



# ReSus survey results and next steps

Reservoir Sustainability Joint Activity

September, 2016

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Reservoir Sustainability (ReSus) Joint Activity

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The steering committee of the Reservoir Sustainability Joint Activity wants to thank all partners from the Geothermal ERA-Net for supporting the work. In addition, we are grateful with all the European stakeholders who participated in our survey.

## **Abstract**

This report summarizes the results of survey performed in the frame of the Reservoir Sustainability (ReSus) Joint Activity. In particular the report describes the survey setup and spread among the principal geothermal stakeholders along the European countries participating in the Geothermal ERA-NET project. The answers to each question proposed in the survey are here reported. The report is concluded with a final section which highlights the main outcomes and possible next step.

## Executive summary

This report describes the main insights and outcomes gathered from the web survey that was set up in the frame of the Reservoir Sustainability (ReSus) Joint Activity (JA) performed within Geothermal ERA-NET project. The sustainable and safe use of geothermal reservoirs and the increasing lifetime of the resource, boreholes and system components were recognized as key factors to foster the development of geothermal energy in the future. The ReSus JA goal is to study geothermal reservoir sustainability.

To such aim a web questionnaire was setup and spread to 161 stakeholders (SH) belonging the countries participating in this Joint Activity among those involved in Geothermal ERA-NET project. 19 SH answered to this invitation by completing the survey, which corresponds to 11.8% of the invited SH.

The results show a good correlation among the groups of the respondents, their domains of activity and their interests. Principal respondents group are: Research and innovation, Upstream geothermal industry (drilling, company, technology suppliers, etc.), Consulting engineering. Those groups are interested mainly in Research & Innovation, Assessment of geothermal potential. Low temperature and EGS resulted as the most interesting geothermal systems at all horizontal scale and at medium to deep.

The SH were asked to comment the reservoir sustainability considering three different point of view (pillar). The survey asked them to rank (or add) criteria relevant for: economic profitability, environmental impact and public acceptance. For each pillar, the most ranked were:

- For economic profitability, reservoir evolution, insurance process and geologic risk got high rank
- Hydrothermal eruption, induced seismicity and chemical pollution are the principal aspects that affect environmental impact
- On public acceptance pillar the most ranked criteria resulted effluent valorisation, induced seismicity and information/communication

As conclusion, although not many answers were gathered from SH, the information retrieved give an interesting picture, which deserve to be deepen in the future. The activity on Reservoir sustainability should be seriously considered to be continued in the framework of the foreseen approved GEOTHERMICA project, in order to assess the possibility to fund research and/or demonstration project in a co-fund join call.

# 1 Introduction

## 1.1 Background survey

The Geothermal ERA-NET project aims to interact with international programs that foster cooperation in the areas of geothermal energy. The Geothermal ERA-NET is the first step towards a coordinated research in the EU through the so-called SET-plan (European Strategic Energy Technology Plan). Further information on the project is available at [www.geothermaleranet.is](http://www.geothermaleranet.is). The consortium of the Geothermal ERA-NET project defined some geothermal topics of interest. Seven Joint Activities (JA) were completed now on these topics. One of these JA was dedicated to the Reservoir Sustainability (ReSus).

To foster the development of geothermal energy it is very important to analyse the practices and the gaps for a sustainable and safe use of geothermal reservoirs as well as increase the lifetime of the resource, boreholes and system components. The goal of the ReSus JA is to study geothermal reservoir sustainability. Beyond the scientific community, the topic of such JA clearly interests the regulation authorities and the operators who seek for sustainable development strategies. Comparing the current practice used by the operators, highlighting the best solutions and studying the unsuccessful cases, we will animate a fruitful debate to capture the current state-of-the-art and explore possible scenarios for future economic and sustainable exploitations

The ReSus JA working group organized a web questionnaire to highlight the objectives of the stakeholders (SH) regarding reservoir sustainability and to collect their practices to achieve them.

The ReSus survey was conducted firstly in September 2015 and secondly in March 2016. The extension allowed to retrieve more input from European SH. The preliminary results were presented during the Geothermal ERA-NET meeting in Reykjavik in April 2016. This report describes the survey results as well as the main outcomes and recommendations gathered by this JA.

## 1.2 Survey description

The questionnaire has two goals. On one hand it aims at highlighting SH's objectives for the reservoir sustainability. On the other hand, the questionnaire is set up to know how they address these objectives. The survey is structured in 2 parts:

Part 1 - Institution typology

Part 2 - Reservoir sustainability concept

Part 1 was dedicated to retrieve information on the respondent institution (i.e., institution activities, institution interests, institution belonging group, and field of interest in terms of horizontal and vertical scale for the geothermal reservoir) in 7 questions. This part is important since it provides the necessary information about the type of SH.

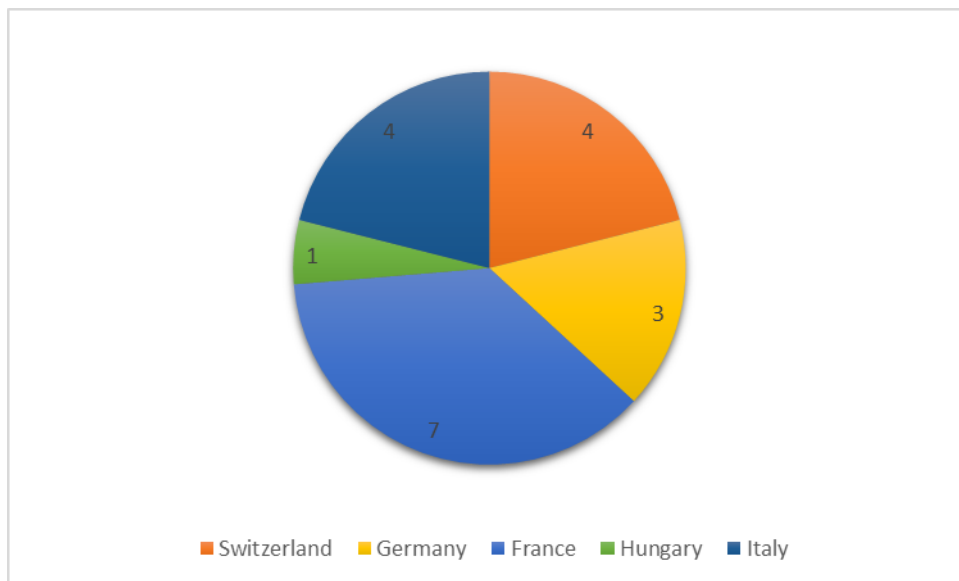
Part 2 surveyed the reservoir sustainability concept from three different points of view, i.e., Economic profitability, Public acceptance and Environmental impact. The SH had to rank some criteria, add possible others criteria, indicate how tackle the top 3 criteria and if any, suggest the main gap(s) that hamper reservoir sustainability for each of the three point of view.

### 1.3 Stakeholder description

The ReSus JA consortium planned to spread the web survey among their countries trying to reach as much different group of geothermal SH as possible. To such aim each JA partner made a survey at national level to define a target list of National SH for the survey. The survey reached about 161 SH, and was answered by 19 of them, with a success rate of over 11.8%. In table 1 the number of the invited SH and completed surveys is shown.

**Table 1 Survey coverage**

	Submitted	Completed Survey	Feedback %
Switzerland	?	4	
Germany	15	3	20
France	119	7	6
Hungary	5	1	20
Italy	22	4	18
<b>TOTAL</b>	<b>161</b>	<b>19</b>	<b>11.8</b>



**Figure 1 Origin survey responders**

Roughly 37% of completed surveys come from France SH, which form the biggest national group. Italy and Switzerland follow with about 21% each, and the Switzerland SH group ranks about 16%. The remaining 5% is from Hungary SH groups (see Table 1 and Figure 1).

The low feedback in some countries might be an indication, that the SH already handle with success sustainability problems for geothermal reservoirs on a national level and therefore showed little interest in the survey. Indeed, this may have likely been the main reason for partner countries in the Geothermal ERA-NET Consortium to be not part of this ReSus JA. The feedback from different countries varies considerably, but with over 10% the overall feedback is not completely satisfying.



## 2 Results

Question 1 asked for basic information about the responder's identity. The interpretation of this question was conducted in section 1.3 of this report. For the analysis of the results and in order to illustrate them better, various forms of graphical depiction were created. All should be self-explanatory. For questions 2, 3, 4 the values on the charts represent the number of hits per category, otherwise for questions from 5 to 10, where we asked to rank the criteria or categories, the values on the charts mean the computed average for each.

It should be noted that all participants answered almost all questions. However, the questions requiring free text were poorly filled-in, denoting a general fatigue of filling out survey. Nevertheless, the results from questions 8, 9, 10 could be not completely exact. For those questions, in this report we consider all the answers gathered; however, among them there could be some denoting possible misunderstanding or wrong fill-in. Appendix A presents all the answers collected from each SH.

### 2.1 Part 1 - Your institution typology

#### 2.1.1 Potential user group

Question 2: Your institution belongs to one of the following potential user groups:

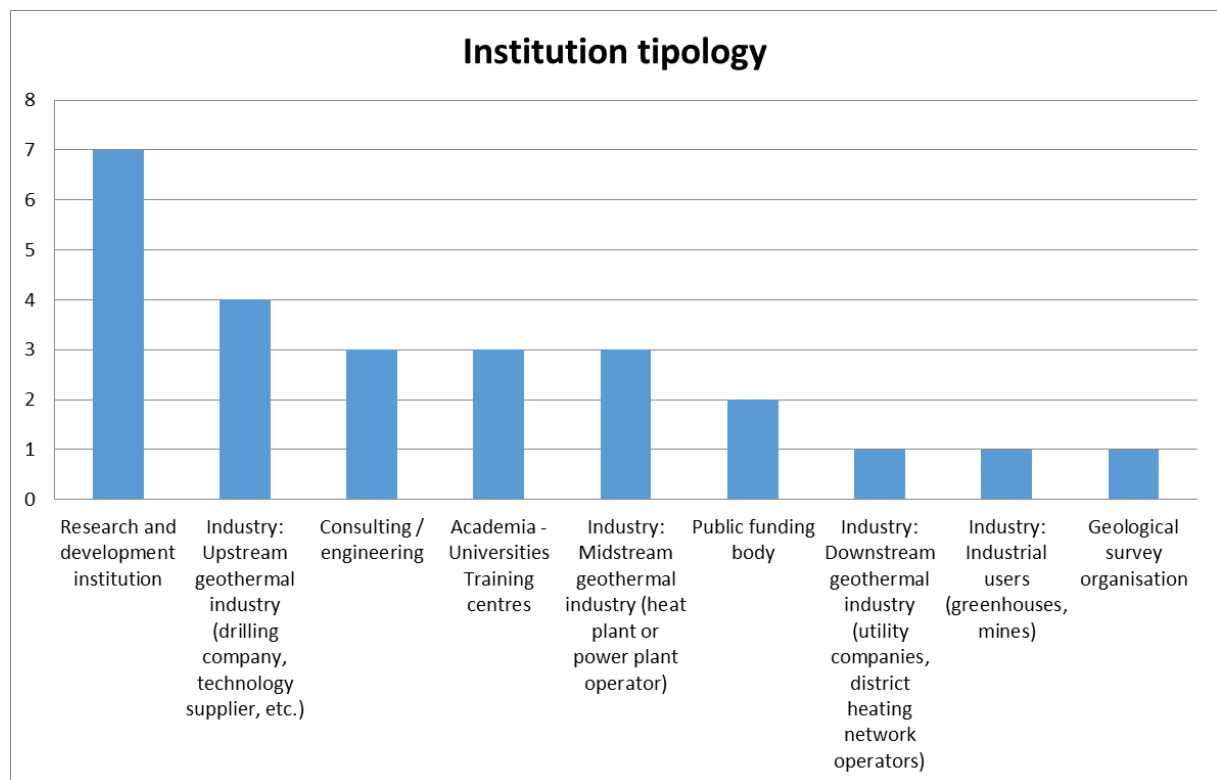


Figure 2 Potential user groups, number of hints per category

#### Description:

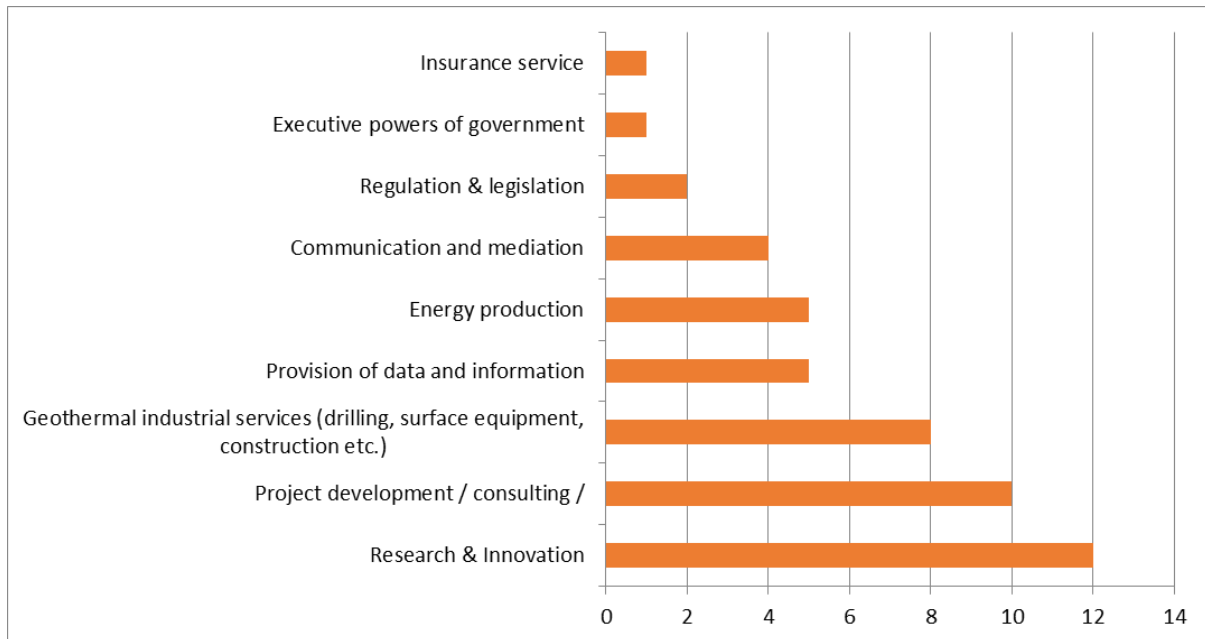
The biggest stakeholder groups are:

- Research and development institutions (largely the most voted), then
- Industry: upstream geothermal industry (drilling company, technology supplier, etc.) and

- With the same number of hits, Consulting / engineering, Academia – Universities & Training centres and Industry: midstream geothermal industry (heat plant or power plant operator

### 2.1.2 Domains of activity

Question 3: Your institution is active in the following domains:



**Figure 3 Domain of activity, number of hints per category**

#### Description:

Most SH are active in the following fields:

- Research & Innovation
- Project development / Consulting
- Geothermal industrial services (drilling, surface equipment, construction etc.)

The remaining domains of activity are of minor interest for the participating SH.

Three domains obtained over 8 of hits (16% of the total hits), which suggests that a significant number of SH are active in more than one domain.

### 2.1.3 Aspects of geothermal energy

Question 4: What aspect of geothermal energy is your institution interested in? 1 (not interested) to 5 (very interested):

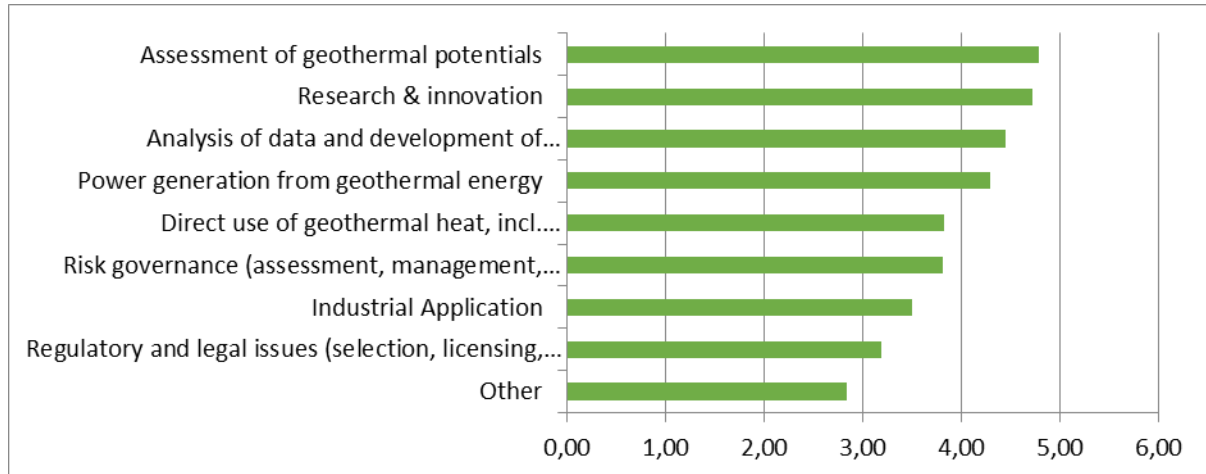


Figure 4 SH most interesting aspects, averaged rating of each aspects

#### Description:

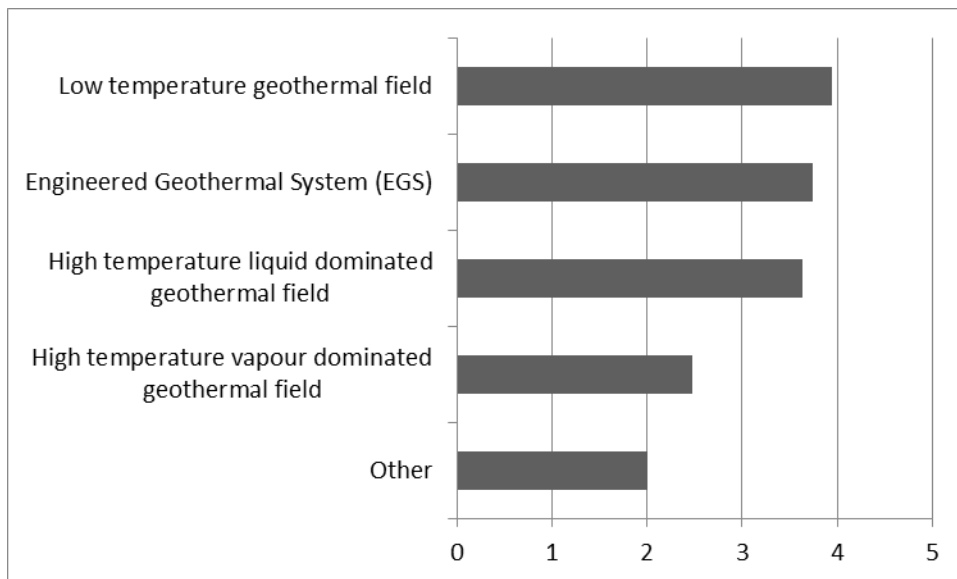
The averages of all aspects lie more or less in the range of 3 to 4 (rather interested to interested). No aspect was clearly and definitely dipping into the range of “not interesting”. The aspect that raised the least interest was “Regulatory and legal issues”. Furthermore, there is significantly more interest in “assessment of geothermal potential” and “research & innovation” than “industrial application”. The results allow a sort of rank of the most interested aspect on geothermal energy of the respondent SH:

- Main interests: Research & Innovation, Assessment of geothermal potential
- Medium interests: Analysis of data and development of processes/workflows, Power generation from geothermal energy
- Minor interests: Risk governance (assessment, management, mitigation), Direct use of geothermal heat, incl. cogeneration (district heating, spas, ...)

In the open text option, the following additional aspects were mentioned (also see Appendix A): exploration process identification and education & training once for each.

### 2.1.4 Institution interests

Question 5: What type of geothermal system is your institution interested in? 1 (not interested) to 5 (very interested):



**Figure 5 Most geothermal system interest, averaged rating of each aspects**

#### Description:

Most SH are interested in the following type of geothermal fields:

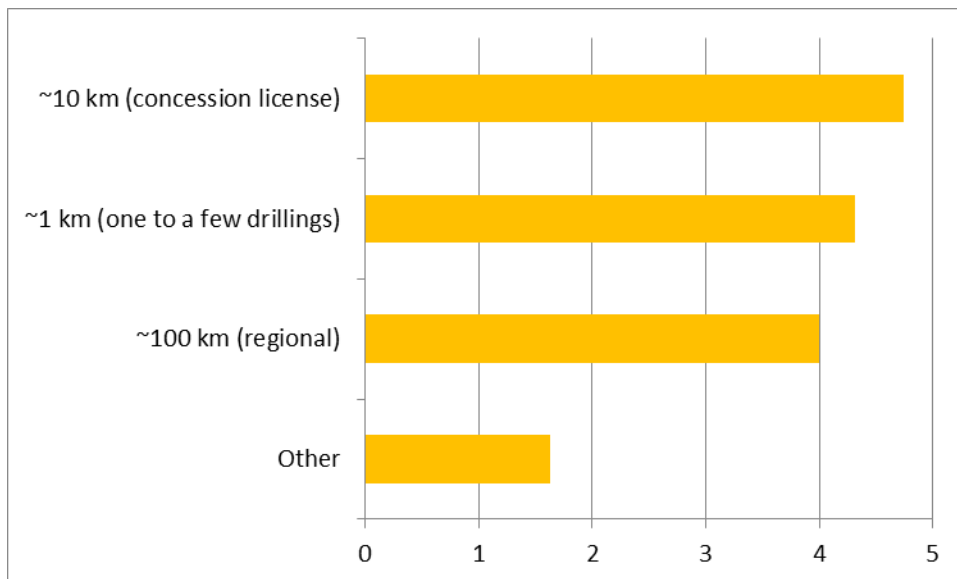
- Low temperature geothermal field
- Engineered Geothermal System (EGS)
- High temperature liquid dominated geothermal field

High temperature vapour dominated geothermal system resulted of minor interest for the participating SH.

In the open text option, the following additional aspects were mentioned (also see Appendix A): heat storage (3 times), very low geothermal energy and cogeneration once for each.

### 2.1.5 Scale of interest

Question 6: The geothermal resource can be managed at various scales. What geothermal system scale, is your institution interested in? 1 (not interested) to 5 (very interested):



**Figure 6 Most geothermal system scale of interest, averaged rating of each aspects**

#### Description:

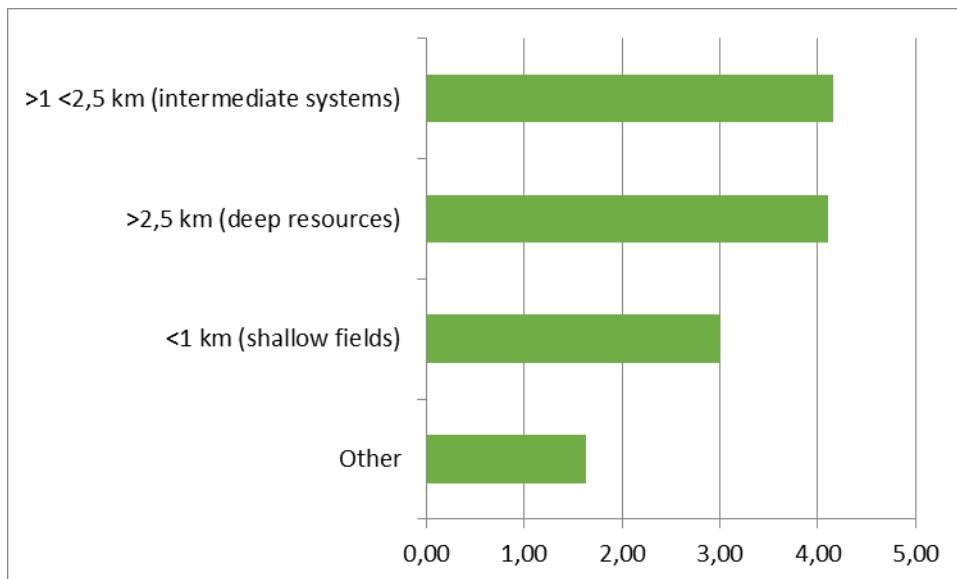
Most SH are interested in the following scale of geothermal fields:

- About 10 km (concession licence)
- About 1 km (one to a few drillings)
- About 100 km (regional)

In the open text option, the following additional aspect was mentioned (also see Appendix A): borehole scale (once).

### 2.1.6 Depth of interest

Question 7: The geothermal resource can be managed at various scales in depth. What scale in depth is your institution interested in? 1 (not interested) to 5 (very interested):



**Figure 7 Most geothermal system scale in depth of interest, averaged rating of each aspects**

#### Description:

Most SH are interested in the following scale of geothermal fields:

- Between 1 and 2.5 km (intermediate systems)
- Higher than 2.5 (deep resources)
- Shallower than 1 km (shallow fields)

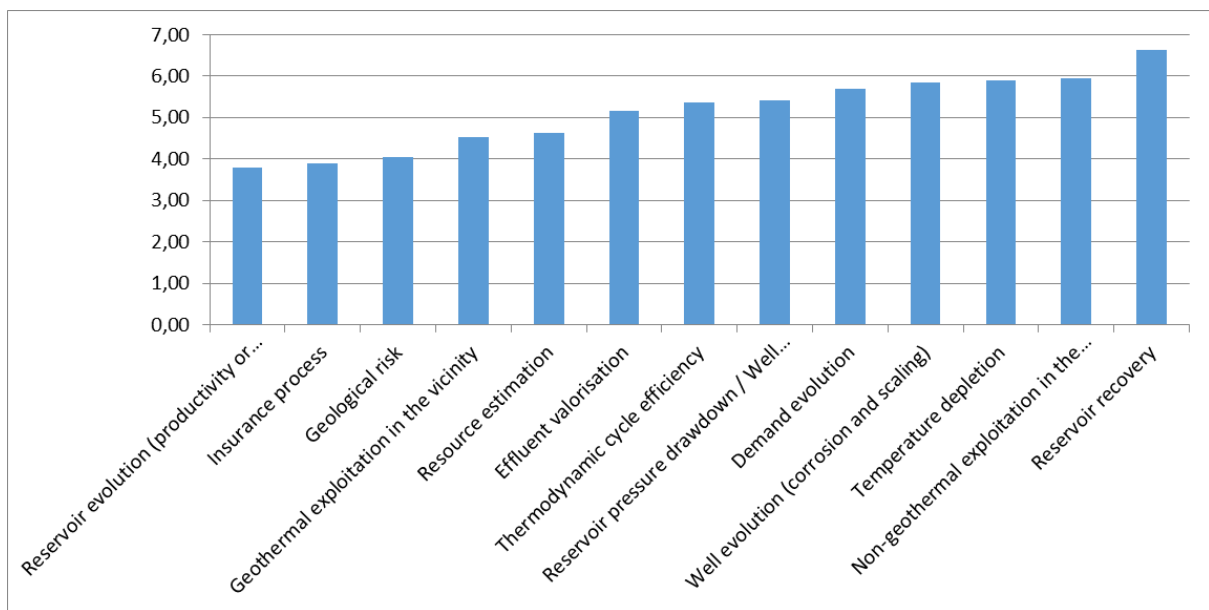
In the open text option, the following additional aspects were mentioned (also see Appendix A): shallower than 200 m (once) and the use of underground laboratories (once).

## 2.2 Part 2 - Reservoir sustainability concept

The following part is structured on the 3 main pillars of sustainability: economic profitability, environment impact, and public acceptance. For each of them, it is proposed to rank the suggested criteria according to the SH experience, add possible others criteria not included in the proposed list, indicate how face the top 3 criteria and if any, suggest the main gap(s) that hamper reservoir sustainability.

### 2.2.1 Economic profitability

Question 8: Please rank the following criteria by numbering them: 1 is the most important, then 2, etc. Do not rank an irrelevant criterion. If a criterion is missing, please describe it in the blank box below “Other n” and rank it (3 max):



**Figure 8 Most criteria on economic profitability pillar, averaged rating of each aspects (NB lower rank value means higher importance)**

#### Description:

Principle (top 5) criteria pointed by SH for economic profitability pillar are here below listed together with the way indicated to tackle with (if present):

**Table 2 Criteria for economic profitability pillar**

#	Top criteria	How to tackle criteria <sup>1</sup>
1	Reservoir evolution (productivity or injectivity losses)	<ul style="list-style-type: none"> <li>Careful reservoir management</li> </ul>
2	Insurance process	<ul style="list-style-type: none"> <li></li> </ul>
3	Geological risk:	<ul style="list-style-type: none"> <li>Process identification – Monitoring - data evaluation</li> <li>The pressure drawdown during well testing and also later, during operation provides exact data for profitability</li> </ul>

<sup>1</sup> Disclaimer note: missing value in the field “How to tackle criteria” means the SH didn’t filled-in the free text box or authors noted that the answer was not reputed valid. Complete answers can be find in the Annex A.

		calculations
4	Geothermal exploitation in the vicinity	•
5	Resource estimation	<ul style="list-style-type: none"> <li>• Data assessment -regional / conceptual modelling – monitoring - numerical evaluation</li> <li>• Calibrated numerical modelling</li> <li>• 3D static and dynamic modelling, will be the base of resources estimation and economic assessments</li> </ul>

In the open criteria text option, the following additional aspects were mentioned (also see Appendix A): taxes and depreciation, royalties, fees (once) and government subsidies (feed-in tariffs or premiums) (once).

Eventually, the main gap(s) that hamper reservoir sustainability regarding the economic profitability

- Most important gaps:
  - Missing transparency of operators / field developer,
  - Demand evolution,
  - Assessment of the reservoir recharge/depletion and need of re-injection,
  - The exploration cost should be partly supported by public funds,
  - Subsurface uncertainties (reservoir imaging and prediction)
  - Pressure drawdown
- Medium important gaps:
  - Establishing academic partnership on sustainability issues
  - Well evolution. Well costs strongly influence the investment and operation costs
  - Problematic re-injection scheme
  - Reservoir continuity, connectivity and 3D permeability
- Other gaps:
  - Geothermal exploitation in the vicinity. Receiving permissions can be more difficult
  - possible negative impact of induced seismicity may hamper public support if not well managed



### 2.2.2 Environmental impact

Question 9: Please rank the following criteria by numbering them: 1 is the most important, then 2, etc. Do not rank an irrelevant criterion. If a criterion is missing, please describe it in the blank box below “Other n” and rank it (3 max):

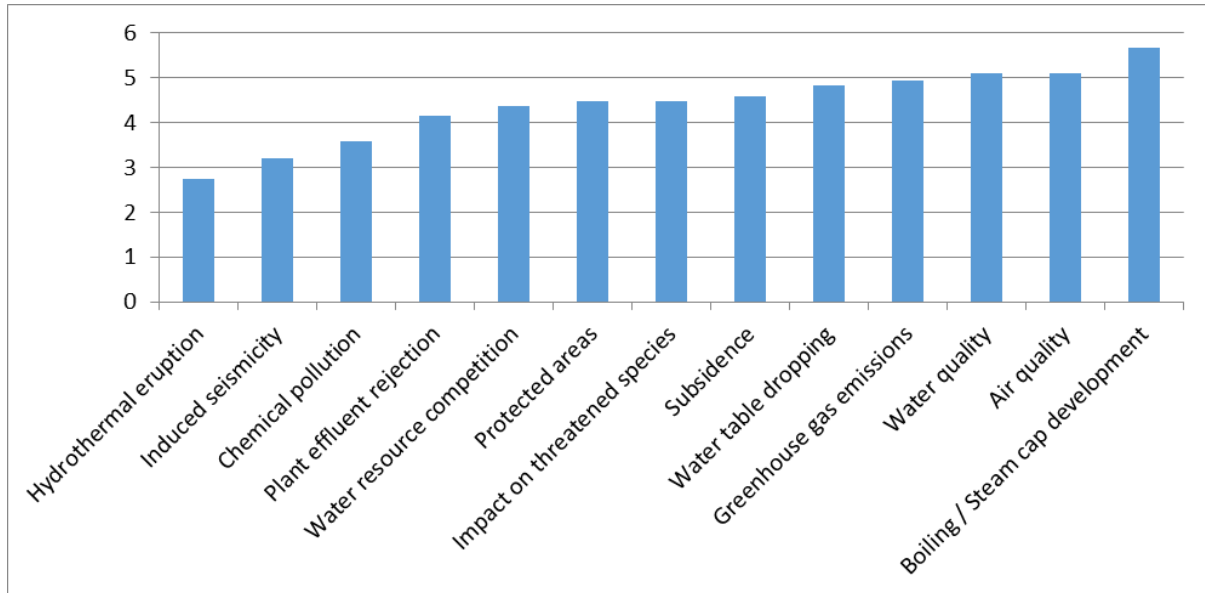


Figure 9 Most criteria on environmental impact pillar, averaged rating of each aspects (NB lower rank value means higher importance)

#### Description:

Principle (top 5) criteria pointed by SH for environmental impact pillar are here below listed together with the way indicated to tackle with:

Table 3 Criteria for environmental impact pillar

#	Top criteria	How to tackle criteria <sup>2</sup>
1	Hydrothermal eruption	•
2	Induced seismicity	<ul style="list-style-type: none"> <li>• Appropriate operational controls to minimize risks</li> <li>• Definition of active monitoring station network (local and national) coupled with theoretical modelling of subsurface stress realise following water circulation and well stimulation</li> </ul>
3	Chemical pollution	•
4	Plant effluent rejection	<ul style="list-style-type: none"> <li>• Measuring pressure gradients and water interfaces behind casings right after drilling and during the lifecycle of the wells. Classic pressure gauges and nuclear tools methods are used</li> </ul>
5	Water resource competition	<ul style="list-style-type: none"> <li>• Geochemical characterisation of key aquifers and sealing stratigraphic units</li> </ul>

In the open criteria text option, the following additional aspects were mentioned (also see Appendix A): noise (once) and traffic (once).

<sup>2</sup> Disclaimer note: missing value in the field “How to tackle criteria” means the SH didn’t filled-in the free text box or authors noted that the answer was not reputed valid. Complete answers can be find in the Annex A.

Eventually, the main gap(s) that hamper reservoir sustainability regarding the economic profitability

- Water resource competition
- Water table drop if reinjection is missing
- Chemical pollution if the system is not closed
- Optimization of the plant operation and management
- Long term monitoring of the potential impacts
- Enhanced communication of the low environmental impact

### 2.2.3 Public acceptance

Question 10: Please rank the following criteria by numbering them: 1 is the most important, then 2, etc. Do not rank an irrelevant criterion. If a criterion is missing, please describe it in the blank box below “Other n” and rank it (3 max) in the matrix:

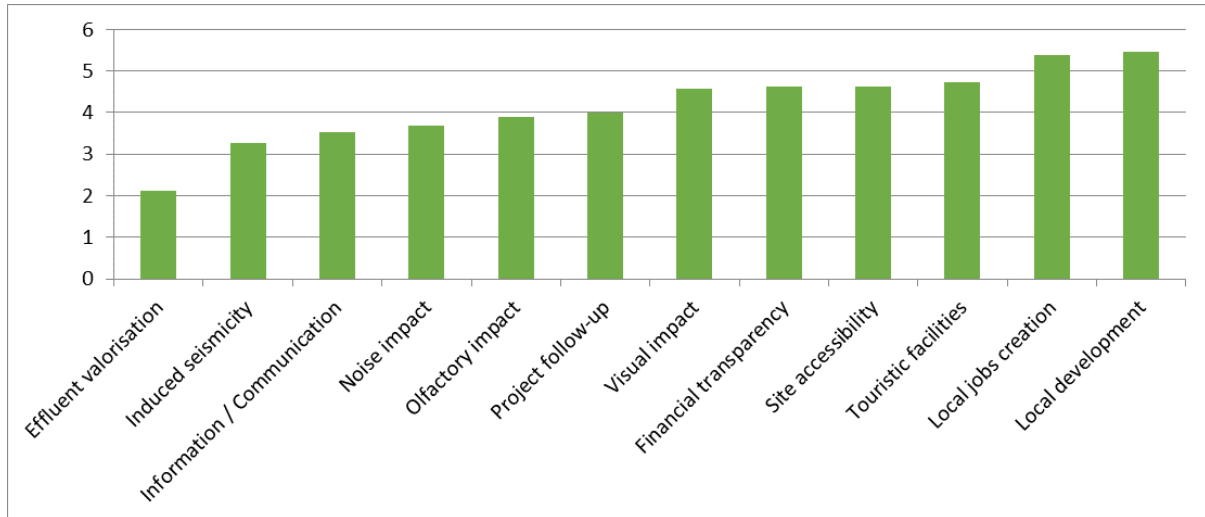


Figure 10 Most criteria on public acceptance pillar, averaged rating of each aspects (NB lower rank value means higher importance)

#### Description:

Principle (top 5) criteria pointed by SH for public acceptance pillar are here below listed together with the way indicated to tackle with:

Table 4 Criteria for public acceptance pillar

#	Top criteria	How to tackle criteria <sup>3</sup>
1	Effluent valorisation	<ul style="list-style-type: none"> <li>Financial support to local community to compensate the annoyance</li> </ul>
2	Induced seismicity	<ul style="list-style-type: none"> <li>Operational controls to minimize risk of felt induced seismicity</li> <li>See above plus installation of ad hoc seismometers station network to establish baseline prior geothermal exploration and exploitation</li> </ul>
3	Information / communication	<ul style="list-style-type: none"> <li>Make projects "owned" by the local community</li> <li>Coordinated effort between Academia and local Industry and Canton to organise communication and demonstration events (e.g. vibroseism) at different scale for different communities (city, village etc)</li> </ul>
4	Noise impact	<ul style="list-style-type: none"> <li></li> </ul>
5	Olfactory impact	<ul style="list-style-type: none"> <li></li> </ul>

<sup>3</sup> Disclaimer note: missing value in the field “How to tackle criteria” means the SH didn’t filled-in the free text box or authors noted that the answer was not reputed valid. Complete answers can be find in the Annex A.

In the open criteria text option, the following additional aspects were mentioned (also see Appendix A): taxes and depreciation, royalties, fees (once) and government subsidies (feed-in tariffs or premiums) (once).

Eventually, the main gap(s) that hamper reservoir sustainability regarding the economic profitability

- Information/communication
- Induced seismicity
- Local development
- the benefit should be directly delivered to local community without intermediate steps
- direct link between operators and administrators

### 2.2.4 Question 11: Any other comment, suggestion or issue with respect to the reservoir sustainability

Only one SH filled in the open text prepared for the question 11, as follow: “It is important to analyses the economic, logistic and social condition of the territory in order to evaluate and improve geothermal utilization. In particular, new industrial applications should be studied case by case.”

### 2.2.5 The three pillars for SH

At completion of the ReSus survey analysis for each pillar we performed a filter by respondent typology to know what was the most important criteria.

The respondent SH were grouped as follow starting from Figure 2:

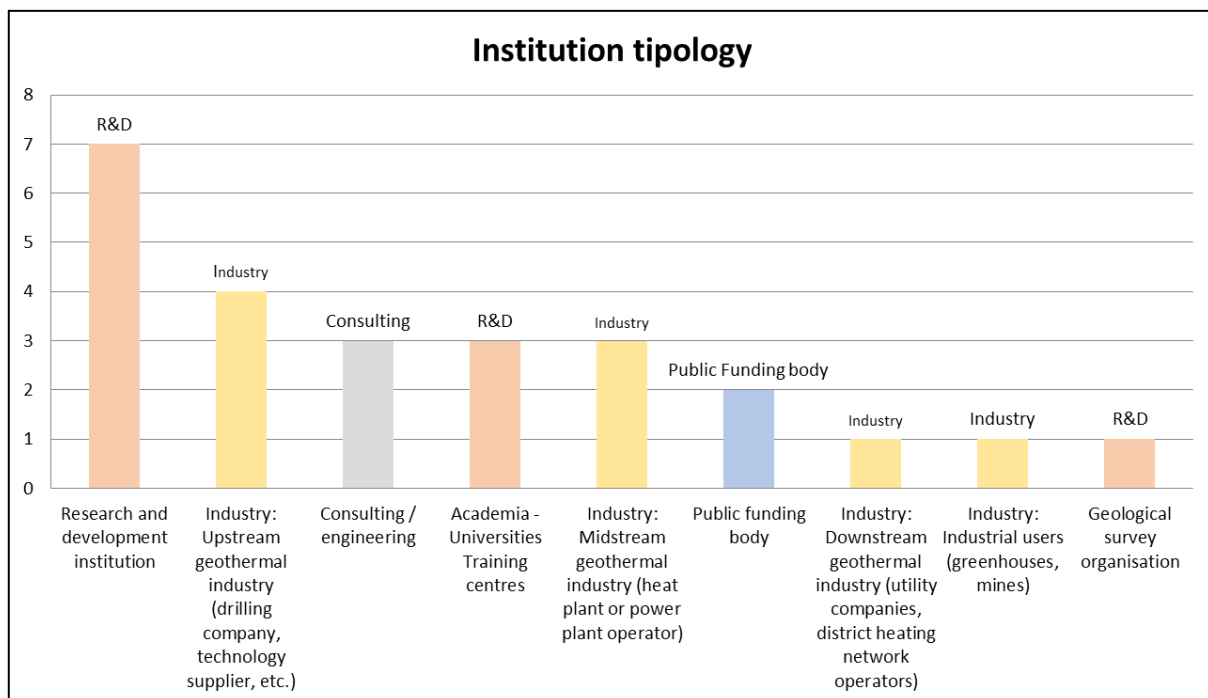


Figure 11 Groups of stakeholders

Figure 12 and Table 5 shows the result regarding the Economic profitability pillar per each SH group.

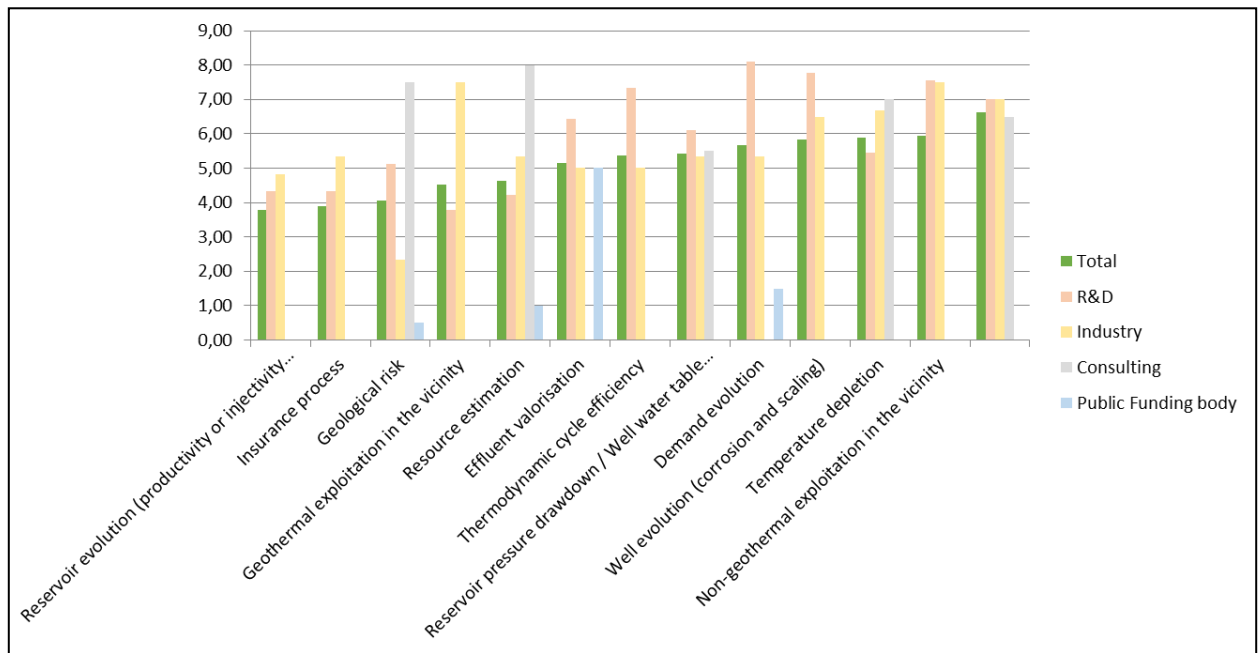


Figure 12 Stakeholder groups most criteria on economic profitability pillar, averaged rating of each aspects (NB lower rank value means higher importance)

Table 5 Economic profitability top criteria per stakeholder groups

Rank	R&D	Industry	Consulting	Public Funding body
1	Geothermal exploitation in the vicinity	Geological risk	Reservoir pressure drawdown / Well water table dropping	Geological risk
2	Resource estimation	Reservoir evolution	Reservoir recovery	Resource estimation
3	Insurance process and Reservoir evolution	Thermodynamic cycle efficiency	Temperature depletion	Demand evolution
4	Geological risk	Insurance process, Resource estimation, Demand evolution, Reservoir pressure drawdown / Well water table dropping	Geological risk	Effluent valorisation
5	Temperature depletion		Resource estimation	
6	Reservoir pressure drawdown / Well water table dropping			

Figure 13 and Table 6 shows the result regarding the Environmental impact pillar per each SH group.

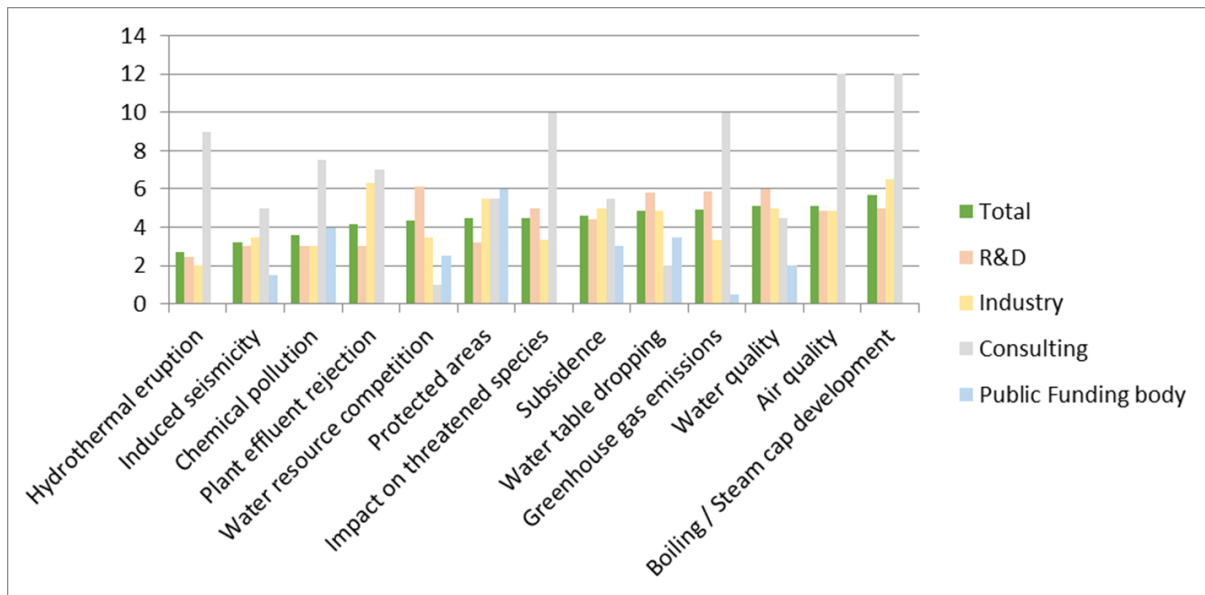


Figure 13 Stakeholder groups most criteria on environmental impact pillar, averaged rating of each aspects (NB lower rank value means higher importance)

Table 6 Environmental impact top criteria per stakeholder groups

Rank	R&D	Industry	Consulting	Public Funding body
1	Hydrothermal eruption	Hydrothermal eruption	Water resource competition	Greenhouse gas emissions
2	Induced seismicity, Chemical pollution, Plant effluent rejection	Chemical pollution	Water table dropping	Induced seismicity
3	Protected areas	Impact on threatened species, Greenhouse gas emissions	Water quality	Water quality
4	Subsidence	Water resource competition	Induced seismicity	Water resource competition
5	Air quality	Water table dropping, Air quality	Protected areas	Subsidence
6			Subsidence	Water table dropping
7			Plant effluent rejection	Chemical pollution

Figure 14 and Table 7 shows the result regarding the Public acceptance pillar per each SH group.

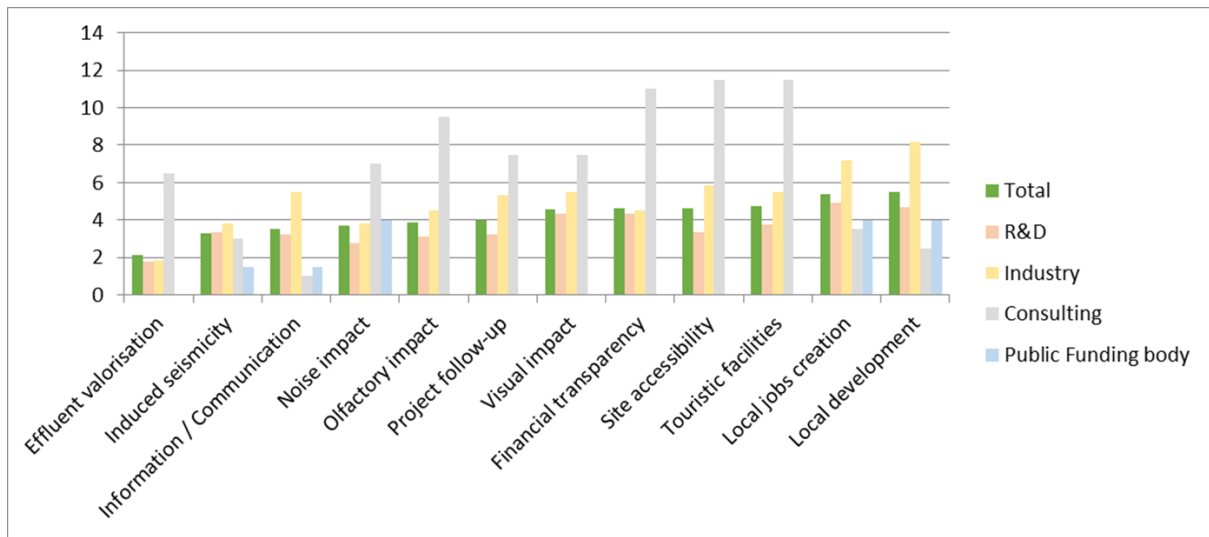


Figure 14 Stakeholder groups most criteria on public acceptance pillar, averaged rating of each aspects (NB lower rank value means higher importance)

Table 7 Public acceptance top criteria per stakeholder groups

Rank	R&D	Industry	Consulting	Public Funding body
1	Effluent valorisation	Effluent valorisation	Information / Communication	Information / Communication, Induced seismicity
2	Noise impact	Induced seismicity, Noise impact	Local development	Noise impact, Local jobs creation, Local development
3	Olfactory impact	Olfactory impact, Financial transparency	Induced seismicity	
4	Project follow-up, Information / Communication	Information / Communication, Visual impact, Touristic facilities	Local jobs creation	
5	Induced seismicity, Site accessibility		Effluent valorisation	
6	Touristic facilities		Noise impact	

### 3 Conclusions and proposed next step

Answers from question ranging 1 to 7 depict clearly the SH who answered the questionnaire. Questions from 8 to 10 focussed on reservoir sustainability regard, the results could be a bit distorted due to possible misinterpretation on how to rank and fill-in, as mentioned in section 2. However, considering that all the answers are appropriate, the main survey outcomes are summarized below:

- Principal respondents belonging group are: research and innovation, upstream geothermal industry (drilling, company, technology suppliers, etc.), consulting engineering
- Domains of activity of the respondents fit well with the resulting group of SH. The domains with the highest score were: research and innovation, project development and consulting and geothermal industrial services (drilling, surface equipment, construction etc.)
- Respondents SH seem to be interested in all the aspects suggested, but mainly in: Research & Innovation, Assessment of geothermal potential
- Low temperature and EGS resulted the most interesting geothermal systems
- High interest on all scale of geothermal system (concession licence top)
- High interest in intermediate and deep system in term of depth
- For economic profitability, reservoir evolution, insurance process and geologic risk got high rank
- Hydrothermal eruption, induced seismicity and chemical pollution are the principal aspects that affect environmental impact
- On public acceptance pillar the most ranked criteria resulted effluent valorisation, induced seismicity and information/communication

The survey didn't reach a number of participants that is fairly representative of all parties involved in the European geothermal energy sector. Yet, considering that reservoir sustainability is of major concern to develop rightly geothermal energy over the European countries, the information retrieved in this study can serve as a basis for future works. This joint activity should be seriously considered and continued in the framework of the forthcoming GEOTHERMICA project, in order to assess the opportunity for funding research and/or demonstration project in a co-fund joint call.



## **Appendix A**

Appendix A is an excel sheet that presents all the answers collected from each stake holders. A copy of the sheet is available at: <http://www.geothermalera.net.is/media/publications-2015/Reservoir-Sustainability--ReSus---Responses-.xlsx>



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