CROWDTHERMAL DELIVERABLE D4.2

GUIDELINES FOR DEVELOPERS AND PROMOTERS OF GEOTHERMAL ENERGY

Summary:

This report presents a Decision Tree algorithm for developers/promoters of geothermal projects to select the most efficient social engagement strategies and financial instruments. The Decision Tree algorithm provides a workflow including a sequence of questions that focus on social, environmental, resource risk and financial factors, following a logical order from start to end with the aim to screen which strategies would be appropriate for a specific setting.

Authors:

Dr Anastasia Ioannou, UofG, Lecturer in Sustainable Resources
Professor Gioia Falcone, UofG, Rankine Chair of Energy Engineering

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EXECUTIVE SUMMARY

This report is part of the CROWDTHERMAL Horizon2020 project and presents a Decision Tree algorithm to be used by the developers/promoters of future geothermal projects to select the most efficient social engagement strategy and financing options. The Decision Tree integrates environmental, social, resource risk, legal and financial aspects that can determine which option(s) is most appropriate under specific conditions.

The main aim of the Decision Tree is to assist developers/promoters of geothermal energy projects, seeking to:

- Enhance public engagement with the project to ensure successful implementation.
- Identify alternative funding solutions for their project.
- To make sure the community receives part of the benefits of the project.

The Decision Tree consists of a set of decision nodes that involve questions related to the above aspects, guiding the user towards the most appropriate social engagement strategy and financing option. Environmental risk mitigation options linked to geothermal exploration and exploitation (CROWDTHERMAL D1.2) are also provided to address potential public environmental concerns about the project, while as far as financial risk mitigation measures are concerned, findings from CROWDTHERMAL D3.2 and D3.3 are also reported as per each financing option. A key determining factor for the selection of appropriate social engagement, and financing and risk mitigation strategies is the development phase of the project. To this end, the first node concerns the identification of the project phase.

The Decision Tree is not intended to provide quantitative answers. It is rather intended to provide a workflow including a sequence of questions that focus on social, environmental, resource risk and financial influencing factors, following a logical order from start to end, with the aim to screen which strategies would be most appropriate for a specific setting.

The Decision Tree combines the outcomes of several deliverables. More in specific, leaf nodes and decision nodes were based on the review of the respective CROWDTHERMAL deliverables:

- social engagement strategies (D1.1, D1.4, D1.5),
- environmental aspects (D1.2),
- (innovative) financing and risk mitigation options (D2.3, D3.2, D3.3).

In addition to the review of the various deliverables, the development of the Decision Tree was based on input from project partners who provided a significant source of knowledge about the specifics on financial, resource-risk and social aspects of a geothermal energy project.

1 INTRODUCTION

CROWDTHERMAL aims to “empower public to directly participate to the development of geothermal projects with the help of alternative financing schemes and social engagement tools”. To identify the most efficient social engagement and financing strategies, enabling successful implementation of a geothermal energy project, developers/promoters need to consider various social, environmental, legal, resource risk, and financial factors throughout the service life of the project.

This report aims to synthesize outcomes derived from deliverables of WPs1-3, related to influencing factors that should be considered when selecting appropriate social engagement and financing options. This is realised by the development of a Decision Tree algorithm that consists of a sequence of questions, integrating social, environmental, and financial influencing factors and following a logical order from start to end with the aim to screen which strategies would be appropriate for a specific setting.

Each stage of the project development is characterised by different risks, requirements, and opportunities. During the early stages of geothermal development, for example, the resource risk is likely to be high; hence, raising capital through traditional bank loan is not often possible. In such cases, alternative sources of capital should be considered (as detailed in D2.3 and D3.2). Lack of social acceptance is a significant risk to the successful implementation of a geothermal energy project and appropriate social engagement strategies should be deployed throughout the service life of the project. Enabling the intellectual and financial participation of the community in the project enhances the public's engagement in and commitment to the project. In the same way, addressing stakeholders' environmental and social concerns can help to remove barriers and local objections to successful implementation of the project.

2 REVIEW OF DECISION TREES IN ENERGY APPLICATIONS

Decision trees are a sequence of possible choices and potential outcomes that take the form of a flow-chart-like tree structure, where each node denotes a test on an attribute value, each branch represents an outcome of the test, and tree leaves represent classes or class distributions (Han et al., 2012; Leimeister & Kolios, 2018; Pegram et al., 2020). It offers a graphical representation which facilitates decision making and a transparent approach to how certain decisions have been made. On the other hand, fidelity of the tree should ensure that no extensive prior knowledge or resources are required to take a decision, hence decision trees often cannot accommodate complex and beyond-normal decisions, and experience from previous projects is required when constructing a tree for inclusion of the realistically key options and influencing factors. Indicative references documenting the method include (Abbott, 2014; Dey, 2012; ISO - IEC, 2013; Pardeshi, 2019).

Decision trees are often used for energy applications in order to facilitate decision making from stakeholders with limited resources and knowledge around the decision-making process. Park et al (Park et al., 2009) used the decision tree method to perform a preliminary screening of remedial options to reduce the loss of gas production in liquid loading. Tan et al (Tan et al., 2010) proposed a methodology that transforms the system dynamics model into an approximate decision tree, estimating the cash flow resulting from energy projects for given predetermined sequence of decisions. Moutis et al (Moutis et al., 2016) presented a novel tool, based on decision trees, with two potential applications: (i) planning of energy storage systems within such MGs, and (ii) controlling energy resources for energy balancing within a PC MG. Huo et al (Huo et al., 2021),

developed a rigorous control mapping method based on decision trees, demonstrating that the decision tree-based dispatch strategy can provide feasible and near optimal dispatch decisions for microgrids. Decision trees are also used in combination with machine learning methods, primarily for classification problems. To this end, Tso et al (Tso & Yau, 2007) documented a comparison between decision trees and machine learning methods for the prediction of electricity consumption, while Yu et al (Yu et al., 2010) developed a building energy demand predictive model based on the decision tree method, which was able to classify and predict categorical variables. Finally, Yaman et al (Yaman et al., 2020), proposed a method to estimate energy consumption and plan maintenance works on energy lines according to energy consumption, analysing parameters such as temperature, pressure and wind, using decision tree methods.
Geothermal-specific studies can be also found in the literature. Hohn et al, (Höhn et al., 2020) used tree-based methods in combination with machine learning, in order to optimise drilling costs, while Assouline et al (Assouline et al., 2019) mapped the very shallow theoretical geothermal potential focusing on three key variables: the ground temperature, and the ground thermal conductivity and diffusivity. Mignan et al (Mignan et al., 2015) combined induced seismicity time-dependent hazard with the RISK-UE macro seismic method and proposed a logic tree approach to capture epistemic uncertainties, while Mena et al (Mena et al., 2013) tested the performance of three model classes for induced seismicity through logic tree branches that capture the epistemic uncertainty of the process for a case study in Switzerland. Sobradelo and Martí (Sobradelo & Martí, 2010) used Bayesian event tree structures to account for external triggers (geothermal, seismic) as a source of volcanic unrest, and looked at the hazard from different types of magma composition and different vent locations (as opposite to a central vent only) to overcome restrictions of conventional trees in the eruptive scenarios they considered, and/or on the possibility of having volcanic unrest triggered by other forces than magmatic. Grant (Grant, 2009) employed decision trees to address the question "is a newly-drilled well good enough?" by considering the range of probable well results, the possible alternatives available (test/accept/side-track), and their cost. Finally, Van Wees et al (Van Wees, J.-D.a, Lokhorst, A.a, Zoethout, 2007) presented a techno-economic model for re-use of exploration and production wells using best practices for asset evaluation from the oil and gas industry, taking into account natural uncertainties and decision trees to evaluate sensitivities and different scenarios.

3 DECISION TREE DEVELOPMENT APPROACH

3.1 SCOPE OF THE DECISION TREE

Target group: The target group of the Decision Tree is developers/promoters of geothermal energy projects, seeking ways to enhance society's engagement with the project to ensure successful implementation, to offer them a part of the reward in exchange for financial and/or intellectual participation, or to find alternative funding solutions for their project. Developers/promoters are expected to have good knowledge of their project, its technical characteristics, and the geology of the location. Therefore,

technology and geology-specific questions (e.g. about the expected temperature range from the geothermal well(s)), which are typically addressed within a feasibility study were not included in the Decision Tree.
Scope: Ultimate decisions (leaf nodes) of the Decision Tree are social engagement strategies and financing options (crowdfunding and other alternative financing options). The Decision Tree is not intended to provide quantitative answers (e.g. the size of premium of a risk mitigation option). It is rather intended to provide a workflow including a sequence of questions that focus on social, environmental and financial influencing factors, following a logical order from start to end. Key questions it aims to address are the following:

- What is the most appropriate social engagement strategy for my project?
- What are the most appropriate (alternative) financing methods for my project?

The decision nodes include financial, social, environmental, and resource-risk related questions which were selected based on the review of the respective CROWDTHERMAL deliverables, as well as additional input from project partners. The Decision Tree aims to flag likely environmental and finance risk mitigation concerns and how to best address them with regards to financing and insurance. A key determining factor for the selection of appropriate social engagement and financing options is the development phase of the project. To this end, the first node of the decision tree concerns the identification of the project phase, followed by the question regarding the user's objective, namely:

- Enhance society's engagement with the project to ensure successful implementation.
- Identify alternative funding solutions for the project.
- Offer part of the reward to the local community.

3.2 METHODOLOGY FOR DEVELOPMENT OF DECISION TREE

The key methodological steps for the development of the Decision Tree are illustrated in Figure 1 and can be summarised as follows:

1. Define top question. This is the overarching question that determines the structure of the Decision Tree and defines the range of alternative options. "What is the most appropriate social engagement strategy for my project?" is the top question of the first branch, and "What are the most appropriate financing and risk mitigation options for my project?" is the top question of the second branch.
2. Define bottom options. These are the leaf nodes/ultimate decisions, namely financing options (crowdfunding and other alternative financing options) and social engagement strategies best suited for the given setting.
3. Identification of social, environmental, financial and resource risk factors that influence the developer's selection of appropriate bottom options. Accordingly, the identified influencing factors were translated into a sequence of questions that structured the Decision Tree. This step included the review of relevant Deliverables from WP1-3, identifying further influencing factors and gathering a list of 43 relevant questions from project partners (experts in social engagement and

financing options for geothermal energy projects). The final set of questions was reduced to a total of 19 questions on the basis that the number of decision nodes must be kept to a minimum to result to a manageable, easy-to-use decision tree. Therefore, some questions were grouped and others omitted.

4. Compile preliminary trees and circulate among the partners to ensure that all influencing factors and bottom events have been captured. Integrate feedback and finalise Decision Tree.

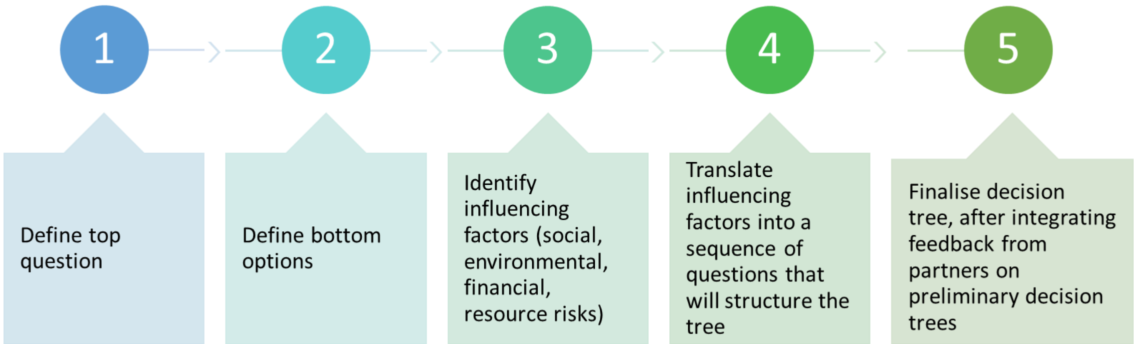

Figure 1 Decision Tree development methodology

4 INFLUENCING FACTORS, SOCIAL ENGAGEMENT STRATEGIES AND FINANCIAL INSTRUMENTS

There are many factors that must be considered when selecting appropriate social engagement strategies and financial and risk mitigation instruments. These factors include awareness/familiarity, resource risk, social and environmental concerns, intellectual and financial participation opportunities, legal compliance and risk mitigation. Due to the considerable number of factors affecting the selection of social engagement and financial instruments, it was clear from the outset that some of them would have to be excluded or aggregated. It also became apparent that different users of the Decision Tree might attach different levels of importance to different decision parameters, while the financial risk varies according to who is the user of the Decision Tree.

4.1 INFLUENCING FACTORS AND DECISION TREE QUESTIONS

A key factor affecting the selection of appropriate social engagement strategies and financial and risk mitigation instruments is the *phase* of the geothermal project. Each phase has a certain risk profile which determines what the risk is for involved investors. Accordingly, the risk determines what kind of capital should ideally be used. D1.4 also suggests that social engagement strategies should be selected taking into consideration the phase of the project and suggests appropriate measures per project phase. However, it is highlighted that engagement measures can shift between phases, if it is opportune for the project course, while the role of contextual factors is also emphasised.

Key *social factors* affecting the acceptance of the level of project, process and context for sustainable energy technologies were identified in D1.1. Most listed factors should be considered when selecting both appropriate social engagement strategies and financial instruments. For example, the lack of experience and familiarity with geothermal technology will affect both the social acceptance, public commitment and the participation to community financing schemes. For more information about public perception factors, the reader can refer to D1.1.

Along with social concerns, *perceived environmental risks* may also hinder the implementation of the project and developers should address any such issues through deploying social engagement strategies (provision of information campaigns, direct communication with relevant stakeholder groups, involvement of independent esteemed scientists to the discussions, comply to the legal procedures, etc.) and environmental risk mitigation strategies (more details can be found in D1.2).

Resource risk is typically high in the early phases of geothermal project development and decreases towards the end of the drilling phase (see Figure 1 in (Baisch et al., 2020), affecting the financial risk of the investment. The expected *financial characteristics* of the investment (including amount of capital required, financial risk and the type of capital) also need to be specified to determine which type of financing could be used during a certain phase of a project.

In general, to choose an appropriate community investment method, all the circumstances of the project, like project phase, phase-related risk, regulatory framework, overall financial position of the project, and government support need to be carefully considered.

Through both the review of deliverables and further input from the project partners, the most appropriate social engagement strategies and financial and risk mitigation strategies were selected as reasonable solutions for the corresponding social, energy supply/demand, environmental, policy and financial aspects of the project. The selection of the appropriate questions leading to the identification of most appropriate social engagement and financial instruments was also supported by discussions within the consortium. Questions reflect awareness/familiarity, resource risk, social risks, environmental risks, financial participation, intellectual participation, legal compliance and risk mitigation aspects. A summary of the Decision Tree questions is presented in Table 1.

Table 1 Decision Tree questions

Domain	Code	Question
Awareness/ Familiarity	QA.1	Is the public familiar with and positively inclined towards geothermal energy and the project?
Resource risk	QR.1	Are you confident about the resource of your project?
	QR.2	Have similar projects been successfully realised in the past in this area?

Social risks	QS.1	Are there social concerns about the project?
Environmental risks	QE.1	Are there environmental concerns about the project?
	QE.2	Are there concerns about atmospheric pollution?
	QE.3	Are there concerns related to water resources?
	QE.4	Are there concerns about seismic events or other land-related risks?
	QE.5	Are there environmental concerns about solid waste?
	QE.6	Are there concerns about noise, visual pollution, and radioactivity?
Financial characteristics	QF.1	Is the local community interested in having financial participation to the project?
	QF.2	Will the community be the geothermal energy user in the area?
	QF.3	Are you interested in decreasing the financial risk for your investors?
	QF.4	What is the size of capital required?
	QF.5	What type of capital is required?
	QF.6	What is the level of financial risk?
	QF.7	Do you wish the community to have high involvement in the project?
Intellectual participation	QI.1	Is the local community interested in having intellectual participation in the project?
Legal compliance	QL.1	Have you checked project compliance with the relevant legal procedures to promote social acceptability?

4.2 SOCIAL ENGAGEMENT STRATEGIES

The deployment of renewable energy projects is highly influenced by the public acceptance of the renewable energy technology (Dwyer & Bidwell, 2019). Effectively planning the communication and engagement strategy is necessary to enhance the social acceptance of a project and ensure conflict prevention, public commitment and financial and/or intellectual participation. Key social engagement strategies include identification of stakeholders/context of the project, establishing a multi-channel approach for the announcement and information of the project (using a broad range of communication tools, including project website, social media, newspapers), encouraging stakeholder engagement and active participation, communicate clear and concrete messages.
The various social engagement strategies included in the Decision Tree are described in more detail in D1.4 Guidelines for public engagement. Social engagement strategies are grouped in Table 2.

Table 2 Social Engagement strategy options (based on results of D1.4)

SE#	General information about geothermal energy to increase knowledge/awareness
1	Announcement of the project through diverse communication channels (newspapers, websites, social media) & progress of the project in regular intervals.
2	Provide information to relevant authorities/stakeholders/public about the benefits of the system, advantages and opportunities, technical information, risks and prevention measures. Hire esteemed scientists to communicate the information and respond to questions.
3	Regional information markets, topic tables (risks, financing, environmental impacts, etc.)
4	Carry out a structured and planned public communication strategy to have a concept of when to communicate, what, to which interest groups and how to communicate it.
SE#	Project-specific information to stakeholders about environmental and other risks, project implementation works, energy production, etc.
5	Communication of exact implementation plans, which phases are imminent and what exactly will be done in which phases. Ensure transparent communication of information.
6	Early and comprehensive provision of information regarding project implementation annoyances including expected noise, steam or odour annoyance as well as increased traffic caused by trucks because building materials need to be transported. Inform citizens about noise peaks/how long the drilling phase is planned to last.
7	Offering site visits/ short films/ virtual reality or 3D presentation of the drilling sites/ flyers with images and explanations/ information events with lectures.
8	An internet platform like the official website for the project could offer an area where questions can be stated and collectively answered by the contact person via FAQ-videos on the website or on social media.
9	Information campaigns about environmental issues, such as seismic events. Increase confidence in the safety of the facility through installation of appropriate environmental risk mitigation measures, for example through local seismic monitoring networks that are installed to report any unwanted activities. Hire external experts/scientists to communicate the information and address stakeholders' questions.
10	Provide access to required information/hearing of stakeholders and public *according to legal framework*, enable communication on topics such as noise, steam or odour annoyance as well as increased traffic caused by trucks because building materials need to be transported.
11	Transparent and open communication of potential breakdown or damage. Information about the occurrence should be given as quickly as possible, questions and conflicts should be dealt with prudently and comprehensively.
12	Writing a public construction diary to keep the public up to date with the progress in construction works (this can be realized, for example, in the form of blog posts on the project´s website).
13	Communication of the yielded renewable energy production (e.g., how many kilowatt hours or megawatt hours of energy were produced per day) CO2 savings to enhance the perceived added value of the project after commissioning.

14	Early and transparent information about the decommissioning to stakeholders and citizens according to legal framework
SE#	Enabling the interaction with the public
15	Set up a project advisory board that meets at regular intervals to exchange information on the latest developments to ensure regular exchange with relevant sector agencies, nature conservation associations or environmental protection associations
16	Assign and maintain a direct and reliable contact person to whom the media and public could turn to with all their questions and concerns
17	Ensure that the participation work and communication work do not end with the completion of the systems´ construction
SE#	Encourage/Enable the participation to fund raising activities and energy use
18	Offering financial participation opportunities of community investors via crowdfunding.
19	Spin-off to other joint energy projects (RES, efficiency)
20	Dialogues with citizens about ideas for local future projects
21	Encourage active citizen participation, i.e. through participation of the municipality to the project, or through a connection to local heating networks so that citizens can be joint users of the energy generated
SE#	Legal procedures
22	Ensure planning permit is in place: Provide access to required information/hearing of stakeholders and public according to legal framework.
23	Ensure drilling permit is in place
24	Ensure construction permits are in place & required information/hearing of stakeholders and public focusing on the construction works, according to legal framework
25	Implementing the necessary decommissioning steps according to the legal framework

4.3 FINANCIAL INSTRUMENTS

Four types of investment capital (D2.3, D3.2 and D3.3) were identified in the context of CROWDTHERMAL: risk absorbing capital, risk sharing capital, debt and reserve. As mentioned above, the selection of the most appropriate finance option depends on the development phase of the project, the type of capital required, the amount of capital, the level of risk and the desired level of community involvement. A set of innovative (or more traditional) but proven financial instruments appropriate to raise different types and amounts of capital, as well as characterised by different levels of risk and community involvement, is summarised in Table 3.

Table 3 (Alternative) financial instruments (Source: D2.3, D3.2 and D3.3)

FI#	Financial Instruments	Type of capital	Amount of capital	Level of risk/Community involvement
1	Subsidies/grants/donations	Risk absorbing	Small-Medium	High risk/involvement limited
2	Crowdfunding (Equity)	Risk-sharing	All amounts	High
3	Crowdfunding (Reward)	Risk-sharing	All amounts	High risk, community non involved
4	Crowdfunding (Loan)	Debt	Small to medium	Moderate risk, low involvement
5	Green bond	Debt	All amounts	Low risk, low involvement
6	Regular bond	Debt	All amounts	Low risk, low involvement
7	Government Match funding (debt, equity or donations (grants))	Risk-absorbing or risk-sharing	All amounts	Moderate to low
8	Retained profits	Risk-sharing	Small and medium	Low risk, low involvement
9	Leasing	Asset-based debt but can be risk sharing/absorbing	Medium	High risk, high involvement
10	Social impact bonds	Risk-absorbing	Medium	High risk, high involvement
11	Revenue-based financing	Risk-sharing	All amounts	High risk, limited involvement
12	Steward ownership	Risk-sharing	All amounts	High risk, high involvement
13	Pay it forward scheme	-	All amounts	No involvement by community, governments high.
14	Guarantee schemes	Risk-absorbing	All amounts	-
15	Decentralized Finance	-	-	-
16	Smart contract	Risk-sharing	All amounts	Moderate risk, Low involvement
17	Tax reliefs	Risk-absorbing	-	-

The different financial and social engagement options presented per project phase are illustrated in Figure 2.

	Project Definition	Exploration	Drilling - First well	Resource development	Construction	Operation	Decommissioning
Financing options	• Subsidies/grants/donations • Crowdfunding (E/R) • Direct lending combined with governmental guarantee • Governmental lease	• Subsidies/grants/donations • Crowdfunding (E/R) • Direct lending combined with governmental guarantee • Governmental lease	• Subsidies/grants, • Crowdfunding (E/(L)/R) • Governmental lease, • Direct lending combined with governmental guarantee • Green bond • Regular loan • Regular bond • Equity	• Crowdfunding (E/(L)/R) • Governmental lease • Direct lending combined with governmental guarantee • Green bond • Regular loan • Regular bond • Equity	• Crowdfunding (L/R) • Direct Lending • Leasing	• Crowdfunding (L/R) • Direct Lending • Leasing	• Retained profits • Governmental subsidies
Social engagement	• Announcement of the project • Information of responsible authorities • Correct and factual information • Identification of opportunities and risks • Far-reaching transparency, accessibility of information materials	• Information of responsible authorities • Planning permits • Asking for need of information/communication • Offering financial participation opportunities • Description of the process, different phases • Direct communication with relevant stakeholder groups	• Drilling permits • Documentation • Regional information markets, topic tables • Dialogue groups • Local office with sufficient consultation times • Site visits of existing projects/video/VR/3D presentatio		• Construction permits • Regional information markets, topic tables • Dialogue groups • Public construction diary	• Monitoring information to the stakeholders/public according to legal framework • Offering further financial participation opportunities • Spin-off to other joint energy projects • Operation starting party • "Local energy party" • Operation diary, website showing produced energy/saved CO2 emissions	• Decommissioning information-information to the stakeholders/public according to the stakeholders/public according to legal framework (focus environment, risks, post-utilization) • Dialogue with citizens for future plans

Figure 2 Financing options and social engagement strategies per project phase (based on D1.4 and D3.2)

4.4 RISK MITIGATION INSTRUMENTS

D1.2 summarises some key environmental risk mitigation measures as per the type of environmental risk (Table 4). Finally, financial risk mitigation options have been analysed in D3.2 and D3.3. as per each financial instrument and a summary can be found in the Appendix, Table A1.

Table 4 List of Environmental risk mitigation measures (Source: D1.2)

ERM#		Environmental Risk Mitigation Options
1	Atmosphere	- Geothermal plant should be designed to avoid any steam releases to the atmosphere and NCGs should be treated at the cooling tower
2	Water	- Installation of wells casing to prevent the groundwater contamination. - Grouting the Borehole Heat Exchangers (BHE) or sealing the annulus - Legal constraints on the installation of geothermal systems (especially open loop) in water protection areas for drinking waters
3	Land	- Project Owner to implement the Protocol for Induced Seismicity Associated with Geothermal Systems - Proper sealing of the boreholes, through a cement based backfill - Installation of local seismic monitoring networks that report any unwanted activities
4	Solid waste	- Selection of contractor(s) with good environmental record - State in contract requirements on special waste ponds - Consider thermodynamic scaling control rather than inhibitors to minimize hazardous substances in the geothermal fluid - Important to select only contractor(s) that have good environmental record. State in contract requirements on special waste ponds

5	Noise, visual pollution and radioactivity	- Careful siting of the plant to avoid ecologically and historically sensitive areas - Minimize surface disturbance and visual impact during construction - Careful landscaping during operation. - Application of sound barriers, such as plantation of trees at adjacent locations. - Ear protective equipment for the workers - Use of inhibitors to keep the radioactive nuclides in solution - Application of hearing protection for the workers - Noise barriers to avoid disturbances of residential areas - Avoiding ecologically sensitive areas where possible

5 DEVELOPMENT OF THE DECISION TREE

The construction of the Decision Tree should follow a logical order from start to end and should end up with a reasonable solution.
The Decision Tree starts by asking the phase of the project, as this is a key determinant for selecting appropriate options. The second node of the decision path refers to user's objective, identified above.
For the first objective, social engagement strategies need to be employed; the decision nodes to select which strategy is most appropriate are explained in Section 5.1. The second and third objectives can be addressed by employing appropriate financial instruments as explained in Section 5.2. Environmental risk mitigation options are also provided; financial risk mitigation options are reported as per financial instrument in the Appendix, Table A1.

5.1 SELECTION OF SOCIAL ENGAGEMENT STRATEGIES

Figure 3-8 illustrate the Decision Tree branches for each project development phase. As mentioned above, the Decision Tree starts with the identification of the relevant project phase, followed by the user's objective. Focusing on the first objective, to enhance social engagement in the project (which can further encourage social acceptance), the selection of the appropriate social engagement strategies is required. Subsequent questions trigger several branches to reflect the screening criteria as determined from the literature. The first question is about social awareness **(QA.1[1])**, followed by questions regarding the compliance with the relevant legal requirements to promote the Social License to Operate **(QL.1)**, public perception of environmental and social risks **(QE.1, QS.1)**, public's appetite for financial **(QF.1)** and/or intellectual participation in the project **(QI.1)**.

[1] The abbreviations list can be found in the Appendix, Table A2.

The Decision Tree starts with the identification of 28 social strategies, which are summarised in Table 2. Some social engagement strategies focus on the dissemination and provision of information about the project, increasing the social outreach. Other strategies emphasise on promoting the interaction with the public and/or the participation of the public in fund raising activities and in the decisions of the project. Finally, other options refer to the compliance with the relevant legal procedures to promote social acceptance.

QA1: The first decision node asks whether the public is aware of what is going to happen and/or whether it is familiar with the potential benefits of the geothermal energy project. In case of "No", specific social engagement activities focusing on educating and informing the public about geothermal energy in general, as well as the specific project under development are suggested. Indicative measures include the announcement of the project through diverse communication channels and progress of the project in regular intervals (SE.1); "Provision of information to relevant authorities/stakeholders/public about the benefits of the system, advantages and opportunities, technical information, risks and prevention measures" (SE.2); "Regional information markets, topic tables (risks, financing, environmental impacts, etc.)" (SE.3); "Carrying out a structured and planned public communication strategy in order to have a concept of when to communicate, what, to which interest groups and how to communicate it" (SE.4), which are intended to increase the knowledge/awareness of the public about the geothermal energy project.

QL.1: Once the awareness of the public has been verified, the next decision node checks the "Compliance with the relevant legal procedures (e.g., licences, formal announcement)?". This is an important question to make sure that all necessary actions (announcement, licenses, information) with all related stakeholders (local communities, local authorities (e.g. municipalities, etc.), direct users, scientists/local universities, and local NGOs) have been conducted. Depending on the project phase, indicative actions include ensuring the planning permit is in place and providing access to required information/hearing of stakeholders and public according to the legal framework (SE.22 and SE.10). Another relevant strategy is setting up a project advisory board that meets at regular intervals to exchange information on the latest developments to ensure regular exchange with relevant sector agencies, nature conservation associations or environmental protection associations (SE.15).

QE.1 and QS.1: Account for the public's environmental and social concerns about the project, respectively. In case the public has expressed concerns about environmental issues throughout the project, general information campaigns about environmental risks, such as seismic events, water use/contamination, noise and visual impacts should be organised (SE.9). Risk mitigation strategies should be employed and communicated with the public to further increase confidence in the safety of the facility, for example through installation of local seismic monitoring networks that report any unwanted activities (ERM.4). Depending on the type of environmental risks of the project (subject to the energy use of the geothermal energy resource and characteristics of the location), the respective risk mitigation measures need to be deployed. Environmental risks and mitigation strategies are documented in more detail in D1.2 Synthesis of environmental factors. Under this node, a set of public engagement strategies are proposed, while the user is also redirected to the Environmental Risk Mitigation (ERM) Decision Tree algorithm to obtain tailored information about risk mitigation options against the relevant environmental risk as perceived by the public. Environmental risk mitigation strategies linked to the respective public concerns are summarised in Table 4. Providing extensive information about the environmental risks and prevention measures to relevant authorities/stakeholders/public should be a priority to reassure the public that the drilling and construction works are safe and will not induce any damages, material/human losses, health and life quality degradation of the local population (SE.2,9). Independent scientists should be invited to speak about the geothermal energy project providing information, and to respond to stakeholders' question about technical and environmental issues to increase public's confidence. At later project phases, the public should also be offered an area where questions can be stated and collectively answered by a contact person via FAQ-videos on the website or on social media (SE.8). The development of a structured and planned public communication strategy to have a concept of when to communicate, what, to which interest groups and how to communicate it would also be an effective method to increase community outreach (SE.4). During project implementation (mainly drilling and construction), the public should be informed about the exact implementation plan, which phases are imminent and what exactly will be done in these phases (SE.5), as well as potential annoyances including expected noise, steam or odour annoyance, traffic caused by trucks at the construction site, as well as information about noise peaks and about how long the drilling phase is planned to last. Risk mitigation measures against noise, visual and odour annoyances should be employed. Transparent communication of information should always be a priority.

Social conflicts/concerns may also prevent a geothermal energy project from advancing to the next phase, and influence public´s acceptance of geothermal energy projects. Social concerns may originate from project-, process- and context-related factors (for more information, refer to CROWDTHERMAL D1.1). For example, a key social concern includes the lack of trust in individuals that are part of the decision process of geothermal energy projects. An important strategy to avoid distrust is through the provision of information about geothermal projects from diverse sources independent of the official information provided by the responsible operator (e.g., SE.11). Information coming from independent scientists and authorities is often perceived by the public as more reliable compared to energy companies or national governments. Another relevant strategy would be to assign and maintain a direct and reliable contact person to whom the media and public could direct their questions and concerns from the early phase of the project (SE.16). Project developers should also carry out a structured and planned public communication strategy of when to communicate, what, to which interest groups and how to communicate it (SE.4). Encouraging active citizen participation, i.e., through participation of the municipality to the project, or through a connection to local heating networks so that citizens can become joint users of the energy generated, tend to increase the feeling of ownership from the public, thus enhancing social acceptability. Other social topics are related to perceived advantages and disadvantages of the project, the experience/familiarity of the public, as well as the wider socio-political context, where awareness raising activities and information campaigns would be appropriate. Ensuring

that there are no social or environmental concerns about the project significantly enhances its social acceptance and the developer/promoter can proceed to the next decision node that focuses on enhancing the engagement of the public.
QF.1, QI.1: Next questions allow screening social engagement options in terms of whether the developer/promoter has engaged with the local community to identify if there is interest in financial **(QF.1)** and/or intellectual **(QI.1)** participation to the project. To enable intellectual participation, similar measures to the previous question are proposed together with measures to increase awareness (SE.6,7,11,12,15,16,21). During the implementation of the project, the developer/promoter can develop a public construction/operation diary to keep the public up to date with the progress in construction works (SE.12), the facility should also offer site visits/short films/virtual reality or 3D presentation of the drilling sites/flyers with images and explanations/information events, so that the public can get the information they are interested in. During operation of the plant, citizens should be informed about the yielded renewable energy production (e.g., how many kilowatt hours or megawatt hours of energy were produced per day), the $CO_{2,eq}$ savings to enhance the perceived added value of the project after commissioning (SE.13). Another way to increase public participation in the project is by investigating opportunities for connection to local heating networks, so that citizens can be joint users of the energy generated (SE.21), while it is important to ensure that the participation work and communication work do not end with the completion of the systems´ construction (SE.17). In case there is interest in financial participation to the project, developers/promoters should offer financial participation opportunities of community investors via crowdfunding platforms (SE.18), and increase knowledge through regional information markets and topic tables (risks, financing, environmental impacts, etc.) (SE.3). During the operation phase, opportunities for spin-off to other joint energy projects (RES, efficiency) (SE.19) and dialogues with citizens about ideas for local future projects (SE.19) could be considered.
In general, during the decommissioning phase of the project, stakeholders and citizens should be given early and transparent information about all activities according to legal framework (SE.14).
The overview provided above about public engagement strategies in geothermal energy projects was based on outputs from D1.4. The reader can refer to D1.4 for more information.
The Decision Tree is in line with the Social License to Operate (SLO) framework detailed in D1.5. The SLO framework distinguishes different levels of social engagement, ranging from a withheld/withdrawn SLO (lowest level) to the status of acceptance (medium level), to approval (high level), to co-ownership (highest level) (D1.5).

5.2 SELECTION OF FINANCIAL INSTRUMENTS

The Decision Tree for the selection of appropriate financial instruments as per the respective project phase are illustrated in Figures 3-8.
In case the user is interested in raising funding (community or other forms of conventional funding) for the project, the focus of this path lies on estimating the level of risk of the

investment. To this end, the subsequent decision node aims to specify the *resource risk* of the project.

QR1, QR2: This is an important step considering that resource risk has a direct impact on the community investors' financial risk, as well as the financial development and success of the project. For example, in case no similar projects have been developed in the area before and/or existing resource data of the location are not credible/confirmed, the geothermal resource risk is typically high. Resource risk is checked by asking two questions:

1. Have similar projects been successfully realised in the past in this area? **(QR.2)**
2. Are you confident about the resource of your project? **(QR.1)**

If the answer to both questions is "No", then the resource risk is considered very high, and the most appropriate financial instruments are subsidies/donations (FI.1) and crowdfunding equity (FI.2). In case, at least one question is "Yes", the resource risk is considered moderate or low and the user can proceed to the next decision nodes to determine the expected *financial characteristics* for the project.

QF.2-QF.7: Questions about the *size* **(QF.4)** and *type* of capital required **(QF.5)** further narrow down the range of financial instrument options appropriate. For example, in case of low-to-medium required capital and risk-absorbing capital type, Government Match funding (FI.7), Leasing (FI.9), Social impact bonds (FI.10) and Guarantee schemes (FI.14) can be considered. However, for high required capital, FI.9 and FI.10 may not be appropriate options.

In case the risk-sharing type of capital is selected, subsequent questions aim to assess the level of *financial risk* **(QF.6)** both for the developer and the community investors **(QF.3)** in the project and specify the *desired level of the public involvement/engagement* **(QF.7)** and whether the *community is going to be the geothermal energy end-user in the area* **(QF.2)**.

Subsidies/grants/donations, governmental lease and crowdfunding (equity) are finance methods that could be employed during the early phases of the project, when the resource risk is typically high. As extensively explained in D2.3 and D3.3, the new approaches to finance for geothermal developments also come with new risks, in need of new risk mitigation approaches. With crowdfunding equity, resource/investment risk is shared with the community investors, while the "return on equity is not payable until a profit is realized" (D3.3). However, it requires handing over a part of the ownership while the return is proportional to the profit. Risk mitigation strategies should include insurance or/and guarantee schemes to protect against financial losses reducing investors' risk (**QF.3**), keeping the crowdfunding proportion to a low amount (e.g. maximum of 10-15%) to reduce the governance risk and integrate tools that can increase the confidence and credibility of a crowdfunded geothermal project. More detailed information about advantages, risks and risk mitigation measures can be found in D3.3 and in the Appendix, Table A1.

As such, financial instruments are initially screened in terms of the *size* and type of the capital required, as according to D3.2, different finance methods are best suited to the respective project phase and financial characteristics. Naturally, higher capital induces higher risk, hence higher discount rates if direct lending is considered, and increases the need for introducing risk mitigation solutions. “Low” capital required include amounts up to 200,000 €, “Medium” = between 200.000 € and 2 Mio. € and “High” = more than 2 Mio. €. Available types of capital include debt, risk absorbing, risk sharing and reserves.

As far as *type of capital* is concerned, during the initial phases of the project, the Developer should investigate whether subsidies/grants/donations are provided by the Government for clean energy projects. In case small-to-medium, debt capital is required, Crowdfunding loan can be used. However, “Crowdfunding loan is challenging in the early project phases when it is difficult to predict the project time component” (D3.3). It lacks the flexibility of Crowdfunding equity since despite a possible delay in the project, the fixed interest rate must be paid in time. Direct lending combined with governmental guarantees can be easier-to-raise capital compared to a bank loan, especially in the early phases of the project. Direct lending is an umbrella type of debt financing where the provision of credit takes place without going through a bank; common instruments include regular loans/bonds, green bonds and social impact bonds. It is a less complex financial option since the project developer must deal with only one financial intermediary. However, “the financial intermediary may ask for a higher collateral, especially in risky phases (e.g., the drilling of the geothermal wells)” (D3.2). Governmental guarantees can be used as a risk mitigation measure.

In case there is interest in financial participation through risk-sharing capital, Crowdfunding equity/reward, revenue-based financing and smart contracts can be used, depending on the respective project phase. In case of debt capital, Crowdfunding loan and direct lending (with guarantees) should be considered for financing the project especially in the early stages of the projects. Green bonds, regular loans and regular bonds without guarantees should be considered during later stages of the project.

QF.2 checks whether the community will be the geothermal energy end-user in the area. If yes, for risk-sharing capital the Reward-based Crowdfunding financing method should be considered as more relevant among other respective instruments. Reward-based Crowdfunding promotes local project ownership, public engagement as well as the acquisition of a social license to operate.

The Decommissioning & Post-Closure (DP) phase of the project is typically financed by Government funds and retained profits.

Finally, in case the aim of the user is to ensure community receives a part of the reward, steward ownership (FI.12) and reward-based crowdfunding (FI.3) are the most appropriate options.

The advantages, risks and risk mitigation measures of key alternative financial instruments, are identified in D3.2 & D3.3 and summarized in Table A1 in the Appendix.

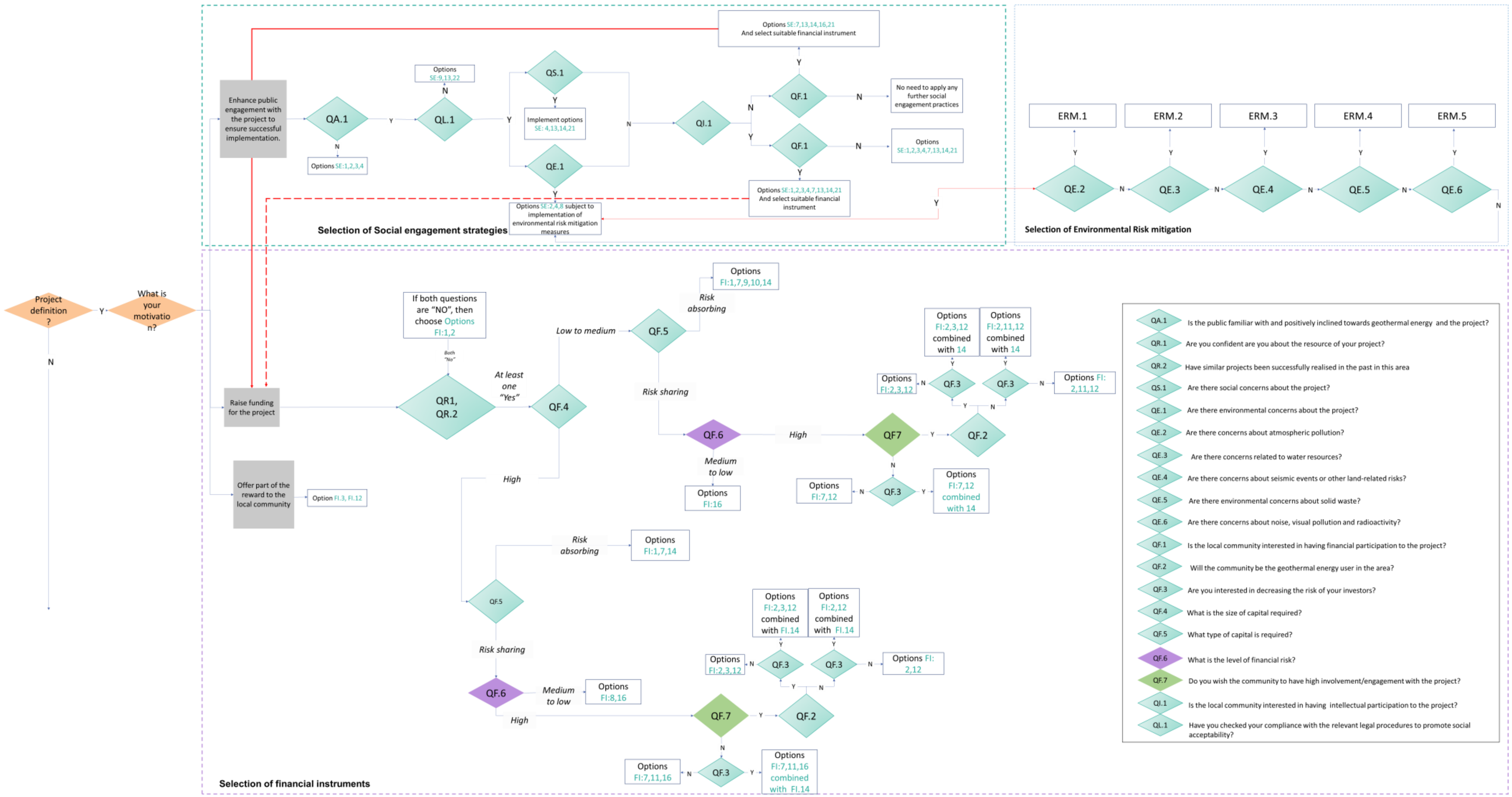

Figure 3 Decision Tree – Project definition phase

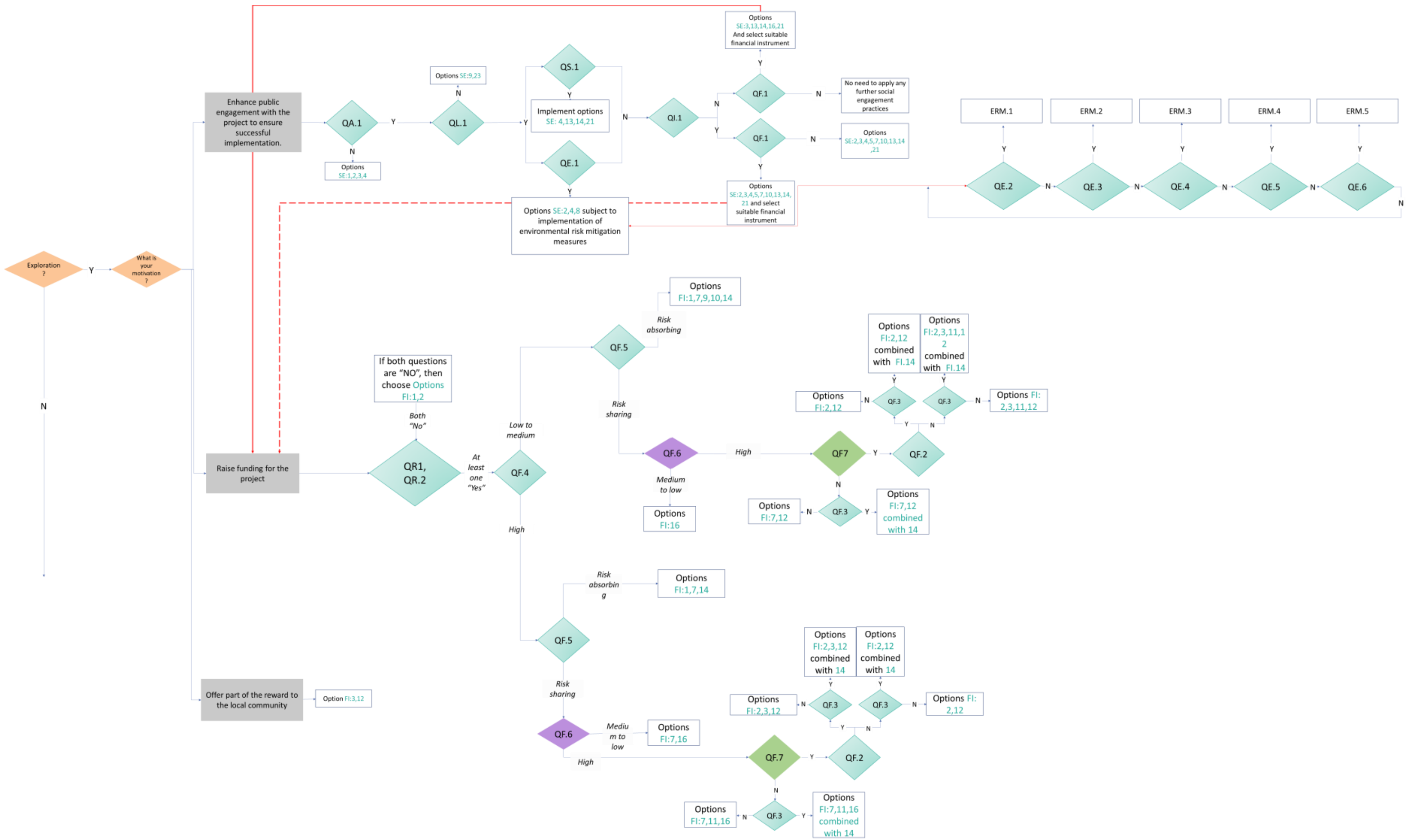

Figure 4 Decision Tree– Exploration phase

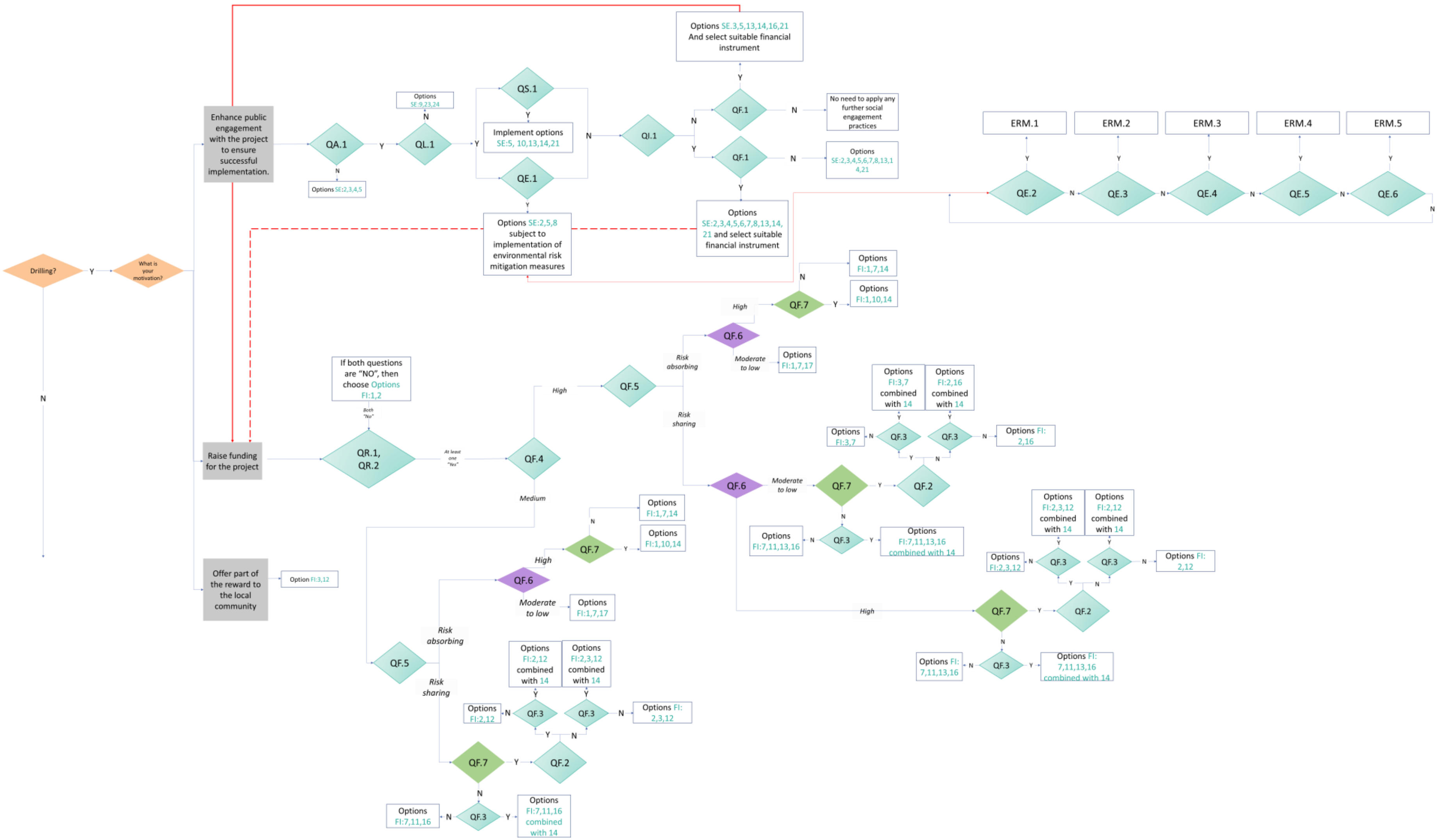

Figure 5 Decision Tree – Drilling phase

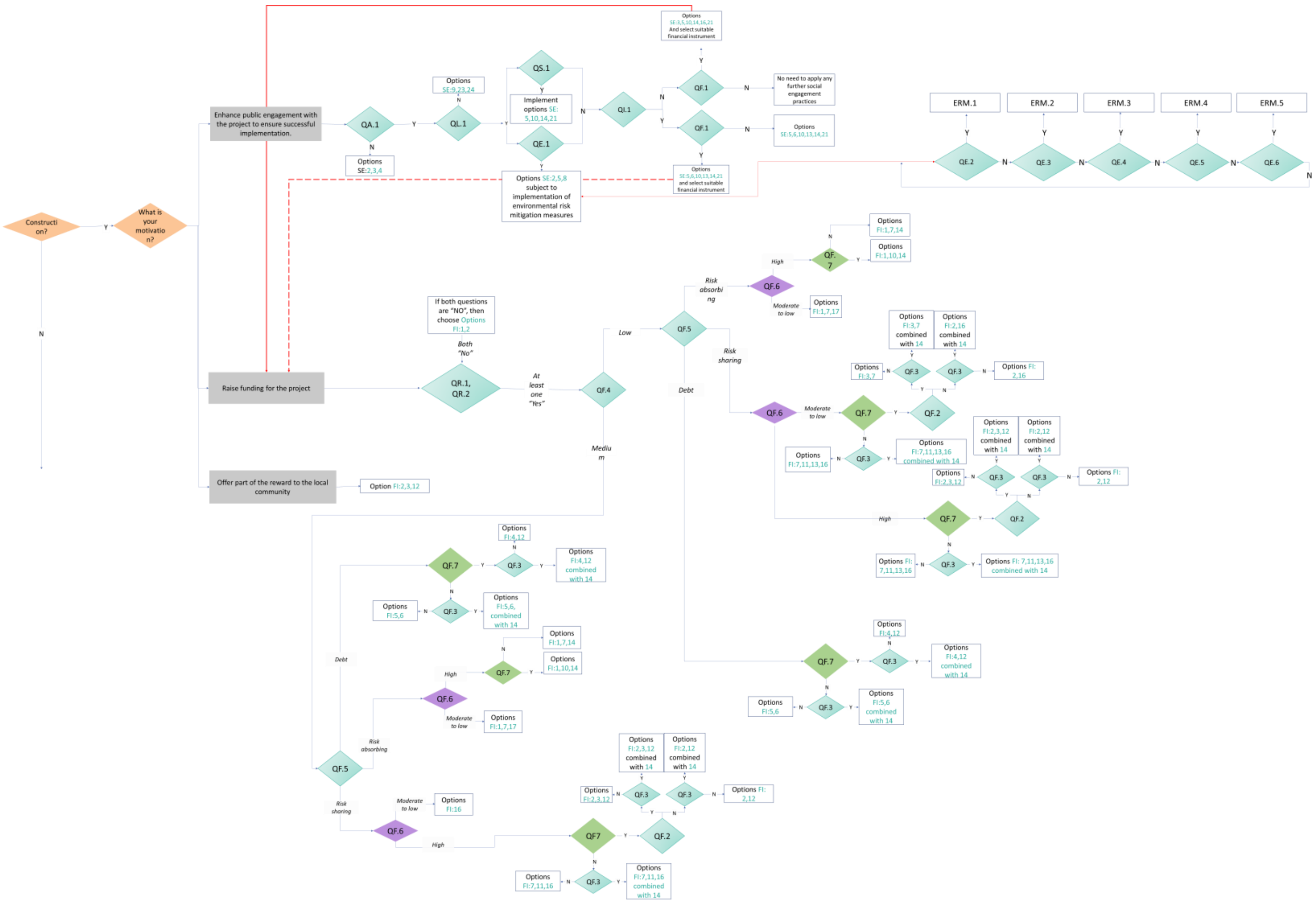

Figure 6 Decision Tree – Construction phase

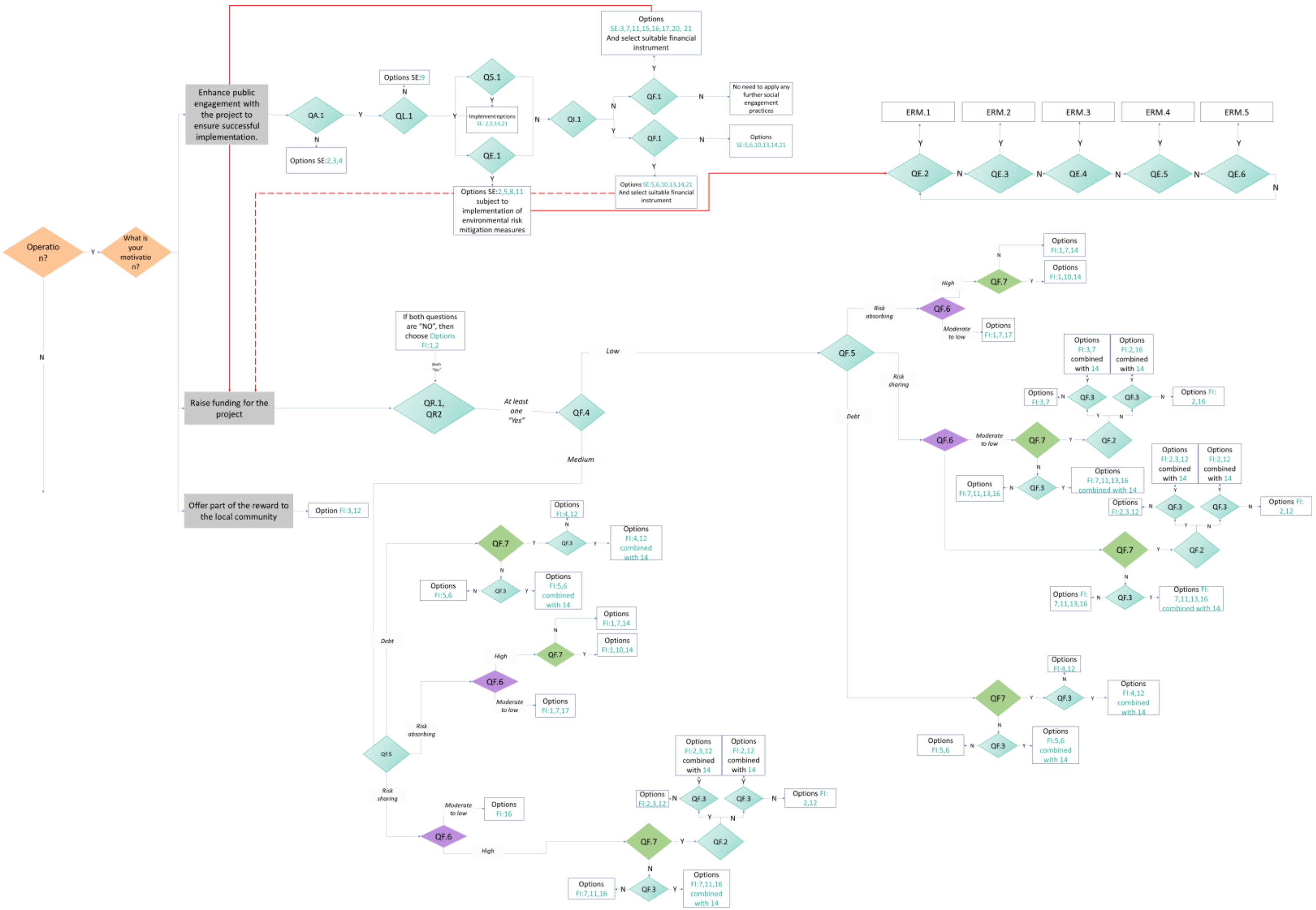

Figure 7 Decision Tree – Operation phase

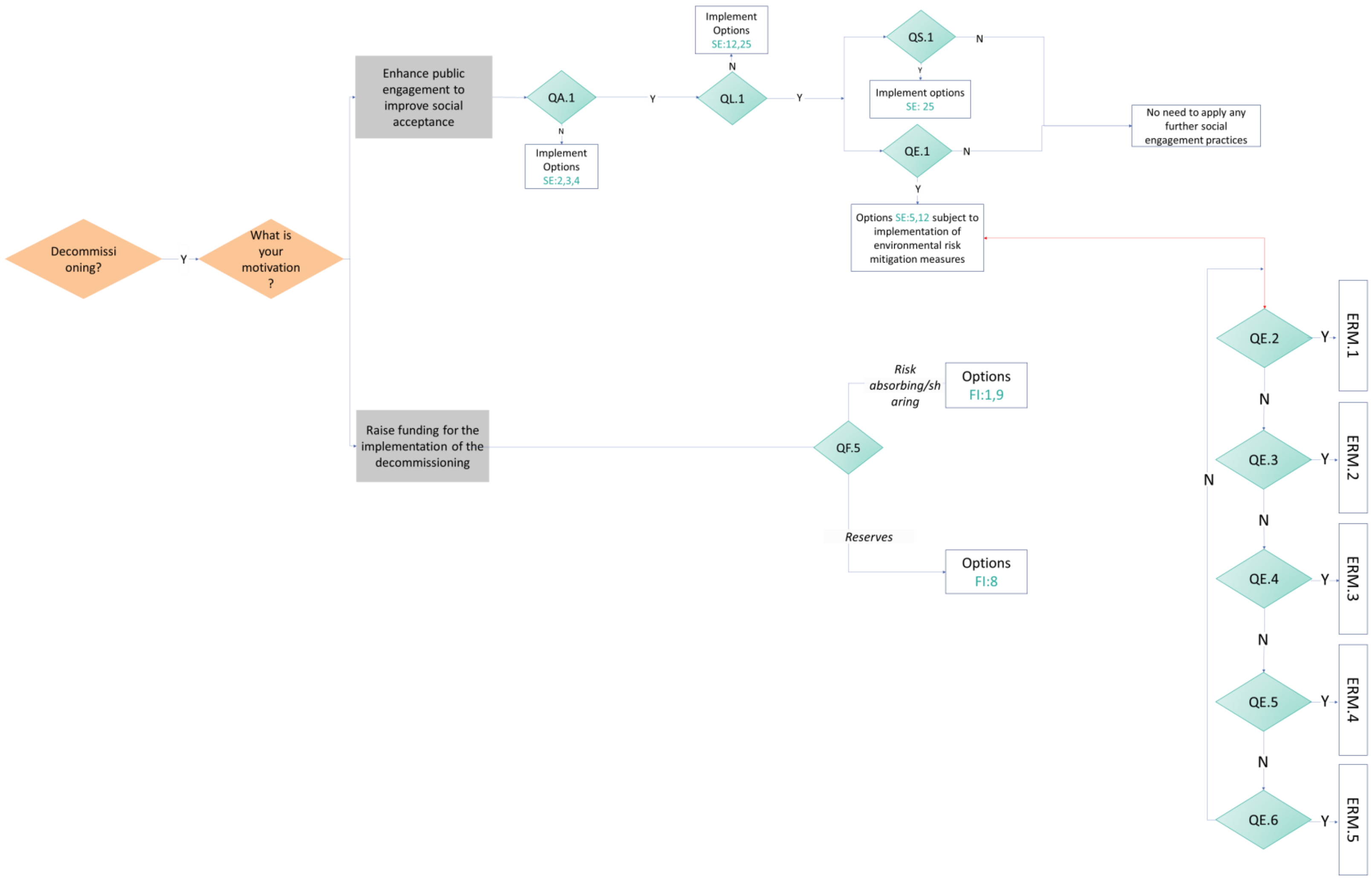

Figure 8 Decision Tree – Decommissioning and Post-Closure

6 CONCLUSION

Decision trees offer a graphical representation to facilitate decision-making and a transparent approach on how certain decisions have been made. The decision tree presented in this report aims to support developers/operators of geothermal energy projects seeking ways to achieve one of the following objectives:

- Enhance society's engagement with the project to ensure successful implementation.
- Identify alternative funding solutions for their project.
- To make sure the community receives part of the benefits of the project.

Leaf nodes of the decision tree algorithm comprised social engagement strategies and (alternative) financing options, while the decision nodes consisted of questions related to social, environmental, resource risk and financial aspects of the project. The development of the decision tree was based on the review of respective CROWDTHERMAL deliverables and input from partners.

It should be highlighted that the decision tree is not intended to provide quantitative answers, but rather, a workflow including a sequence of questions originating from the social, environmental, and financial background of the project, following a logical order from start to end. It cannot prioritise most relevant strategies that a developer/promoter should choose (which can be realised, for example, by means of a Multi-criteria decision analysis), while the list of questions that has been shortlisted to increase the useability of the decision tree is not to be considered exhaustive.

The Decision Tree will also serve as guidance to the development of the online "Core Services" during the second half of CROWDTHERMAL.

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LIST OF DELIVERABLES

Hildebrand, J., Rühmland, S., & Klein, K. (2020). CROWDTHERMAL Deliverable D1.1: International Review Of Public Perception Studies.

Ioannou, A., & Falcone, G. (2020). CROWDTHERMAL Deliverable 1.2: Synthesis of environmental factors.

Hildebrand, J., Klein, K., Wagner, M., & Jahns, A. (2020). CROWDTHERMAL Deliverable D1.4: Guidelines For Public Engagement.

Friederichs, G. (2021). CROWDTHERMAL Deliverable D2.3: Innovative Finance Mechanisms For Geothermal Energy.

Baisch, C., Wolpert, P., Friederichs, G., & Kraml, M. (2020). CROWDTHERMAL Deliverable 3.2: Alternative Finance Risk Inventory.

Baisch, C., Wolpert, P., Friederichs, G., & Kraml, M. (2020). CROWDTHERMAL Deliverable 3.3: Alternative Finance Risks' Mitigation Tools.

APPENDIX

Table A1 Alternative financing advantages, risks and risk mitigation measures (adopted from D3.2, D3.3.)

Alternative financing	Advantages	Risks	Risk mitigation
Crowdfunding (general)	– Funding the high-risk phase of a geothermal project – Possible up to the legal maximum crowdfunding threshold limit. – Can enhance the social acceptance.	– Investors usually expect high return rates. – Project developer still owns the exploration risk unless a geothermal risk mitigation insurance or fund is in place. – EU regulation will limit crowdfunding to 5 Mio. €. – Risk of not reaching a desired crowdfunding target (due to insufficient interest of the public as a result of lack of knowledge, inexperience with crowdfunding, unfamiliarity with geothermal, possible bad image of geothermal investments) – Legal obligations – Insolvency risk	– Start early with professional marketing and public relation activities. – Communication and information should be publicly available to ensure sufficient participation. – Engage the community through events, workshops, and other social engagement formats. – restrict the (early) participation in community funding to inhabitants of the community or region and to apply different conditions depending on the proximity to the project. – Utilizing the heat from a geothermal project commonly enhances the local engagement of the public, because the community can directly see and feel the merits of the geothermal energy as opposed to power that is fed into a central grid. – Keep local governments involved from the beginning and throughout all project phases. – Discuss municipal benefits: green 'speed' passes for administrative procedures or tax-saving in municipal taxes. – A high degree of trust/confidence in the integrity of the project developer and its key personnel / board members is essential. Involve locally well-known individuals, experts of the renewable energy community and/or reputable institutions for trust building and credibility increase. – In order to prevent illegal activities, crowdfunding projects should install additional technical measures like a good supervisory board with geothermal experts, or a paid expert advisory board. – Try to apply match funding with a trustworthy platform or public institution to increase both credibility and the amount of funding. – Check for best practise de-risking measures (e.g. https://www.georisk-project.eu/georisk-tool/ and https://www.geoenvi.eu/publications/re

			port-on-mitigation-measures/) as well as potential geothermal risk mitigation schemes (e.g. https://www.georisk-project.eu/publications/review-of-existing-derisking-schemes-for-geothermal-energy/) helping to offset the resource-related risk. – Check for opportunities of governmental guarantees or insurance products within crowdfunding platforms. – An upfront alternative financing concept needs to be in place in case the crowdfunding cannot provide sufficient capital. It should be planned hand in hand with traditional financing in order to achieve a robust overall financing plan. – Include a financial go/no go decision point at the point in time when it is clear whether the desired crowdfunding threshold value can be reached or not. – Careful contingency planning should be applied in the overall financing plan, especially with regard to the drilling costs. – A possible way to scale up the total amount of crowdfunding for a project developer can be "serial-crowdfunding". – One measure to mitigate the risk of not reaching a crowdfunding target is private fund co-investing. In this case, platforms have their own fund that will co-invest in crowdfunding deals. – In order to avoid the extensive equity or debt regulations present in most countries and to avoid any possible crowdfunding size limits, project developers can also try to work with donations. – Understanding and developing a project in a holistic way, taking into consideration technical, financial and social dimensions and their interdependency generally reduces the risk of interface problems and increases the chances for a social license to operate.
Crowdfunding (Equity)	– Crowdfunding equity is a very promising concept to obtain a social license to operate from the community. – Crowdfunding (equity) is usually generated in a committed	– Shares/equity require relinquishing a part of the ownership. – The return is not limited to an interest rate, but grows with the profit of the project. – Before drilling, it is difficult to judge what the project and thus the shares/equity are worth and to find a balance between the	– The presence and conditions of insurance that protect from financial losses should be investigated. – Project developers should think in advance about the financial structure and shareholder involvement (i.e. to which degree and in which format shareholders are involved in the decision making). – A nominee structure instead of a direct shareholding structure can add benefit

	investor group, which supports the project development financially, but also ideologically (e.g. renewable energy projects). – The resource risk and risk of the investment is shared with the community investors. – The return on equity is not payable until a profit is realized. For a geothermal project this means that the return only needs to be paid back after the very expensive wells are drilled, the power plant is constructed and the energy is sold on the market (positive cash flow). – A large and possibly local commitment of the community investors also forms an opportunity for the project developer to attract additional larger, non-community investors. Local banks or pension funds, for example, might be more motivated to invest in a project and more prepared to take on risks if the community investors form a risk base (and e.g. in the case of energy companies also a	amount of crowd investors' interest and the equity level. – A large duty of care is needed, because equity investors often want to be integrated into the decision making process. – The involvement of many different small investors implies a governance risk. General assembly rules need to be followed. – The amount of reporting requested for equity models is high. – Having to give a say to equity investors can be staff- and time-consuming. Co-ownership of a few hundred individuals as opposed to a small number of large investors bears the risk of tedious decision making processes. – In crowdfunding equity, a project developer's commitment towards the shareholders needs to last from the beginning of the funding until the end of the project (inability to exit investments). Equity can only be bought back if the investors are willing to give it back. – The uncertain outcome of a geothermal project can lead to a conflict of interest between the project developer, the crowdfunding platform and the community investors. – If the results of the project are below expectations, it might be difficult to find investors for possible future projects. – Illicit activities of the platforms like financial fraud need to be considered. – Legal requirements for crowdfunding equity are more complicated than for crowdfunding loans.	to project developers in that they only deal with one shareholder. – A low to moderate crowdfunding proportion (e.g. maximum of 10-15%) of the overall project financing plan can reduce the governance risk. – Tools that can increase the confidence and credibility of a crowdfunded geothermal project towards all stakeholders are considered an important mitigation measure in crowdfunding equity. Possible examples are official sustainability certifications/ concepts/labels, institutional match funding, patronage of well-known persons from the renewable energy community, and the involvement of geothermal experts. – To increase local support, a sense of local project ownership could e.g. be achieved by offering local community shareholding/equity for free or for a low price to inhabitants of a certain radius around the project site.

	client base) for the project.		
Crowdfunding (Reward-based)	– Reward-based crowdfunding is a promising approach to enhance local project ownership and to obtain a scial license to operate. – The reward only has to be given when the project is realized. Repayment of the funding is therefore not always necessary. – If the project takes longer than expected, there is no liquidity problem. – No monetary return has to be paid. – The community investors are the customers at the same time, e.g. heat or electricity consumers. The commitment of the crowd is therefore proven, and investors will be mostly local.	– Reward-based crowdfunding has not been applied in the geothermal industry yet. – There is a risk that investors are not satisfied with the realized reward. – There is also a reputation risk concerning the treatment of the crowdfunding investors. – A potential second round of funding may not be filled if the reward offered is not as expected, e.g. the geothermal wells deliver less water and temperature than anticipated. – If a geothermal project does not deliver as much energy as originally planned, the project developer might have to buy the energy elsewhere to provide the promised rewards to the community. – It is difficult to raise high amounts of funding through this usually very local method.	– It is recommended to research upfront what the potential reward-based crowdfunding investors are interested in most. – Communication is a key element for this form of usually very local crowdfunding.
Crowdfunding (Loan)	– As opposed to crowdfunding equity, crowdfunding loans do not require relinquishing part of the ownership of the project to investors. – The interest paid on crowdfunding loans is fixed. As such, there is no upward risk in	– Crowdfunding loans are less flexible than crowdfunding equity. – Crowdfunding loans are challenging in the early project phases, when it is difficult to predict the project time component. Despite a possible delay in the project, the fixed interest rate must be paid in time. – Another risk is the unclear result of the geothermal project. A well may be dry or less productive than	– Equity or reward-based crowdfunding are typically more suited for the early geothermal project development phases. – Investigate if the government will guarantee the loan to reduce the risks for the community. – Raising funds through a convertible loan that can be converted into equity, if needed, could be another strategy to mitigate the risk.

	the cost of capital for the project developer. – Project developers have the ability to decide when the loan is funded. The point in time when funds are made available to the project as well as the point in time when the funds need to be repaid are clear and can be planned. The timing of the cash flow is easier to control as for example with crowdfunding equity.	planned and revenue might not be enough to pay the fixed interest rate of the loan. – The loan has to be refinanced after the duration has expired. – Community investors are less committed to a project as opposed to equity or reward-based methods. – Reaching local people and thus increasing local acceptance might require additional social engagement tools.	
Direct lending combined with governmental guarantee	– It may be easier to attract funding through direct lending than through a bank. – The use of a financial intermediary can help in the process of direct lending, as they have an existing network which makes it easier to reach potential investors than for a project developer. – As opposed to crowdfunding, direct lending through a financial intermediary does not involve the risk of incomplete funding. – If using a financial intermediary, the risk of	– A risk when using direct lending is that the result of the project (i.e. flow rate and temperature) may not be enough to pay the fixed interest rate of the loan. – Due to unexpected delays of the project (e.g. drilling risks or citizen initiatives), the projects can be delayed while the fixed interest rate must be paid in time. – The loan has to be refinanced after the duration has expired, which also limits the flexibility during project development. – If going through a financial intermediary this intermediary may ask for a high level of collateral, especially in risky phases (e.g. the drilling of the geothermal wells). However, this collateral may not be available. – Green bonds as one instrument used in direct lending might not be applicable for single geothermal projects, so they may require the pooling of projects in a portfolio approach.	– One mitigation measure could be to raise funds through a convertible loan that can be converted into equity. This increases the potential of an upward return for investors and thus makes the loan more attractive for investors. It also increases the flexibility of repayments for the project developer which can be useful if the project results are delayed. – Another mitigation measure is a (governmental) guarantee, so the loan can be repaid to the financial intermediary even if the project does not generate enough income (in time) for repayment, e.g. like shown in EIF 2019. – Collaterals can be used to guarantee investors that a means to generate repayments is still available. – Project developers can pool own projects or projects from several developers/investors in order to create risk profiles in line with the objectives of financial intermediaries. Bundling projects can reduce transaction costs and streamline investments.

	repayment to the community lies with the financial intermediary, not with the project developer directly. – The project developer only has to deal with one investor (the financial intermediary).		
Leasing	– The largest advantage for project developers acting as a Lessee in the late project development phases is the absence of the resource-related risk. The risky early development phases are carried out by e.g. the government. – As there is almost no exploration risk for the Lessee in this case, a project developer applying leasing can raise money for the follow-up phases through traditional bank finance like for any other energy project. – The late development phases of a geothermal project are clearer and less risky, so it is easier to match the maturity of the financial instrument to the costs of the	– The Lessor may have conditions concerning turnover etc. making it impossible to get access to this form of financing. – The Lessor can reclaim ownership if payments are not made in time. – A lot of specific knowledge is required to monitor the project and repayments as they are tied to the leased object or project. – In the late project development phases, traditional bank loans might be possible at lower costs.	– Leasing can be understood as a financial mitigation measure in itself. It reduces the risk for the investor, because the asset is used as collateral and can be reclaimed when a business is not paying.

	specific project and phase. – For a geothermal project developer, it can be easier to raise capital via leasing compared to e.g. direct lending, as collateral is arranged in the leasing contract itself. If the lease financing goes wrong, the ownership of the plant or well transfers to the party who has supplied the finance. This is a form of guarantee.		

Table A2 Abbreviation list

Abbreviation	Meaning
Decision tree questions	
QA.x	Awareness-related questions
QR.x	Resource risk-related questions
QS.x	Social concerns-related questions
QE.x	Environmental concerns-related questions
QF.x	Financial characteristics-related questions
QI.x	Intellectual participation-related questions
QL.x	Legal compliance-related questions
Social engagement options	
SE.x	Social Engagement strategy x
Environmental risk mitigation options	
ERM.x	Environmental risk mitigation measure x
Financial instrument options	
FI.x	Financial instrument x