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Assessment of enhanced geothermal projects and their optimal long-term usage plans by using the DMS-TOUGE decision-making support tool

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INTRODUCTION

Large untapped geothermal energy potential can provide a constant source of renewable baseload electricity and heat. It also has a low environmental impact with small land area footprint and nearly zero greenhouse gases emissions.

In Europe, enormous untapped geothermal potential consists of low permeable bedrock, only exploitable by Enhanced Geothermal Systems (EGS) technology. Hydraulic stimulation is required to enhance the permeability of the reservoir to create enough connectivity for water or perhaps CO_2 as heat transfer fluid. By recirculating fluid through the reservoir, the thermal energy stored in the hot rock mass gets extracted.

STUDY APPROACH

The tool called DMS-TOUGE will be capable of site-specific environmental and economic analysis with the focus on low-enthalpy energy from co-produced hot water and it will consider: existing infrastructure or future facilities, extension or upgrade, co-use/re-use of existing boreholes, different geological features such as sedimentary rocks, granitic rocks, volcanic and potential geothermal wells. The tool examines the enhanced geothermal systems projects in a holistic way considering: technology details, geothermal site characteristics, energy prices, spatial data, social impact, and environmental impact. (Figure 1.)

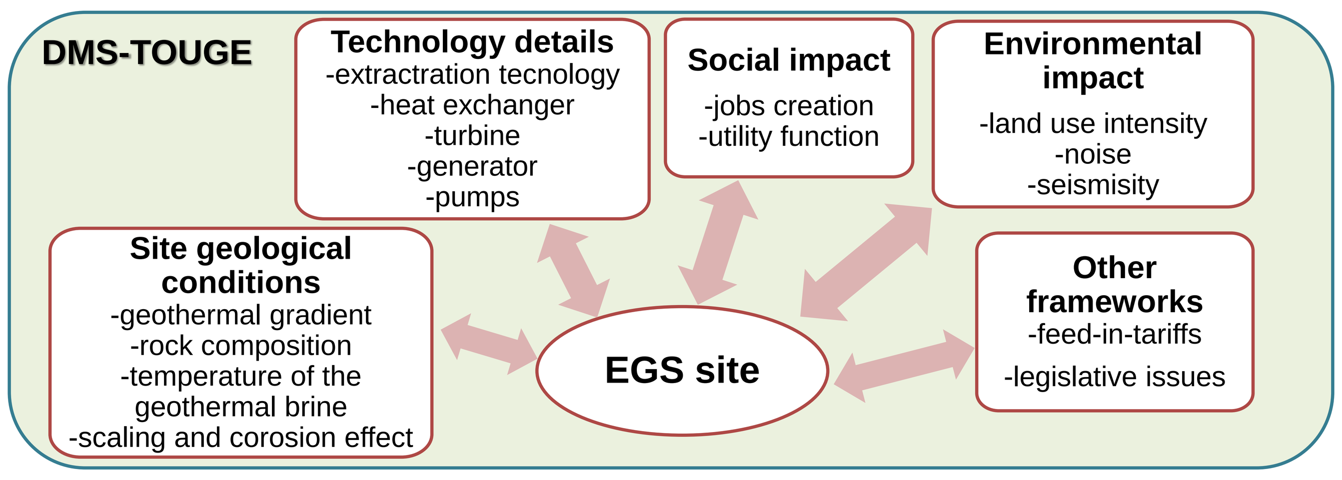

Figure 1. Parameters that the DMS-TOUGE will examine – holistic approach

METHODOLOGY

The DMS-TOUGE will be capable of using both internal and external data entered by a decision maker (DM), such as water temperature, geothermal capacity, electricity and heat prices, injection water flow rate values, technology details of the turbine, generator type, heat exchangers. Output data will be in two forms, as raw data, or in a form of decisions suitable for decision makers and investors. For that needs the raw data will be processed by a special subprocess, a separate multiple-criteria decision-making (MCDM) process, into a decision. (Figure 2.)

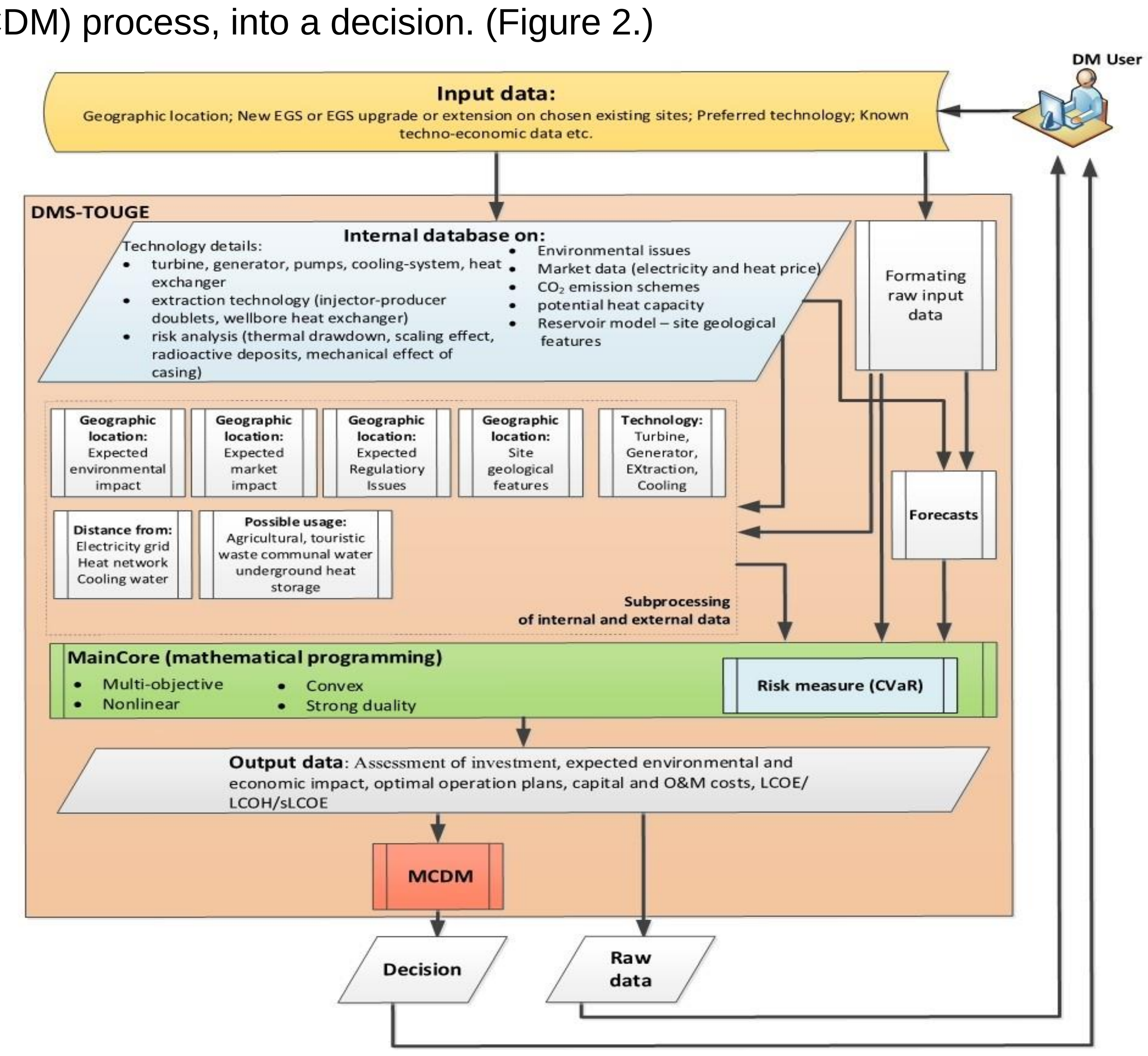

Figure 2. Schematic description of main processes in DMS-TOUGE

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MULTI-CRITERIA DECISION-MAKING (MCDM)

For MCDM analysis in the DMS-TOUGE, the weighted decision matrix (WDM) will be used. A set of criterions for valuing different EGS alternatives are defined. (Figure 3.) Each criterion has associated weight in order to value its relative importance in decision making. Performance, x_{ij}, of alternative i on criterion j is defined with numerical value from 1 to 5, whose higher value means better performance, $x_{ij} \in \{1,2,3,4,5\}$. Finally, total performance, X_i, of i[th] EGS alternative on all criteria, $\forall j$, is assessed by summing all performance values, x_{ij}, multiplied by its weight as shown in Equation 1,

$$X_i = \sum_{j}^{J} w_j \cdot x_{ij} \qquad (1)$$

where X_i is the total performance of i[th] EGS option, $i \in I$, where I is a total number of EGS options. The w_j is weight i.e. relative importance in the decision making of criterion j, $j \in J$, where J is a total number of criteria. The x_{ij} is the performance of option i on criterion j.

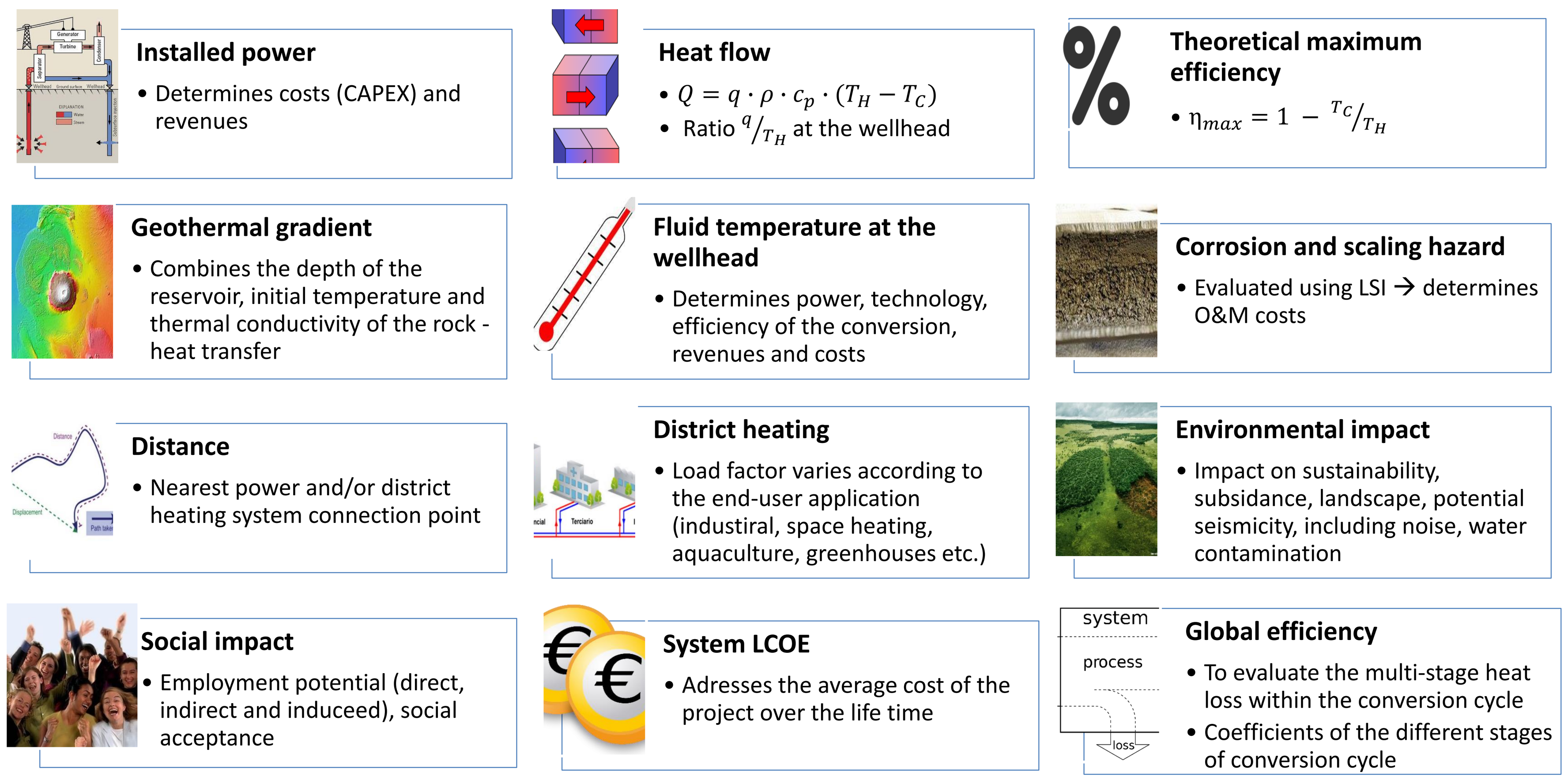

Figure 3. Defined criteria for the MCDM matrix

RESULTS AND DISCUSSION

The matrix is used to rank four different sites in Table 1. for two given end uses. For a successful comparison, the geothermal projects being compared should be targeting the same end use, so that the comparison considers how key technical and economic factors are being utilised. According to MCDM, the following results were obtained (Table 2. and Table 3.). Also, a sensitivity analysis was carried for independent variables affecting the LCOE (Figure 4.).

Table 1. Input parameters for the DMS-TOUGE and MCDM matrix

Parameter	Unit	Site 1	Site 2	Site 3	Site 4
Brine flow rate, q	L/s	83.33	20	5.5	77.1
Inlet temperature, T_H	°C	170	80	140	80
Outlet temperature, T_C	°C	70	32	70	40
Geothermal gradient	°C/100m	6.18	6.1	3	6
Number of wells	No.	1	1	1	1
Specific heat capacity, c_p	J/kgK	4185.5	4185.5	4185.5	4185.5
Corrosion and scaling	LSI	1.5	0.5	0.5	0.5
Fluid density[1], ρ	kg/m³	897.3	971.76	925.9	971.76
Th. efficiency, $\eta_{max,ele}$	%	6.18	6.1	3	6
Max. efficiency, $\eta_{max,heat}$	%	76.47	62.5	78.57	53.33

Table 2. MCDM matrix – only electricity production

Criterion	Site 1	Site 2	Site 3	Site 4
$x_{i,1}$	4	1	1	1
$x_{i,2}$	1	2	4	1
$x_{i,3}$	3	1	2	1
$x_{i,4}$	5	5	3	5
$x_{i,5}$	5	2	4	2
$x_{i,6}$	1	1	1	1
$x_{i,7}$	1	4	4	4
$x_{i,8}$	4	5	4	5
$x_{i,9}$	5	5	5	5
$x_{i,10}$	3	3	3	3
$x_{i,11}$	5	5	5	5
$x_{i,12}$	5	5	5	5
Final	3.5	2.83	3	2.75

Table 3. MCDM matrix – only heat production

Criterion	Site 1	Site 2	Site 3	Site 4
$x_{i,1}$	4	5	4	4
$x_{i,2}$	1	2	3	1
$x_{i,3}$	5	5	5	5
$x_{i,4}$	5	5	3	5
$x_{i,5}$	5	2	4	2
$x_{i,6}$	4	4	4	4
$x_{i,7}$	1	4	4	4
$x_{i,8}$	3	4	3	4
$x_{i,9}$	2	2	2	2
$x_{i,10}$	1	1	1	1
$x_{i,11}$	4	5	4	5
$x_{i,12}$	5	5	5	5
Final	3.33	3.67	3.5	3.5

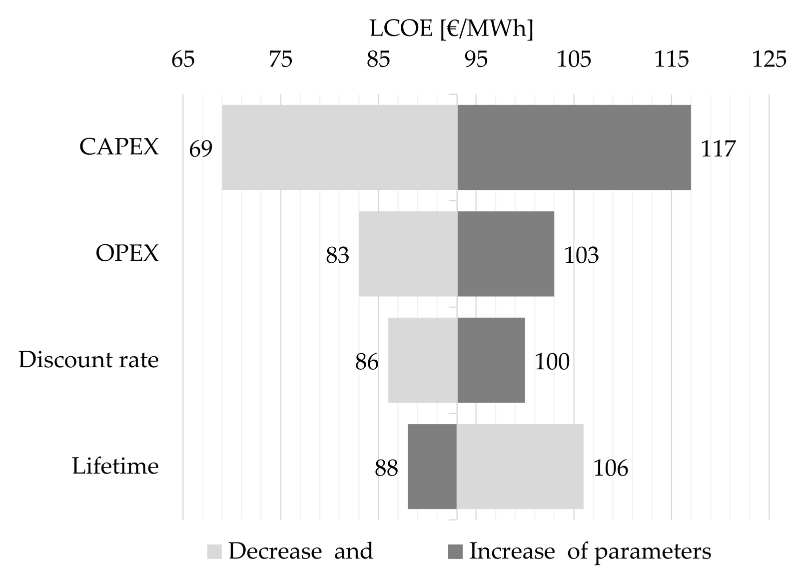

Figure 4. Tornado plot showing sensitivity analysis of LCOE

CONCLUSIONS

The tool will, among others, provide LCOE of the selected technology, environmental and social impact. The paper contributes with expanded and detailed criteria related to environmental and social impact giving the necessary emphasis on so far neglected important aspects for successful completion of geothermal projects.