop on Geothermal Energy	LPRC	Presentation and brochure distribution: *Adrienn Cseko, Gabriella Foti*	Researchers, industry and decision makers (Spain & Canary Islands - national and regional level)	70	Spain	https://drive.google.com/file/d/1HFxOFnScGqGKOLaE_NQaV5RSqt-cS1td/view?usp=sharing
23.05.2019	CHPM2030 International Conference	EFG	The project's international conference, Delft. Presentations by *Tamás Madarász, Chris Rochelle, Xochitl Dominguez, Joost Helsen, Árni Ragnarsson, Vojtech Wertich, Tamás Miklovicz*	Geoscientists, geothermal energy experts	100	Europe	https://www.chpm2030.eu/chpm2030-final-conference/

11-14.06.2019	European Geothermal Congress The Hague, Netherlands	UNIM, USZ	Research article and presentation *Tamás Madarász, Máté Osvald*	Geothermal energy sector	100	Mainly Europe	http://europeangeothermalcongress.eu/
12-14.06.2019	Constructing Social Futures – Sustainability, Responsibility and Power	LPRC	Application of foresight methods in the research of a disruptive geothermal technology (CHPM), presentation by *Tamas Miklovicz*	Researchers	25	Europe, Canada, New Zealand	https://prezi.com/view/V7dpjdAUjmYDOPzxSaCs
18.-20.9.2018	IGSHPA, Stockholm, SE	SGU	Open workshop discussions Gerhard Schwarz	Scientists, practitioners	90	worldwide	
13.2.2019	GeoTherm, Baltic Sea Symposium, Offenburg, GER	SGU	Geothermal Applications in Sweden *Gerhard Schwarz (by invitation)*	Scientists, stakeholders, public authorities, practitioners	80	mainly Europe	http://iea-gia.org/publications-2/working-group-publications/2019-baltic-nations-symposium-presentations/

National conferences and workshop

Date	Event details (name & place)	Partner(s) involved	Type of dissemination activity (presentation, poster, exhibition, etc)	Type of audience	Estimated size of audience	Countries addressed	File name of supporting document
15.5.2019	Innovation cluster warm & cold, Stockholm, SE	SGU	Open workshop discussions *Gerhard Schwarz*	Scientists, practitioners	30	Sweden	http://varmtochkallt.se/nyhet/uppstartsmote/

Publications in journals or on the internet

Date	Journal/link	Partner(s) involved	Title of publication, author(s)	Type of audience	Estimated size of audience	Countries addressed	File name of supporting document
13.12.2018	Geofluids	USZ, BGS	Laboratory leaching tests to investigate mobilisation and recovery of metals from geothermal reservoirs *M. Osvald, A.D. Kilpatrick, C.A. Rochelle, J. Szanyi, T. Medgyes and B. Kóbor*	scientists		worldwide	https://doi.org/10.1155/2018/6509420

14.05.2019	European Geologist	EFG	Paper about project deliverables published by CHPM2030 *Anita Stein*	geoscientists	50 000	worldwide	https://eurogeologists.eu/wp-content/uploads/2019/05/EGJ47_web.pdf
14.05.2019	European Geologist	UNIM	Co-production of clean energy and metals – the CHPM concept *É. Hartai, T. Madarász & the CHPM2030 Team*	geoscientists	50 000	worldwide	https://eurogeologists.eu/wp-content/uploads/2019/05/EGJ47_web.pdf
11.06.2019	European Geothermal Congress 2019, conference proceeding	UNIM	CHPM2030 - novel concept of combined heat, power and metal extraction from geothermal brines *T. Madarász, É. Hartai, & the CHPM2030 Team*	geoscientists			
12.06.2019	Constructing Social Futures – Sustainability, Responsibility and Power (conference)	LPRC	Application of foresight methods in the research of a disruptive geothermal technology (CHPM) (abstract) *Tamás Miklovicz*	foresight community		worldwide	12.06.2019_LPRC

Other types of promotion

Date	Means of promotion (event, publication, etc)	Partner(s) involved	Type of dissemination activity (newsletter, public event, promotional products, etc.)	Type of audience	Size of audience	Countries addressed	File name of supporting document
15.08.2018	Newsletter	EFG	Newsletter on CHPM2030 project	geoscientists	50 000	International	https://mailchi.mp/3337ea1ba19e/chpm2030-project-news-1361501
08.2019	Brochures (3 in total)	EFG, UNIM	CHPM2030 brochure (3) in several European languages	geoscientists	10 000	International	https://www.chpm2030.eu/wp-content/uploads/2018/08/CHPM2030_brochure3_20180814.pdf
01.2019	Video	EFG	Launch of the second project video	wide public	5000	International	https://youtu.be/KycincLt9FQ
10.2018	Raw Materials week and Final conference in Delft	EFG	Presentation of the CHPM2030 Poster	wide public	5000	International	

05-06.2019	CHPM2030 Delphi survey, 1st round	LPRC	The 2 round delphi survey was launched within WP6.	Researchers, industry		International	
15.06.2018	Newsletter	EFG	Newsletter on CHPM2030 project	geoscientists	50 000	International	https://mailchi.mp/98f50f8bb4b2/chpm2030-project-news-1633341
06-07.2019	CHPM2030 Delphi survey, 2nd round	LPRC	The 2 round delphi survey was launched within WP6. Read more about it here: https://www.lapalmacentre.eu/delphi-survey-in-the-pipeline/	Researchers, industry	1120 (both rounds)	Europe, Canada, Mexico, Ethiopia, India, Turkey, Philippines, Australia, New Zealand	https://docs.google.com/forms/d/e/1FAIpQLSf1DmsYfojjEGyAMG25rD-2f8R1HNlhTVH9_ZvCmu5Dfw96IA/viewform
2019 (21.06, 27.05, 15.03.) 2018 (06.12, 11.09, 31.07, 13.07, 14.06, 28.05, 17.04, 04.04.) 2017 (15.11. 20.09, 05.09, 16.05, 28.04, 04.04.) 2016 (18.10, 20.01.)	LPRC website posts	LPRC	LPRC websites news items: https://www.lapalmacentre.eu/tag/chpm2030/	public		International	
Continuous	LPRC social media news/posts	LPRC	Websites news items are shared on LPRC's LinkedIn: https://www.linkedin.com/company/la-palma-research-centre-sl/	public		International	

			Facebook (https://www.facebook.com/lapalmaresearch/) Regular tweets about CHPM2030 events from https://twitter.com/lapalmaresearch and https://twitter.com/miktamasaccounts.				
24.03.2019	GeoNews	EFG	News on CHPM2030 project	geoscientists	50 000	EU	https://mailchi.mp/6d65f1be2f0f/geonews-march?e=47eacc751a
30.04.2019	GeoNews	EFG	News on CHPM2030 project	geoscientists	50 000	EU	https://mailchi.mp/bf88b2da9658/geonews-march-2884541
30.05.2019	GeoNews	EFG	News on CHPM2030 project	geoscientists	50 000	EU	https://us8.campaign-archive.com/?u=7622a1c0fc286079ff6a153b7&id=ffac33fc0d
Continuous	EFG website/social media news/posts	EFG	News about CHPM2030 are shared on EFG's website, LinkedIn, Facebook and Twitter	wide public	50 000	International	
Continuous	EFGeoWeek	EFG	News on the CHPM2030 project were disseminated in EFG's weekly news compilation	geoscientists	50 000	International	http://efgeoweek.eurogeologists.eu/#/

EFG LTPs

In addition to the dissemination activities by the project partners, EFG Linked Third Parties carried out *302* dissemination items in the reporting period, with a large geographical coverage in Europe (conferences, workshops, social media, national websites, newsletters, circulars).