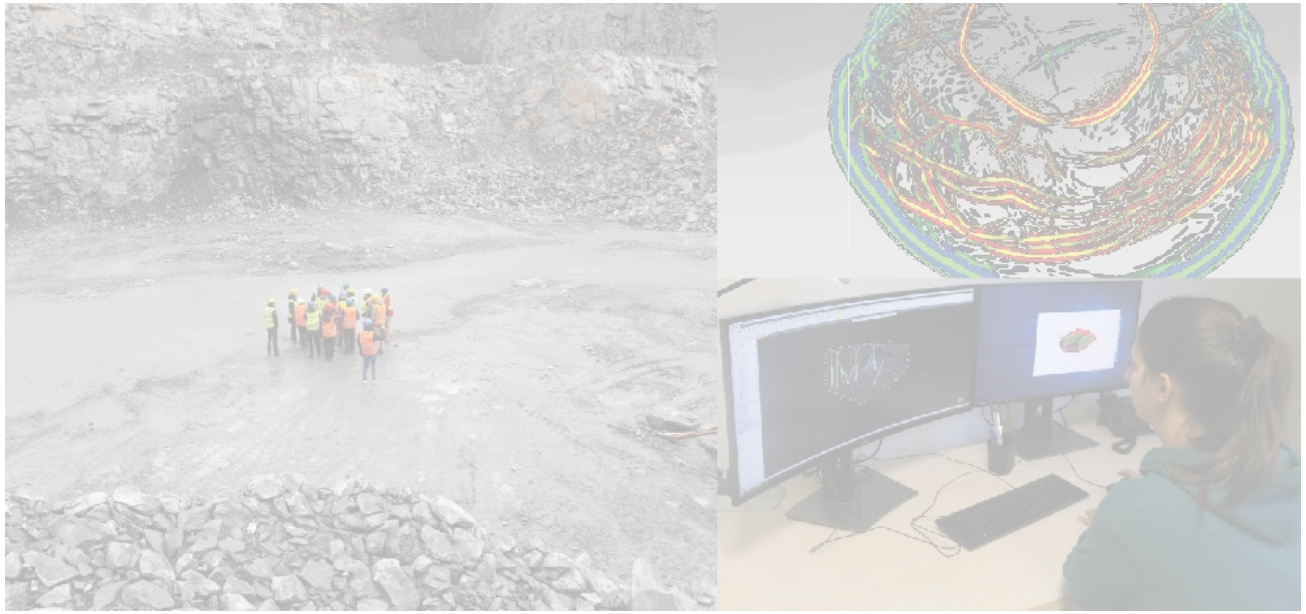

Site-specific environmental and economic assessment of EGS using DMT

Decision Making Tool (DMT) structure and role

Ivan Rajšl

Sara Raos, Josipa Hranić - UNIZG-FER

MEET Project – Geothermal Winter School – February 2021

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 792037

Introduction

Why Go Geothermal?

Zero GHG Emissions

Environmental responsibility and energy diversity in overall energy mix

Vast and consistent base load energy resource

Suitable and aplicable to every country

Renewable energy source as long as the earth exists

Provides electricity, heating and cooling

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Hydrothermal Geothermal Resource

Preconditions

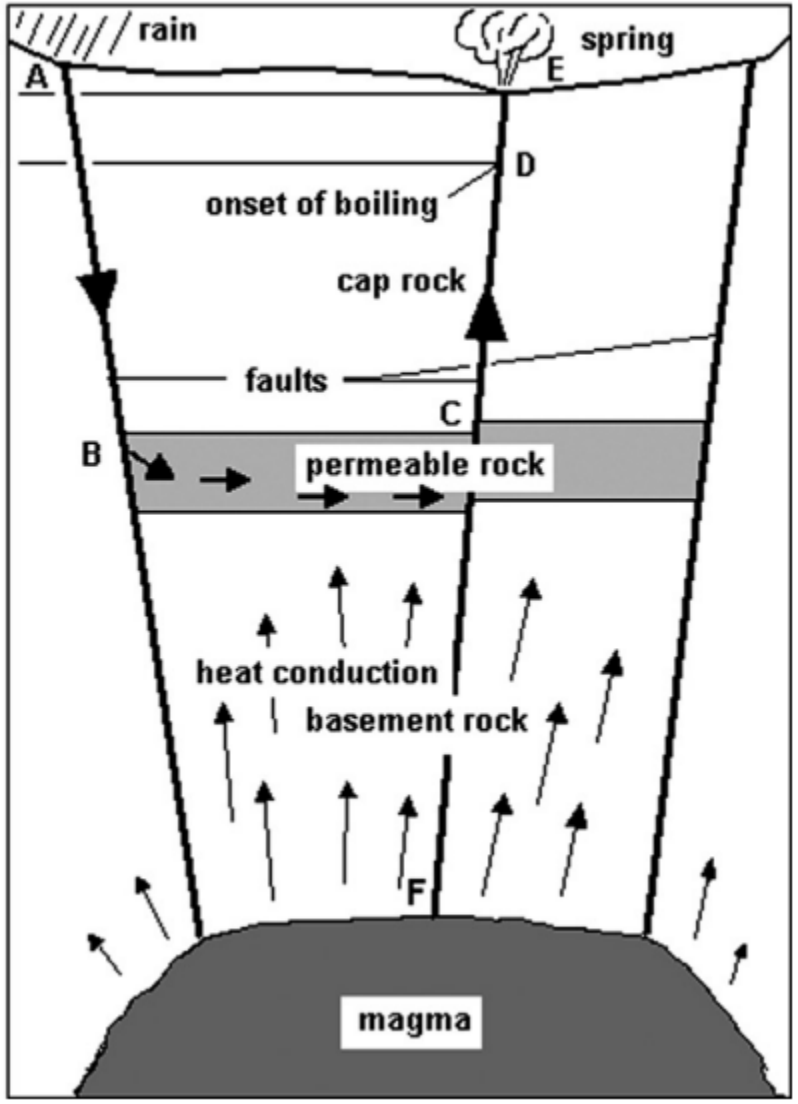
A large heat source

A permeable reservoir

A supply of water

An overlying layer of impervious rock

A reliable recharge mechanism



DiPippo, Geothermal Power Plants, Fourth Edition

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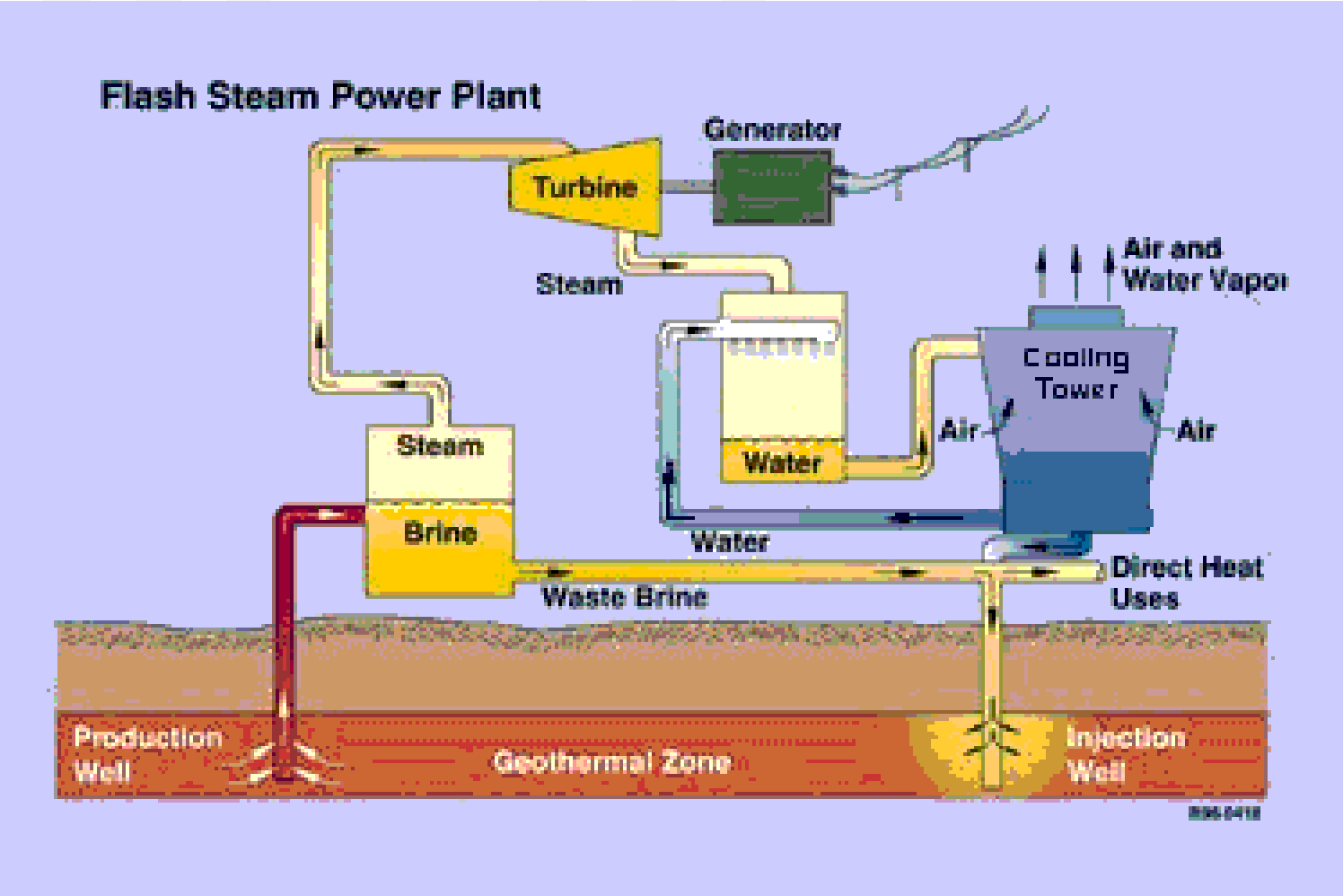
Geothermal site

Interdisciplinary



https://people.uwec.edu/piercech/210webs/renewable/geothermal.htm

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Lindal diagram

Geothermal energy application

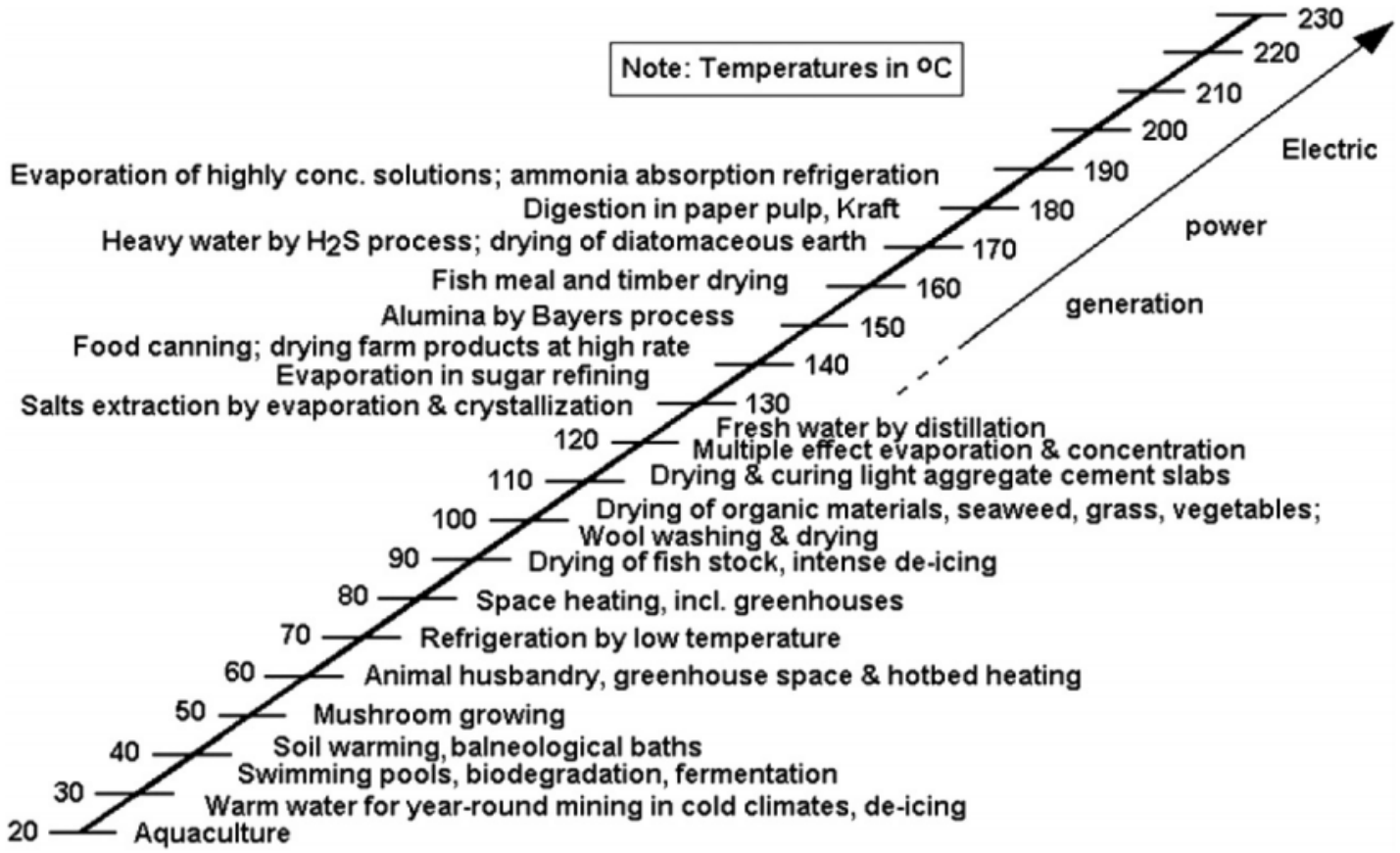

FIGURE I.1 Modified Lindal diagram showing applications for geothermal fluids.

DiPippo, Geothermal Power Plants, Fourth Edition

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Lindal diagram

Geothermal energy application

Lindal Diagram for mining, Patsa 2015.

https://isleofrocks30.com/the-lindal-diagram-an-overview/

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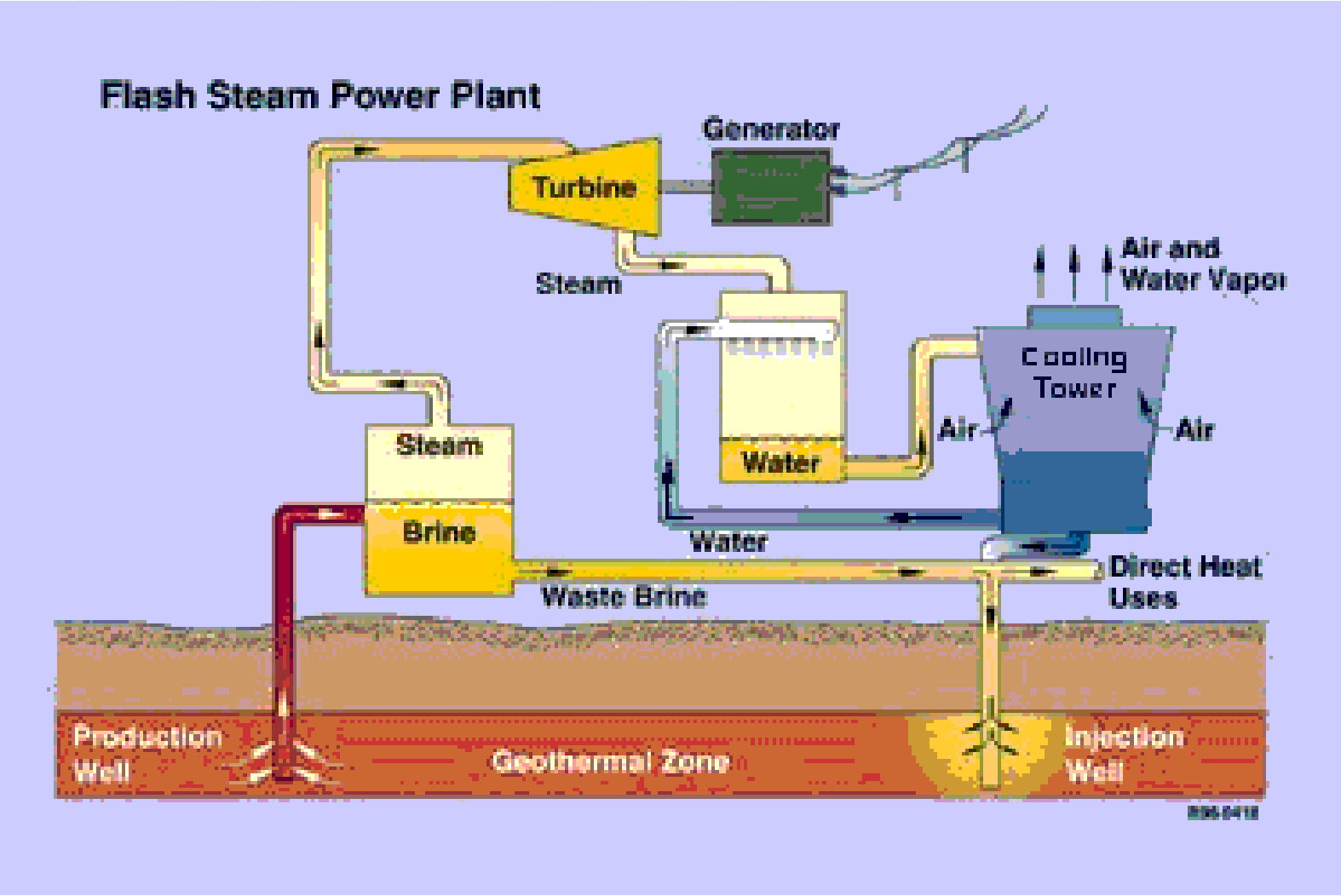
Types of geothermal power plants

Flash Steam Power Plant

https://people.uwec.edu/piercech/210webs/renewable/geothermal.htm



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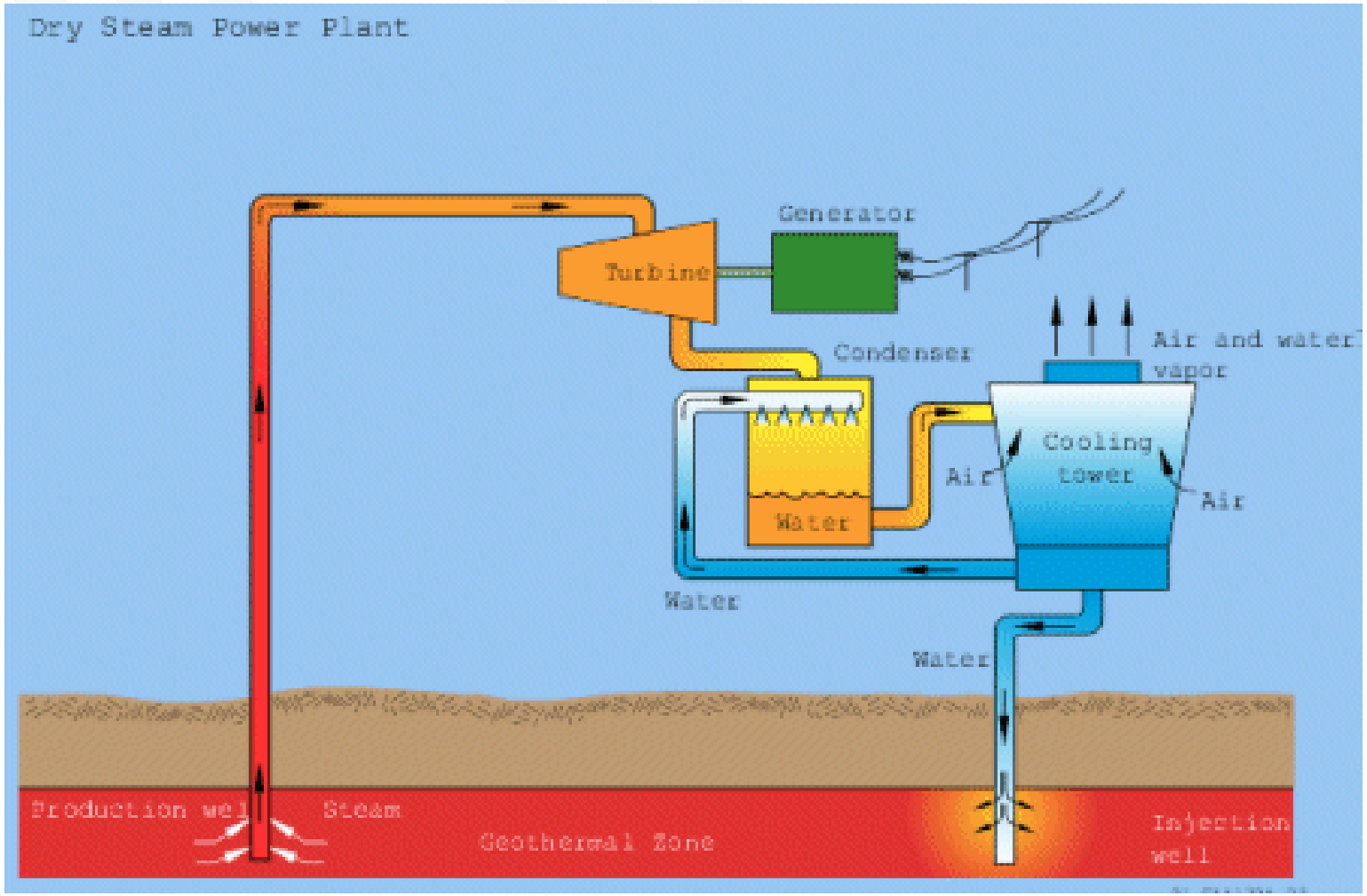
Types of geothermal power plants

Dry Steam Power Plant



https://people.uwec.edu/piercech/210webs/renewable/geothermal.htm

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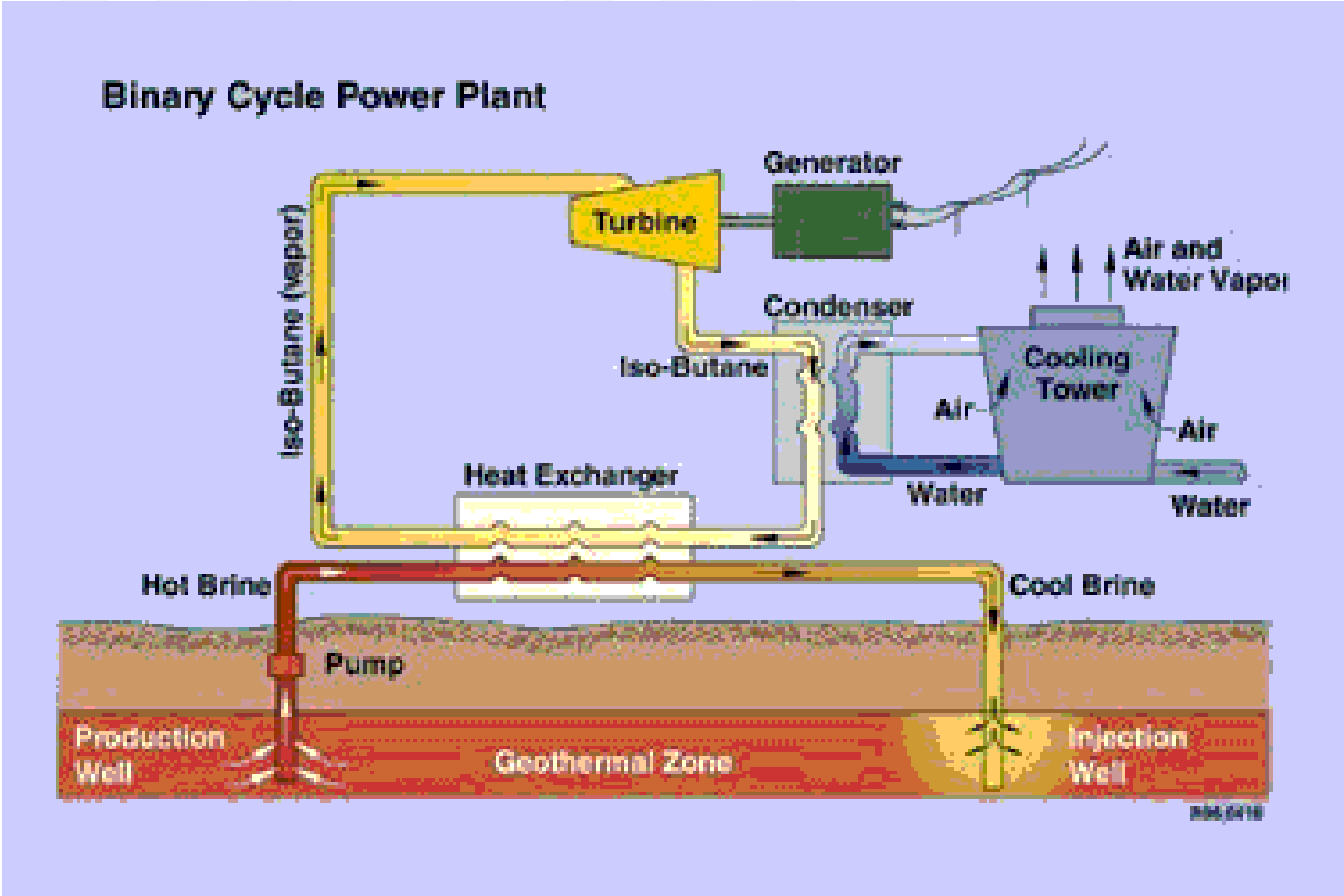
Types of geothermal power plants

Binary Cycle Power Plant

https://people.uwec.edu/piercech/210webs/renewable/geothermal.htm



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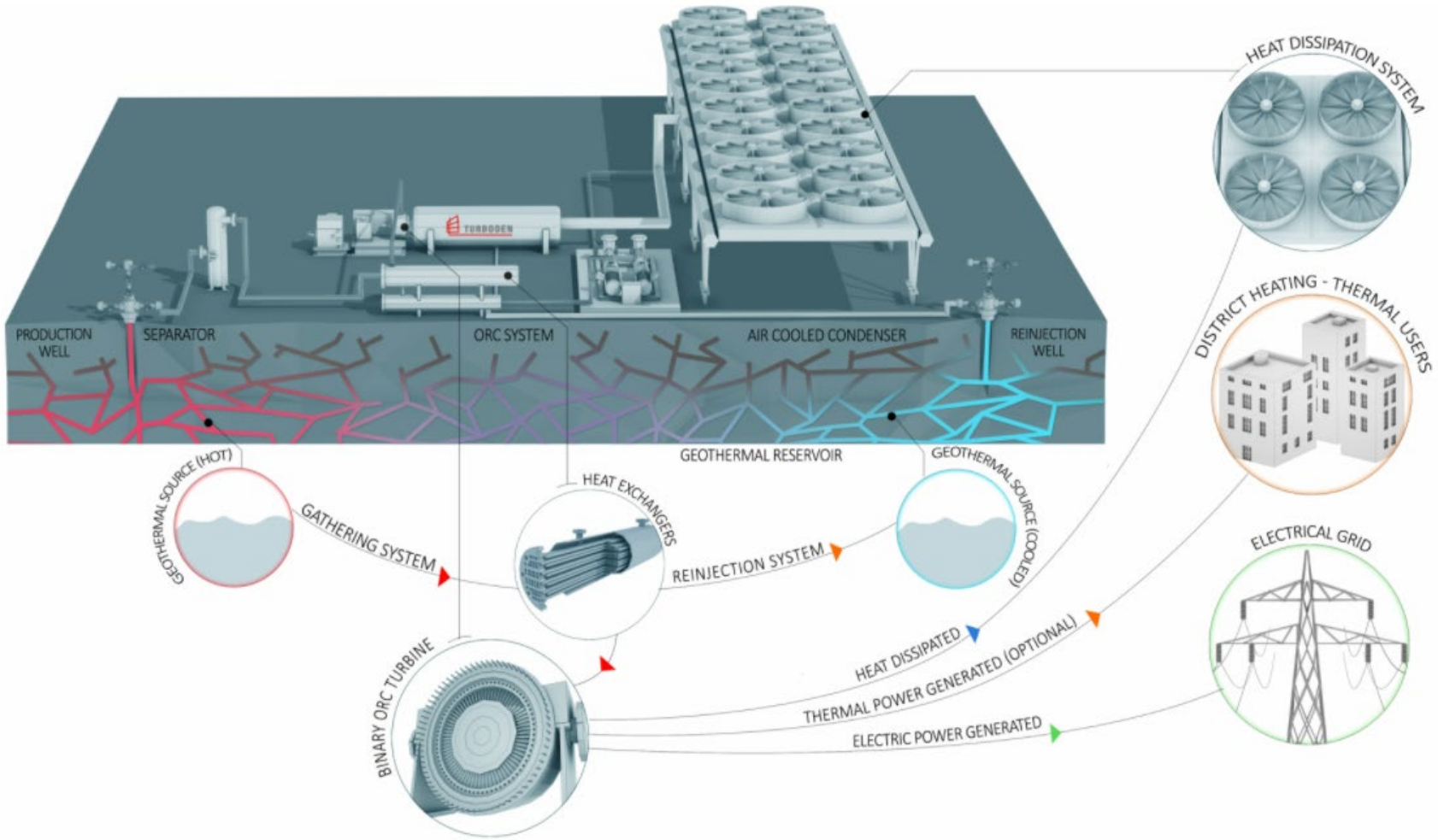
Types of geothermal power plants

ORC Binary Cycle Power Plant

https://www.turboden.com/solutions/1052/geothermal



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Potential issues with EGS

Site specific

Too low brine temperature

Long distance to power grid

Long distance to heat demand

Contaminated brine

Corrosion and scaling

Induced seismicity

Societal acceptance

...

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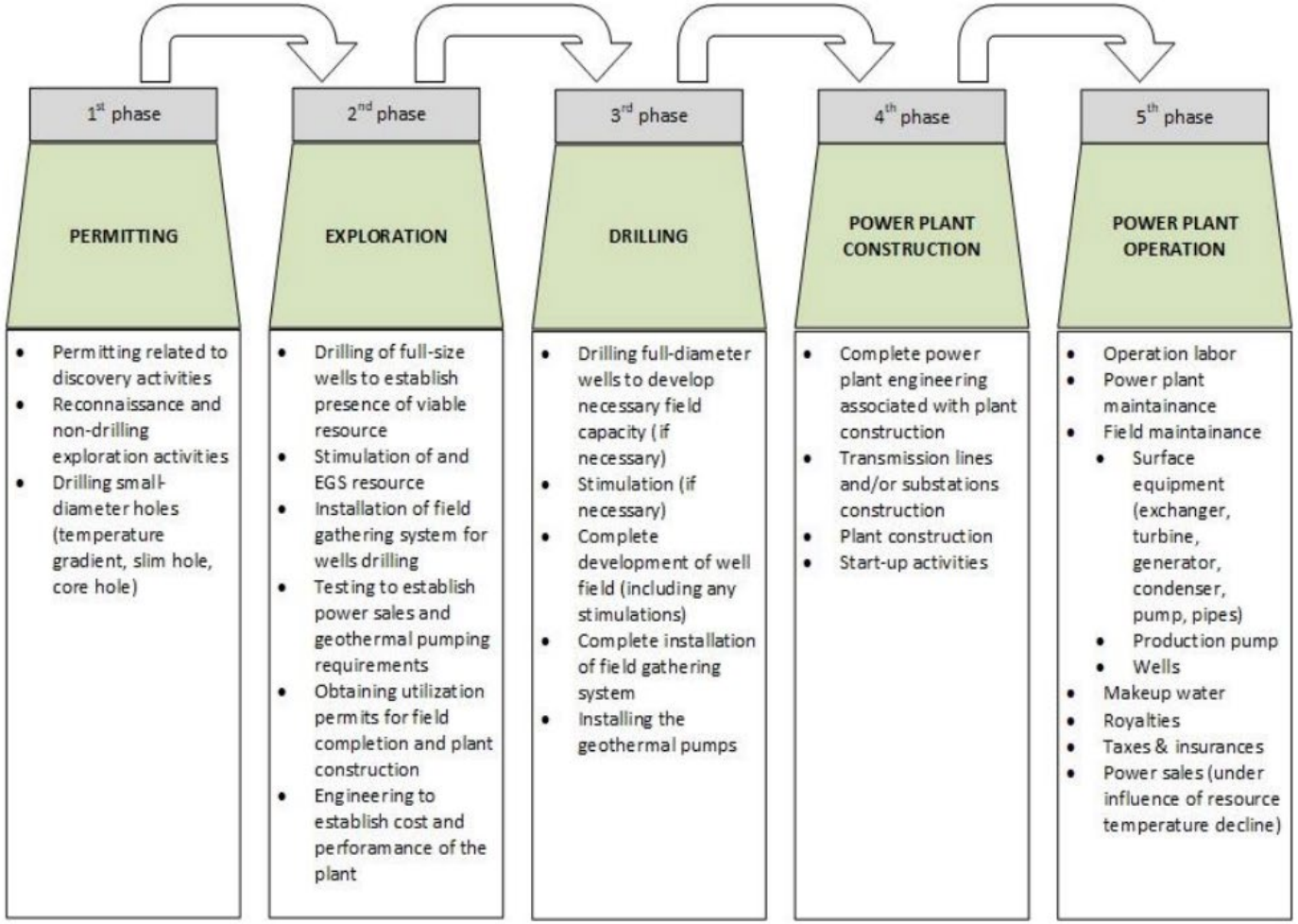
Geothermal site development

Development Stages



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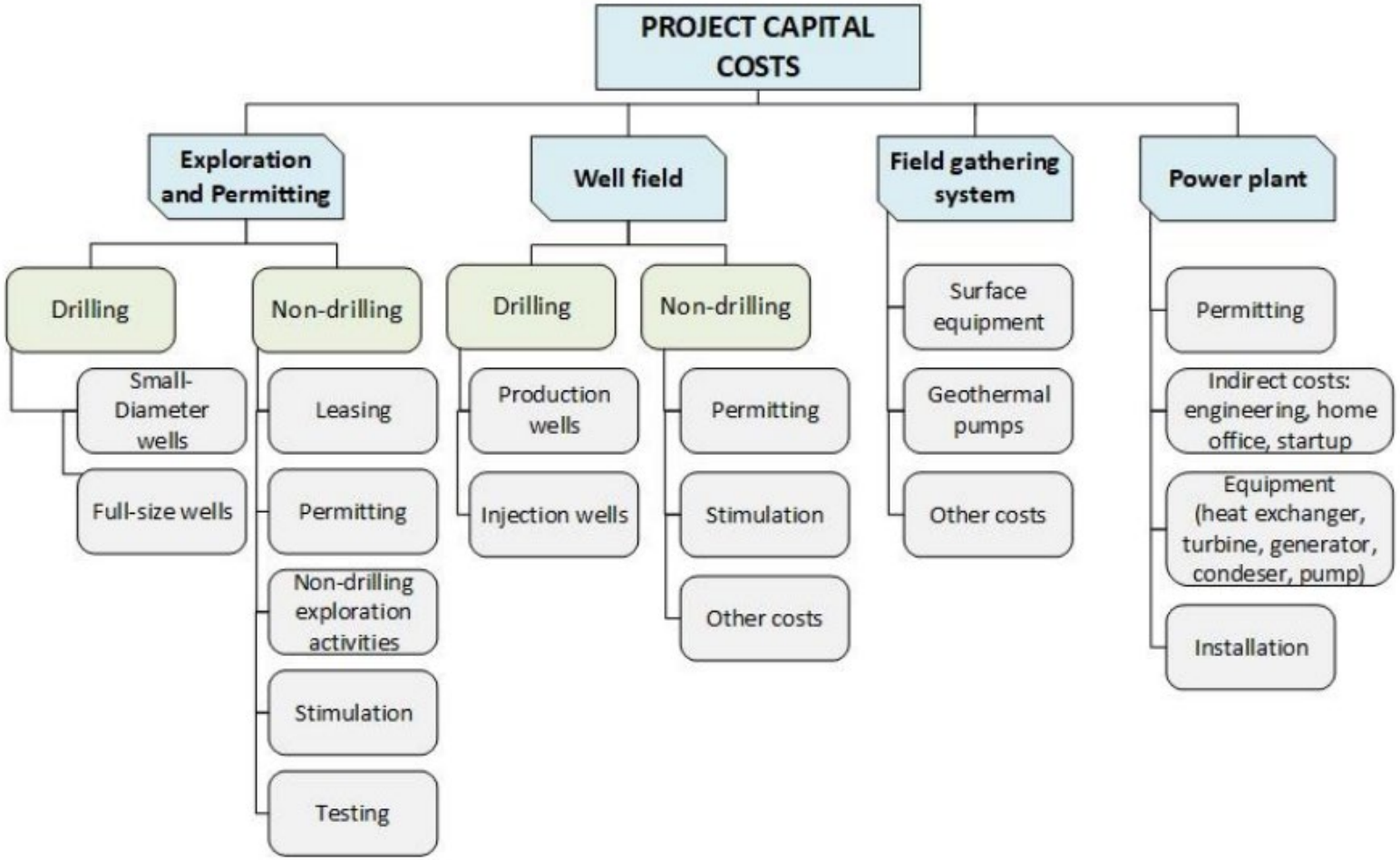
Geothermal site development

Project capital costs



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Possible solution

DMT

Decision making tool within MEET project

Evaluation of different energy transformation options

- only electricity
- only heat
- CHP

Technical, financial, ecological and societal aspects

Provides output that can be used for determining best geothermal potential utilisation

Provides grades for different options using MCDM built-in module

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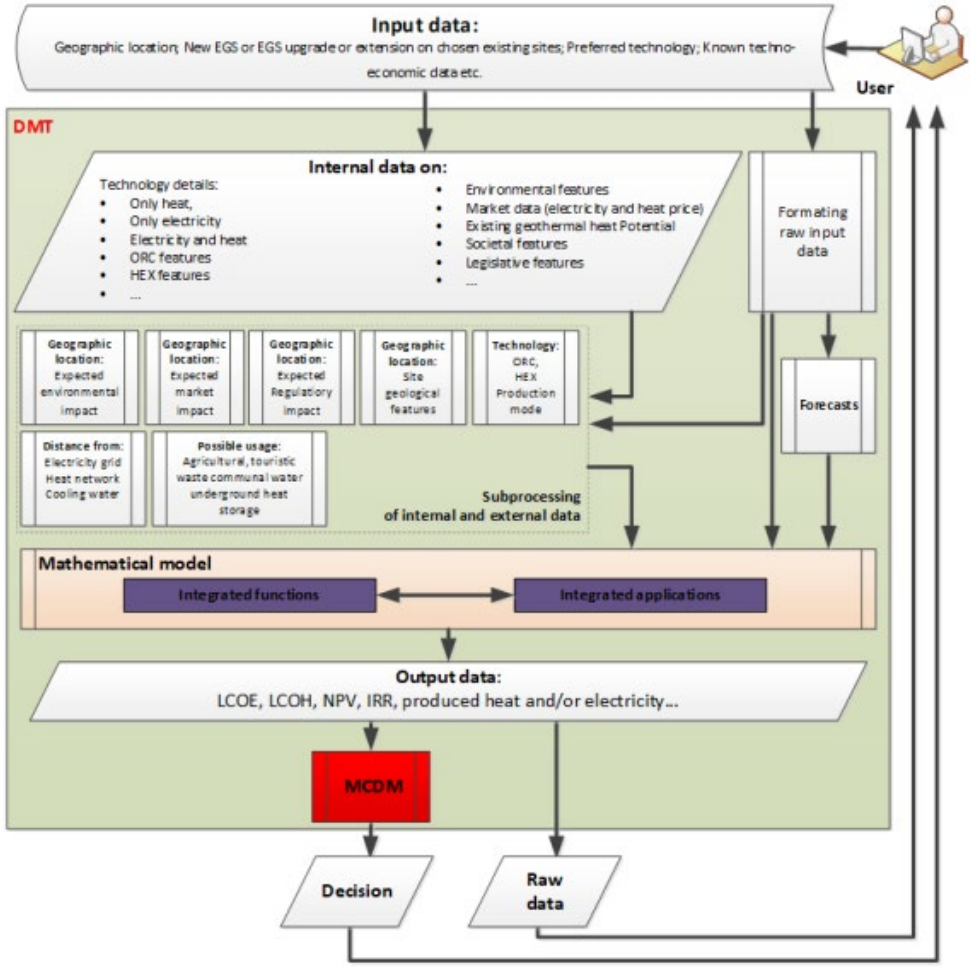
DMT

Concept and main features of the DMT



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DMT

DESCRIPTION OF TOOL CONTENT AND PURPOSE

It is crucial to develop satisfactory **level of support** that can be used for every site of interest and for different ways of geothermal energy exploitation

Combines **technical, economic, environmental and social** aspects of geothermal projects and therefore, provides background for a comprehensive assessment of Enhanced Geothermal Systems, EGS projects

Can be used for obtaining economic criteria like **IRR** (Internal Rate of Return), **LCOE** (Levelized Cost of Energy) and **NPV** (Net Present Value)

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DMT

DESCRIPTION OF TOOL CONTENT AND PURPOSE

Most of the input parameters that can be exactly **monetarized** have option, either by default values or user specified

Other parameters that are **hard to monetarized**, such as social acceptance, environmental aspects and others are taken into account in last stage of grading of specific EGS project using **multiple-criteria decision-making** (MCDM) approach that enables comparison between several approaches and/or different sites

MCDM also allows user **specific attitudes** (subjective goals) by putting different weights to specific influencing factors

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DMT

DESCRIPTION OF TOOL CONTENT AND PURPOSE

Focus is switched from modelling and exploring geothermal potential in different locations to **modelling above surface phenomena**

In this way better approach to assess energy transfer from its geothermal source to final users is allowed

Tool is modelled in **MATLAB**

Executable version (standalone)

MATLAB version for **further research**

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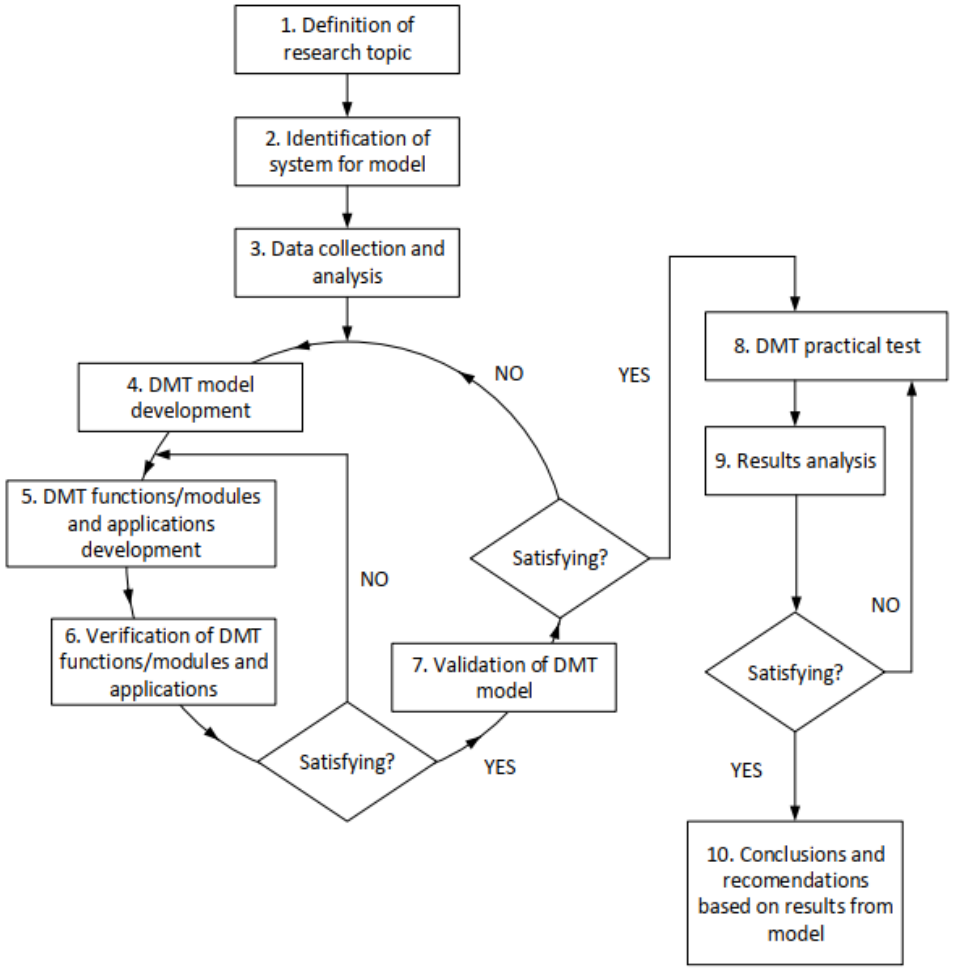
DMT

Flowchart of DMT modelling approach



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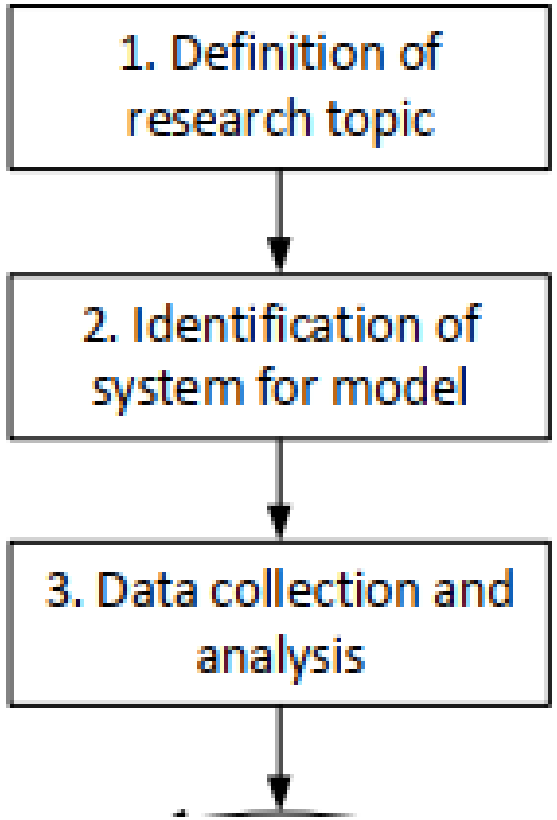
DMT

Flowchart of DMT modelling approach



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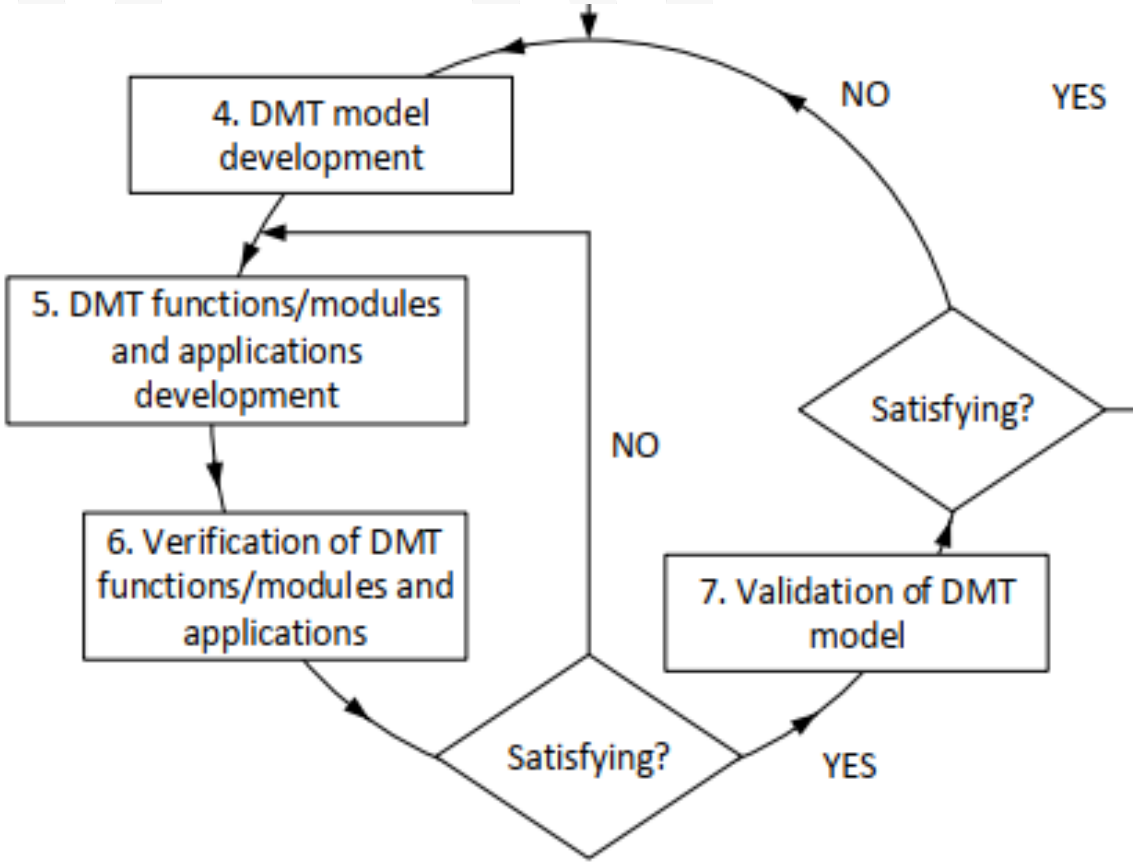
Flowchart of DMT modelling approach



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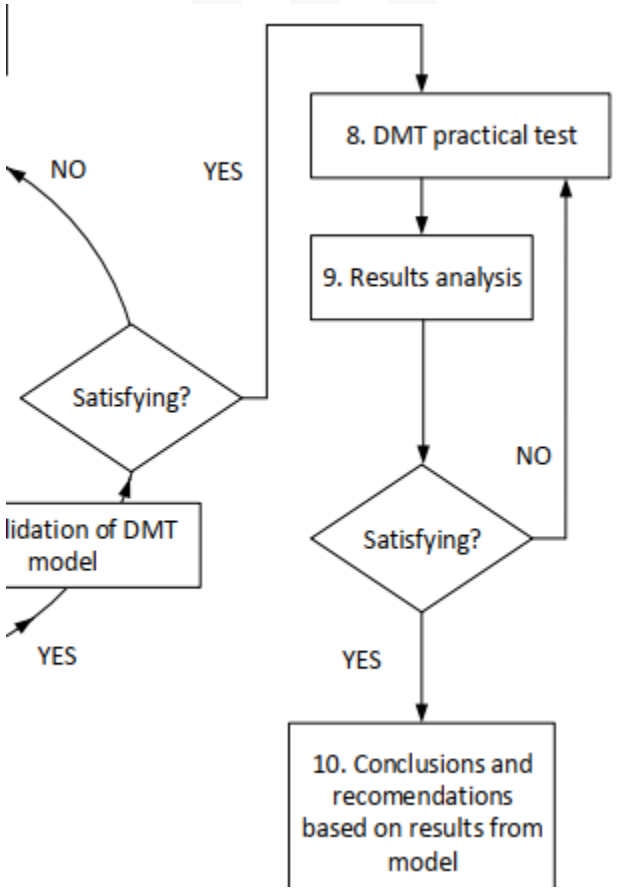
DMT

Flowchart of DMT modelling approach



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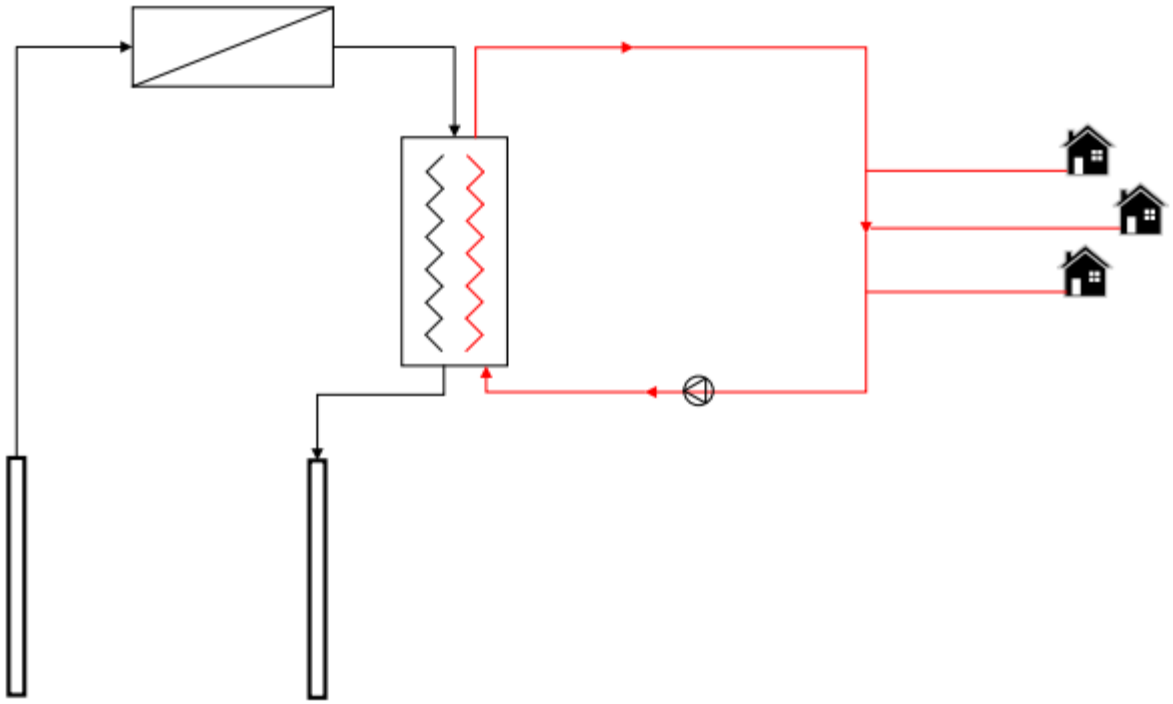
DMT – production modes

Only heat production mode



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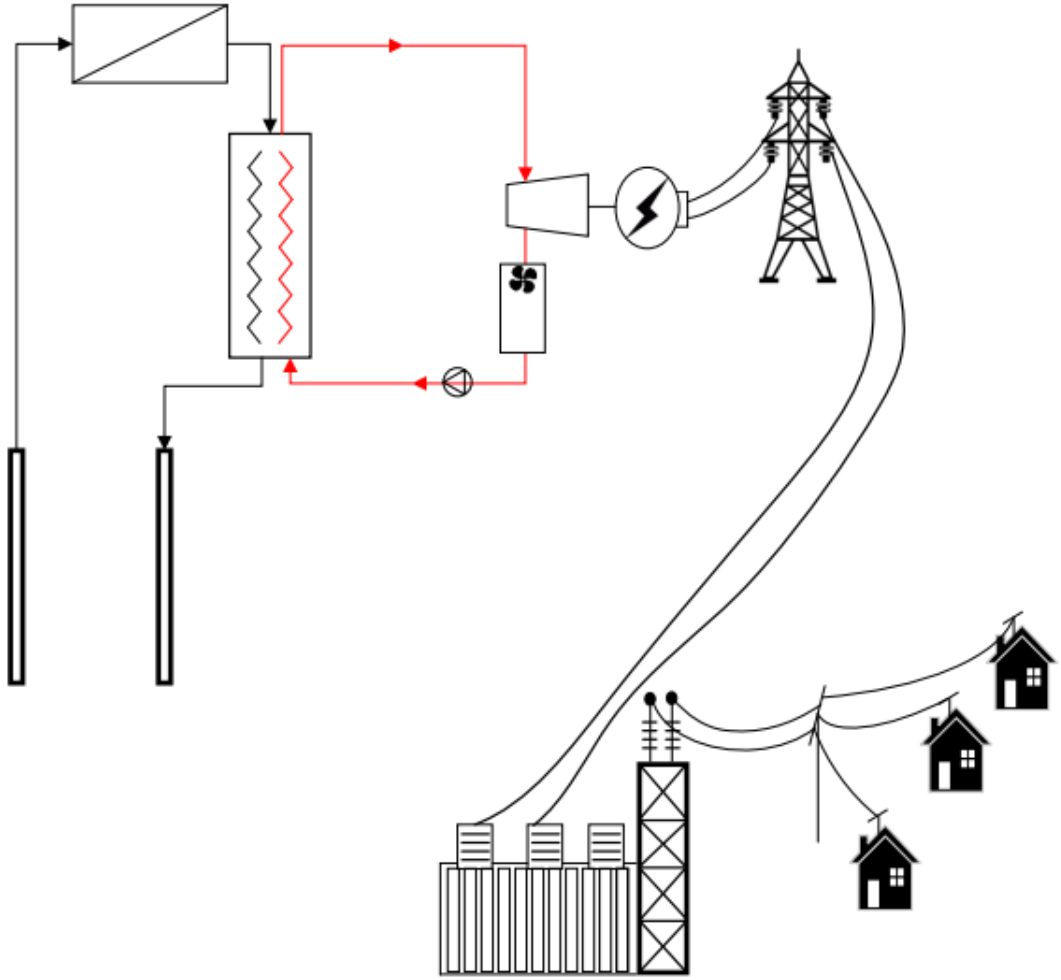
DMT – production modes

Only electricity production mode



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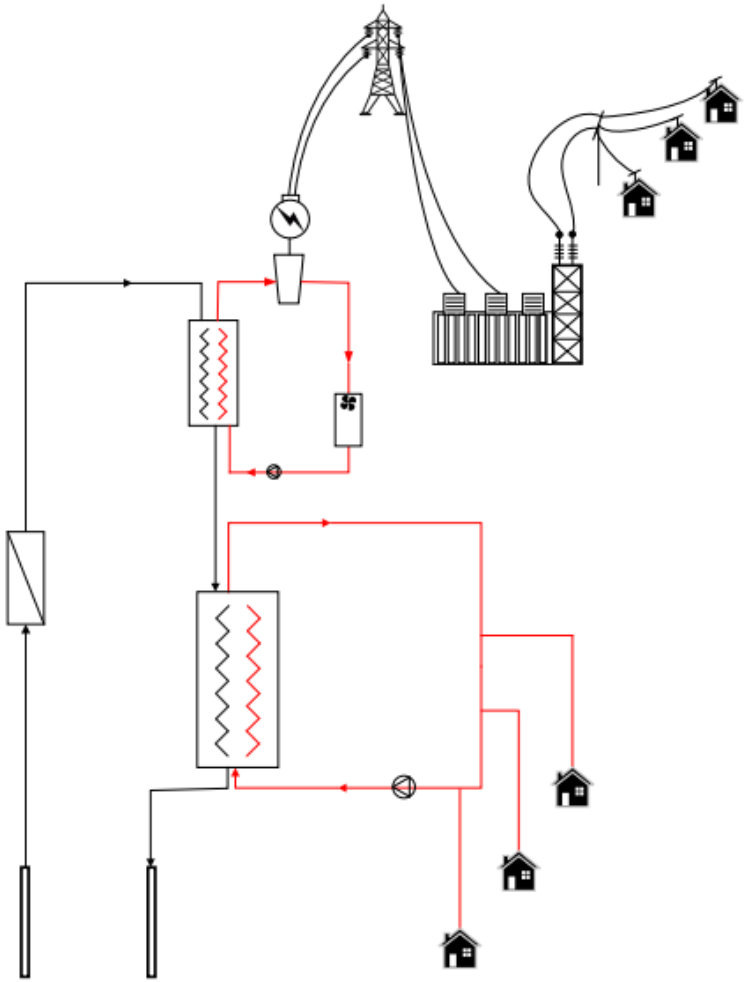
DMT – production modes

CHP production in series - topping production mode



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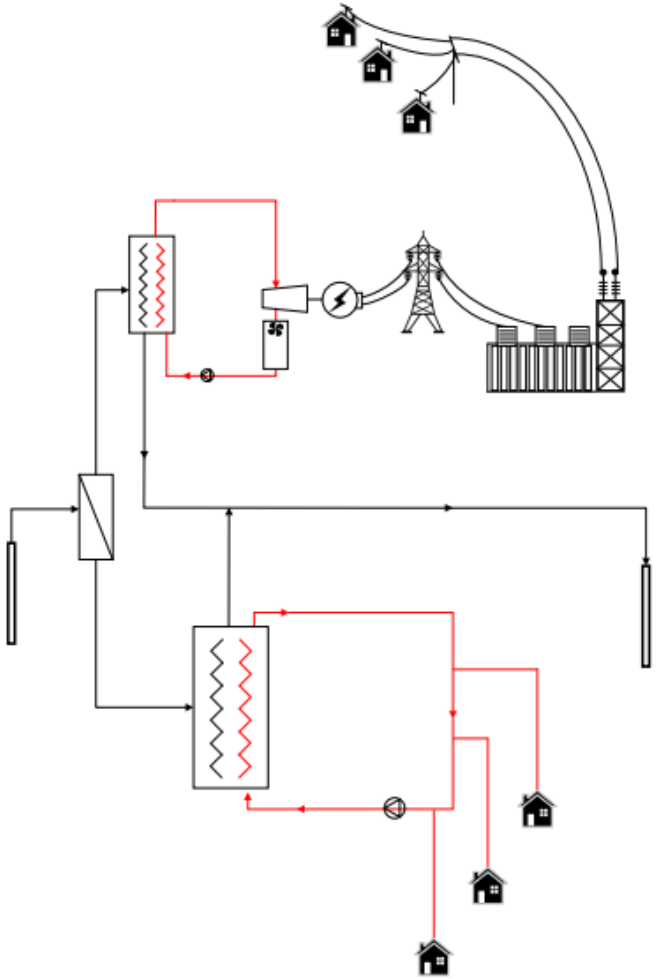
DMT – production modes

CHP production in parallel



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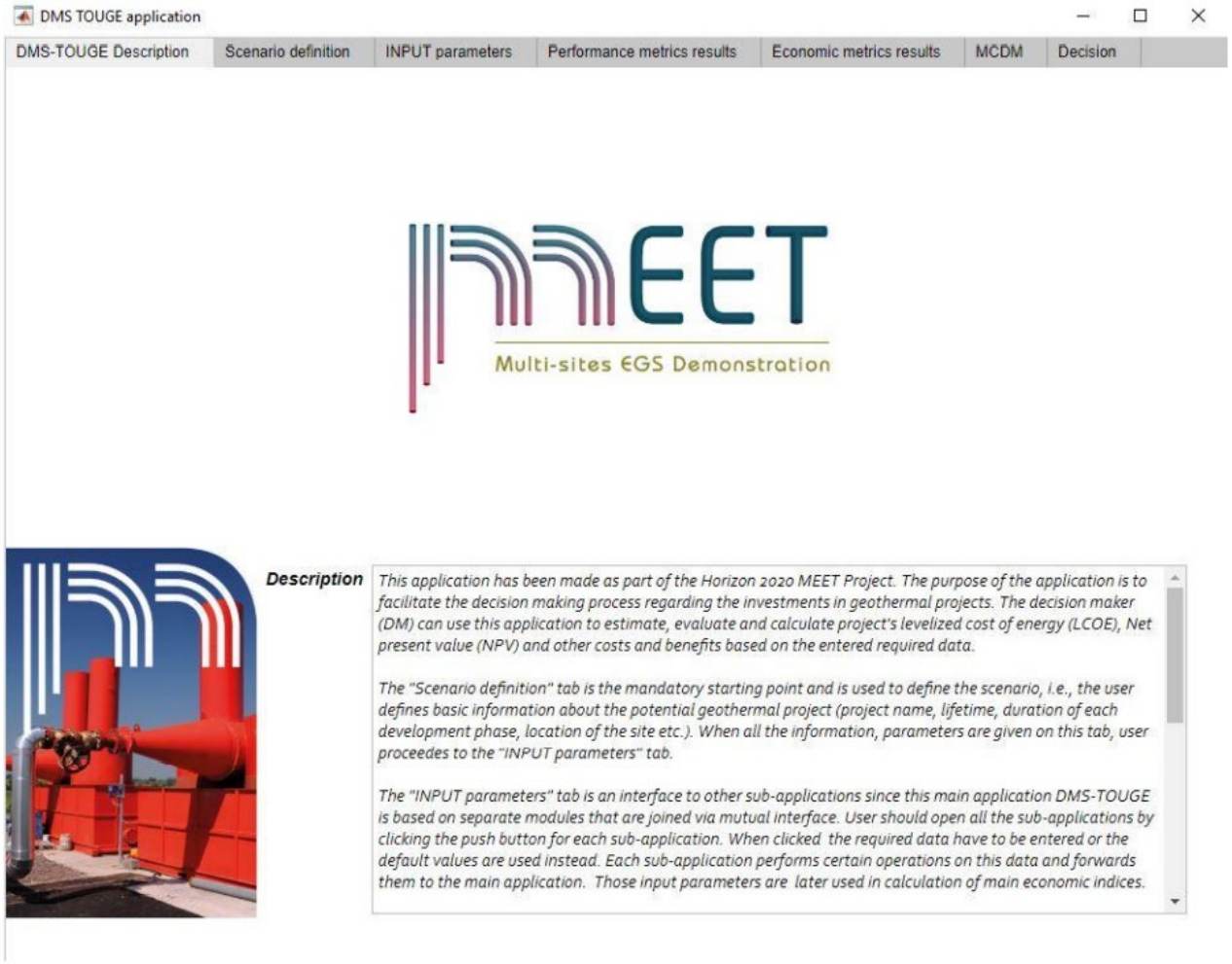
DMT

APPLICATION LAYOUT



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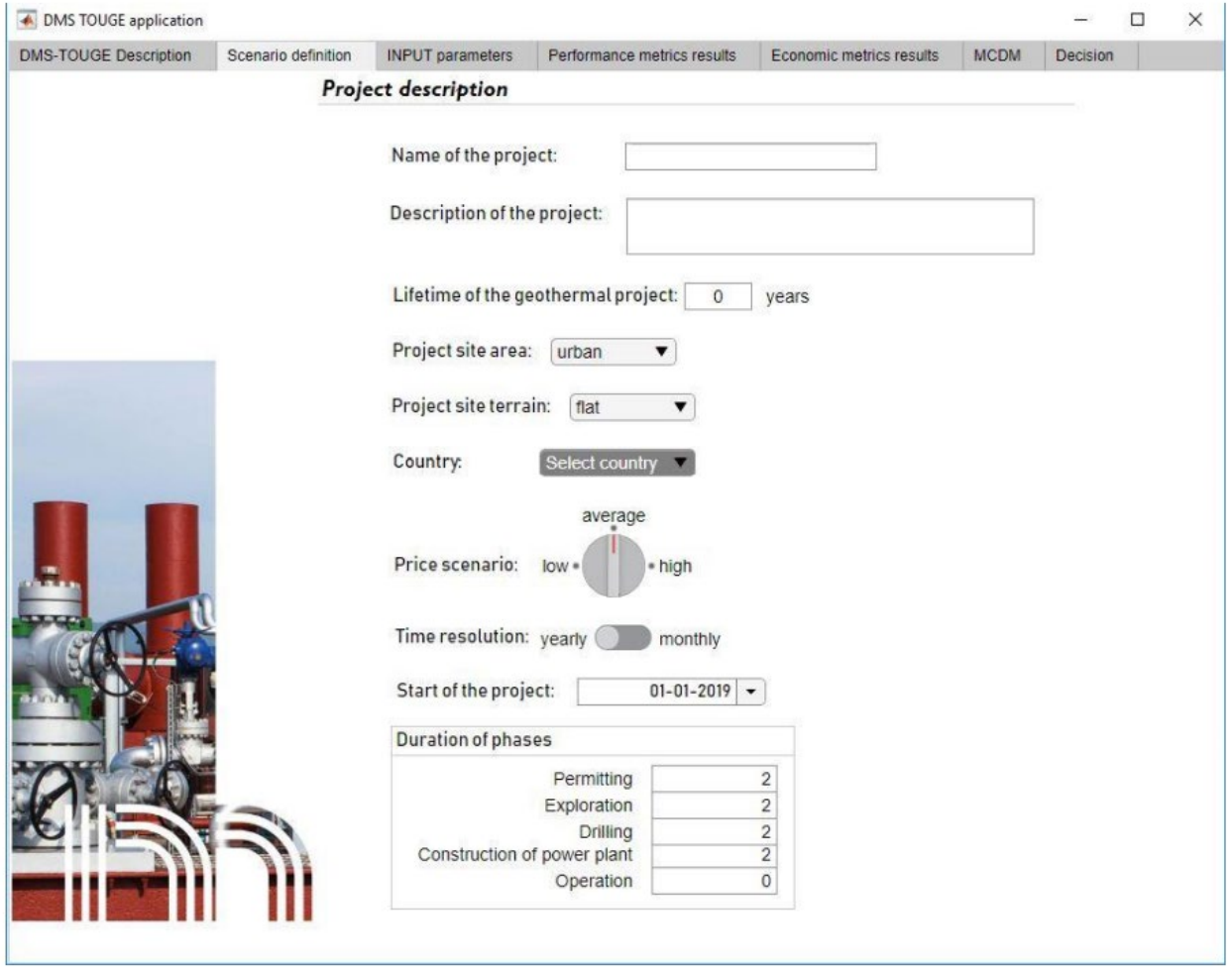
DMT

Scenario definition



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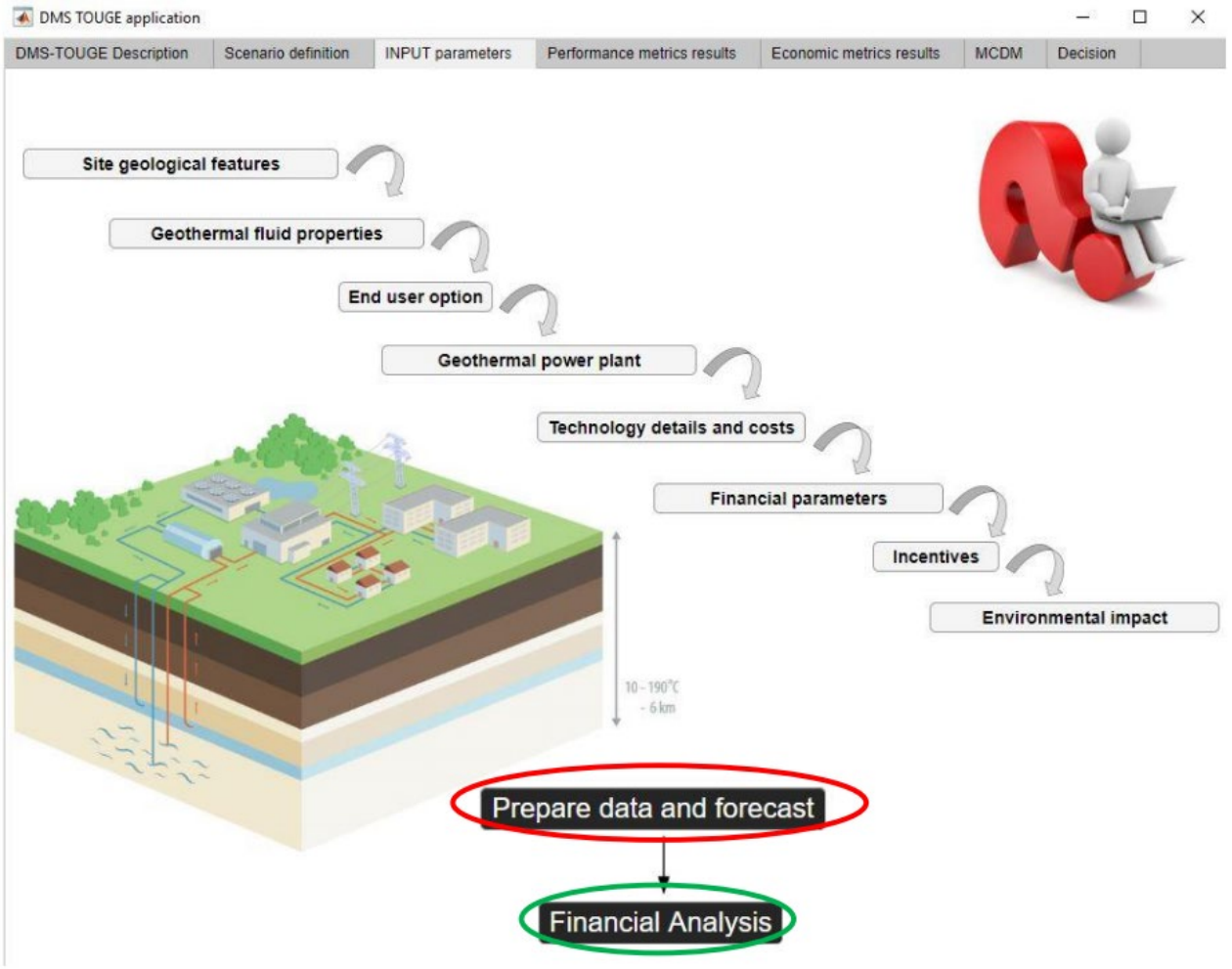
DMT

INPUT parameters



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DMT

MCDM module

Criterion	Description	Unit
$x_{i,1}$	Installed capacity	p.u.
$x_{i,2}$	Equivalent heat flow	$m^2/h°C$
$x_{i,3}$	Theoretical maximum efficiency	%
$x_{i,4}$	Geothermal gradient	°C/100m
$x_{i,5}$	Fluid temperature at the wellhead	°C
$x_{i,6}$	Corrosion and scaling	-
$x_{i,7}$	Distance from the grid	km
$x_{i,8}$	Load factor	-
$x_{i,9}$	Environmental impact	Average of all sub-criterions
$x_{i,10}$	Social impact	Average of all sub-criterions
$x_{i,11}$	sLCOE	p.u.
$x_{i,12}$	Global efficiency	%

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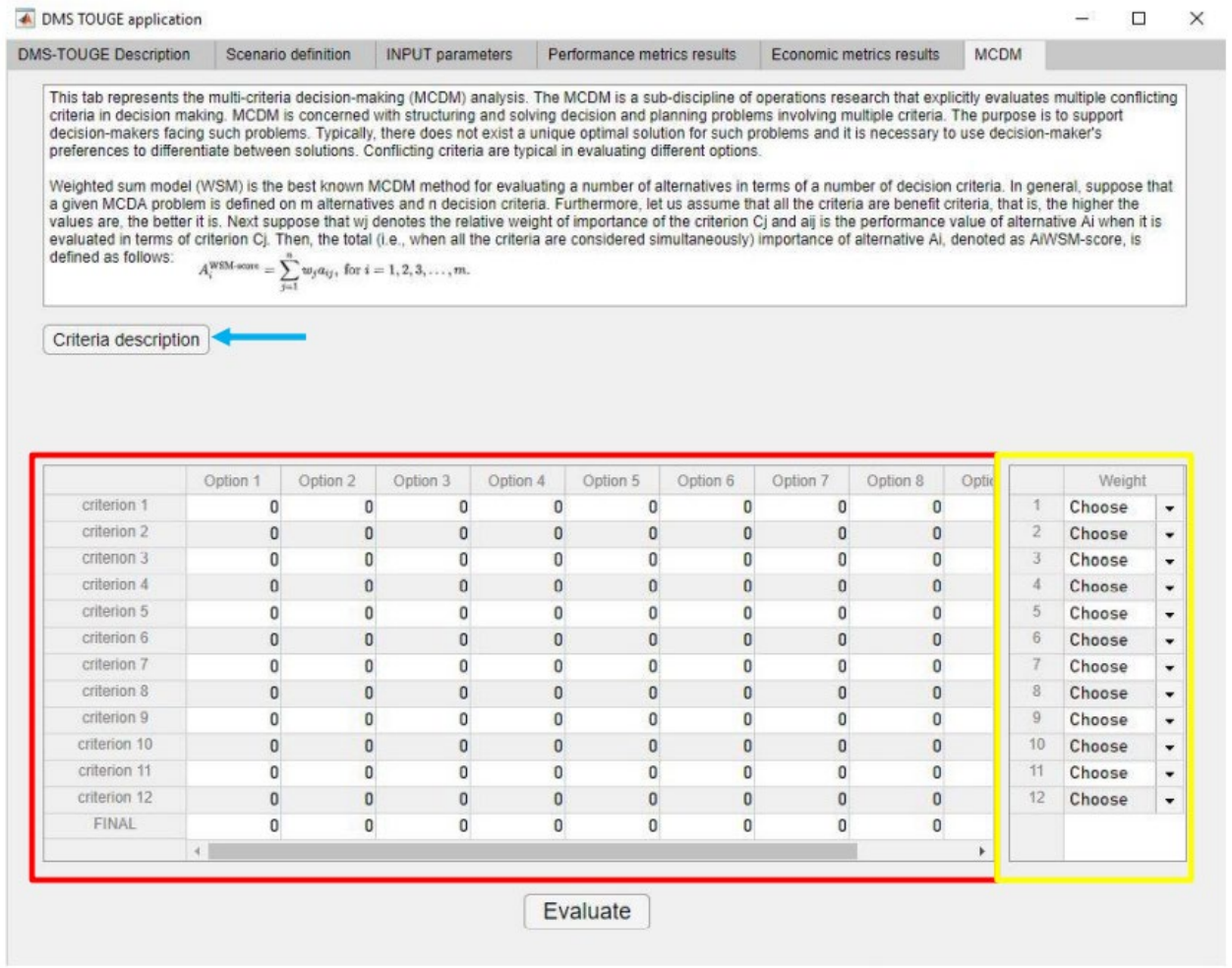
DMT

MCDM module



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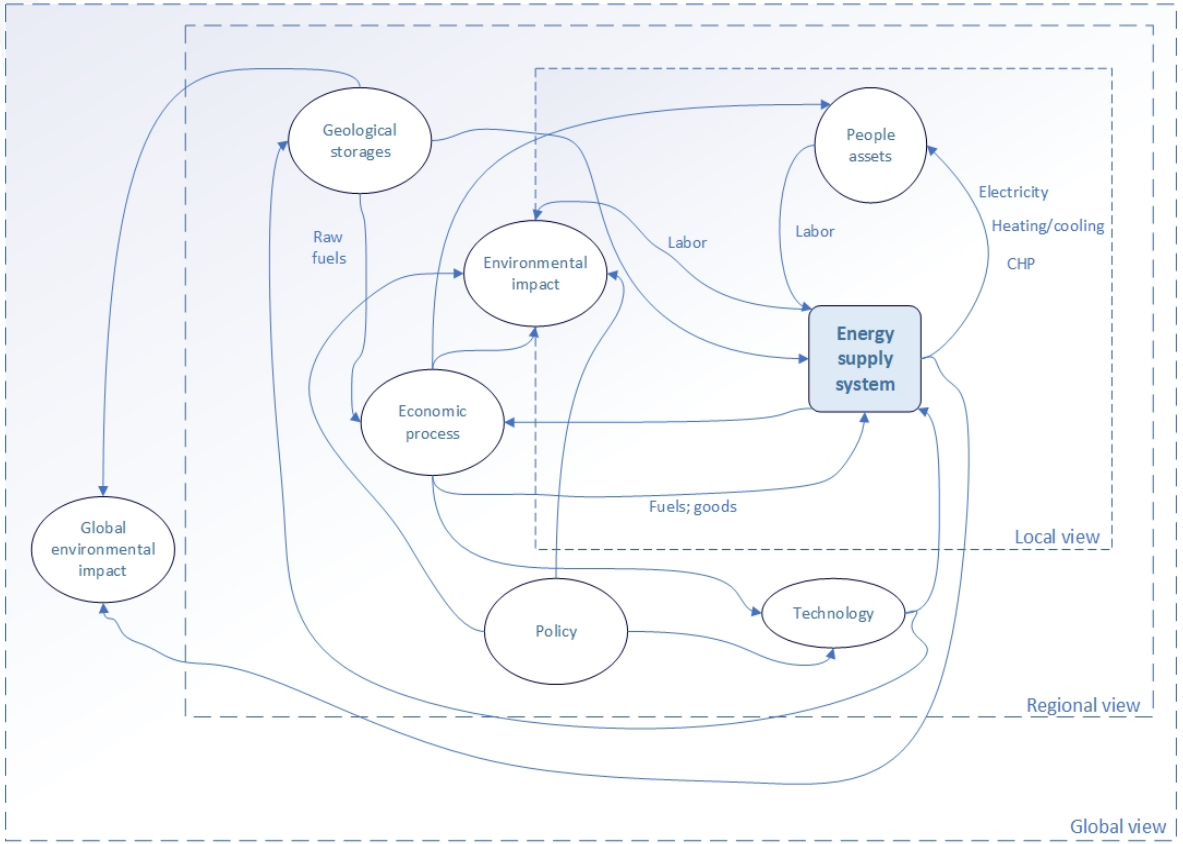
MCDM

Energy projects planning

Balanced techno-socio-economic evaluation → difficult to accomplish because of many **conflicting criteria and their interactions**

Rational **decision-making (DM)** in energy supply system is **difficult and complex**

Multi-criteria decision analysis (MCDA) - operational evaluation and decision support approach suitable for addressing complex problems featuring *high uncertainty*, *conflicting objects*, *different forms of data* and *information*, *multi interests* and *perspectives*



Complex interactions of energy system

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MCDM

MCDA process in energy decision-making

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Criteria selection

Decision makers are often faced with multiple *quantifiable* and *non-quantifiable* criteria

Technical	•Efficiency •Capacity factor •……
Economic	• Investment cost; O&M cost • Net present value (NPV) • ……
Environmental	•Avoided CO2 emissions •Land use •……
Social	• Social acceptability • Job creation • ……

Typical evaluation criteria of energy supply systems

Geological setting	•permeability •Porosity •……
Technical	•Efficiency •Capacity factor •……
Economic	• Investment cost; O&M cost • Net present value (NPV) • ……
Environmental	•Avoided CO2 emissions •Land use •……
Social	• Social acceptability • Job creation • ……

Typical evaluation criteria of geothermal energy project

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AHP

Analytical Hierarchy Process

Provides objective mathematics to process the inescapably subjective and personal preferences of an individual or a group in making a decision

Synthesizing criteria method that calculates ratio-scaled importance of alternatives through **pairwise comparison** of criteria, sub-criteria and alternatives

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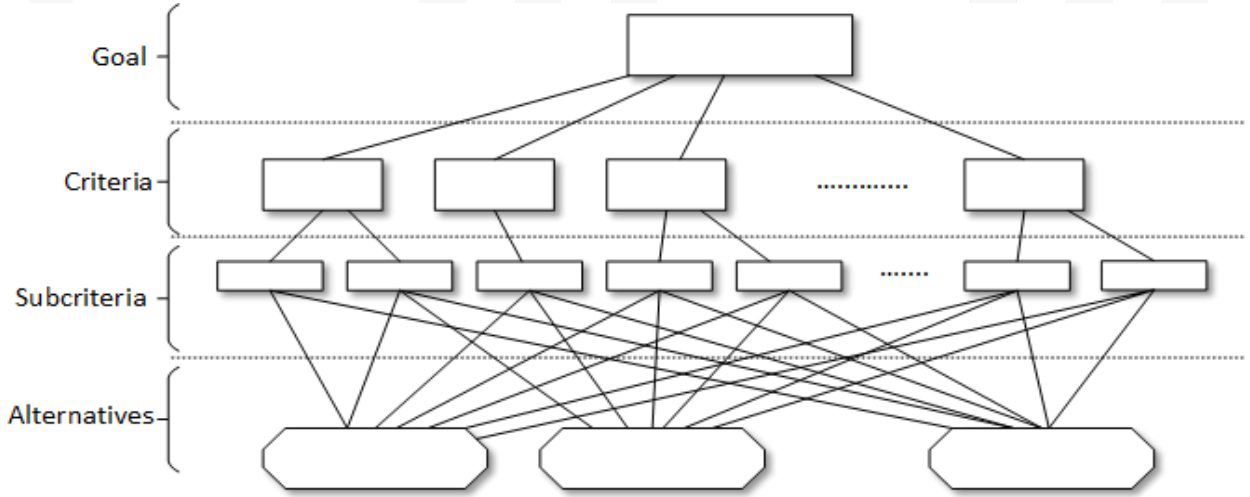
AHP

Analytical Hierarchy Process

Decomposition of a complex problem into a hierarchy (consist of several levels)



$$A = \begin{bmatrix} 1 & a_{1,2} & \cdots & a_{1,n} \\ a_{2,1} & 1 & \cdots & a_{2,n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n,1} & a_{n,2} & \cdots & 1 \end{bmatrix}$$

Importance weight value, $a_{i,j}$	Value explanation
1	Two factors are equal in importance
2	1st factor is equal to weakly more important than the 2nd factor
3	1st factor is weakly more important than the 2nd factor
4	1st factor is moderate to strongly more important than the 2nd factor
5	1st factor is strongly more important than the 2nd factor
6	1st factor is strong to very strongly more important than the 2nd factor
7	1st factor is very strongly more important than the 2nd factor
8	1st factor is very strongly to extremely more important than the 2nd factor
9	1st factor is extremely more important than the 2nd factor
1/9, 1/8, …, 1/2	The reciprocal number expresses an opposite judgment

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AHP SURVEY

CREATED CASE STUDY

28 criteria (influencing factors) were accounted

3 different alternatives – only electricity, direct usage and CHP

6 different points of view

	Industry	Educational institution	Research and technology organistaion (RTO)	Small- and medium-sized enterprises (SME)	Local community	Other	TOTAL
Number of respondents (persons)	4	10	7	13	1	2	**37**
Number of respondents with CR < 0.15	4	9	5	13	1	2	**34**
Consistency passing ratio (%)	100.00	90.00	71.43	100.00	100.00	100.00	**91.89**

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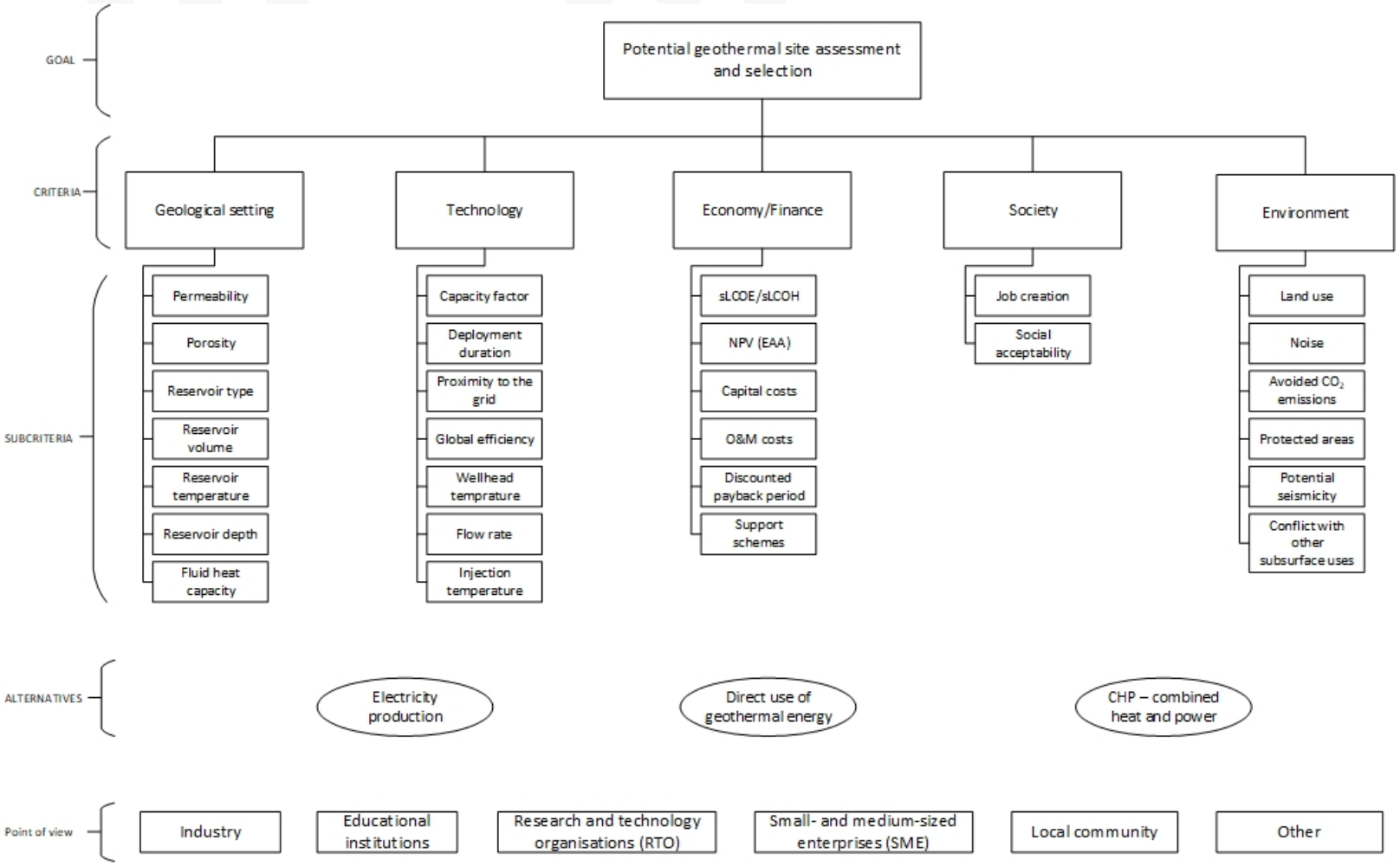
AHP SURVEY

CREATED CASE STUDY



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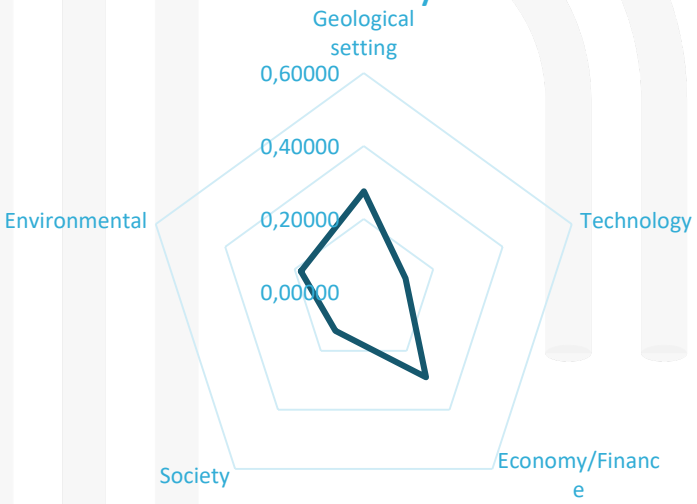
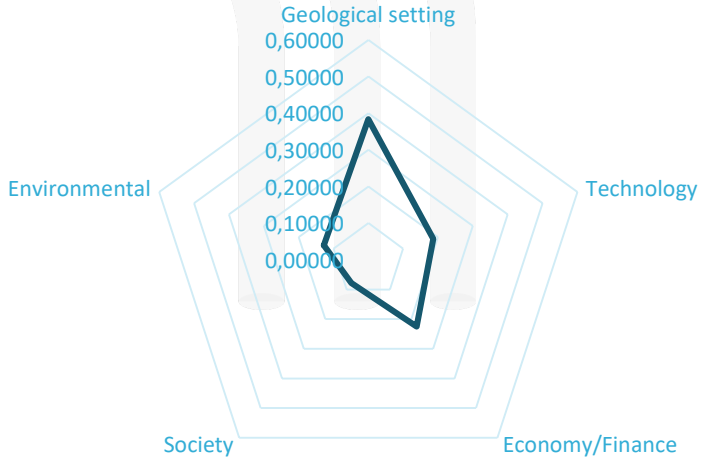
AHP SURVEY

Results

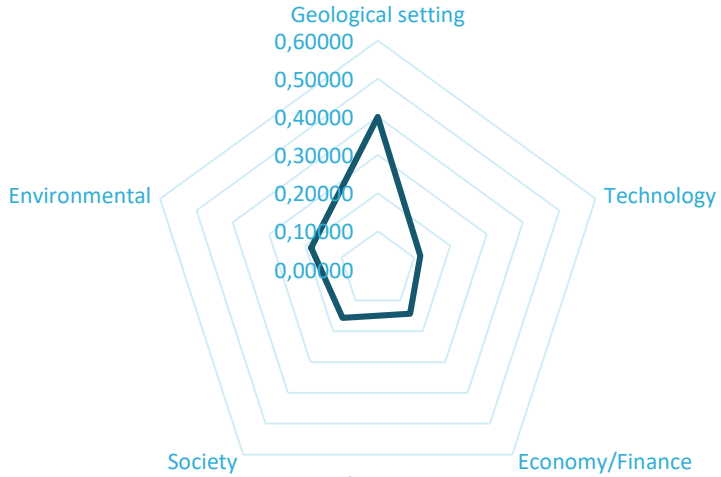
Industry



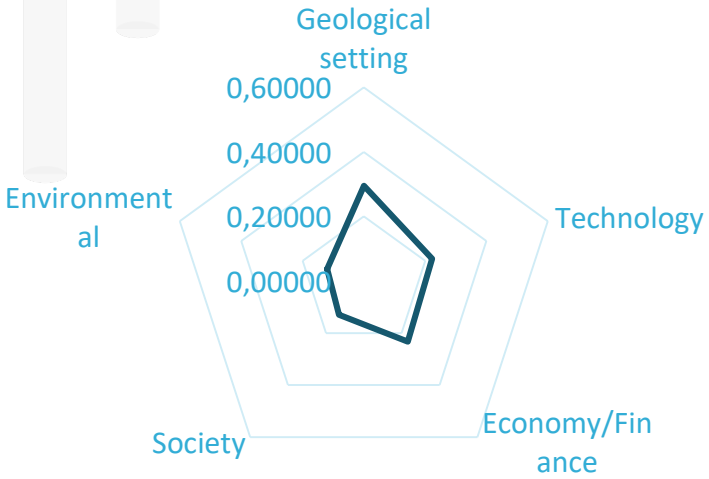
Educational institution



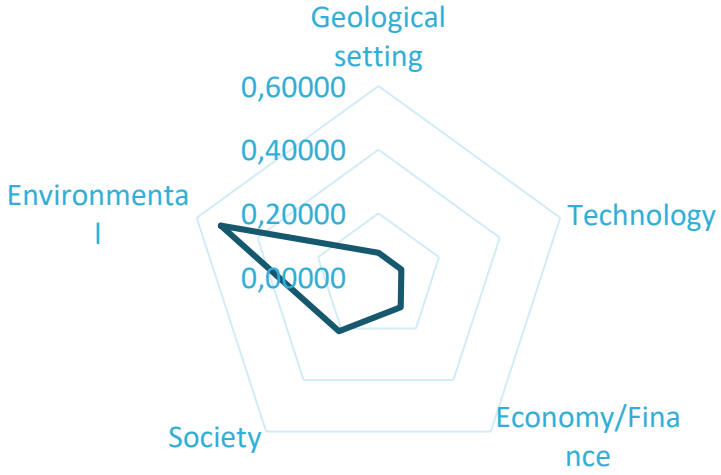
RTO



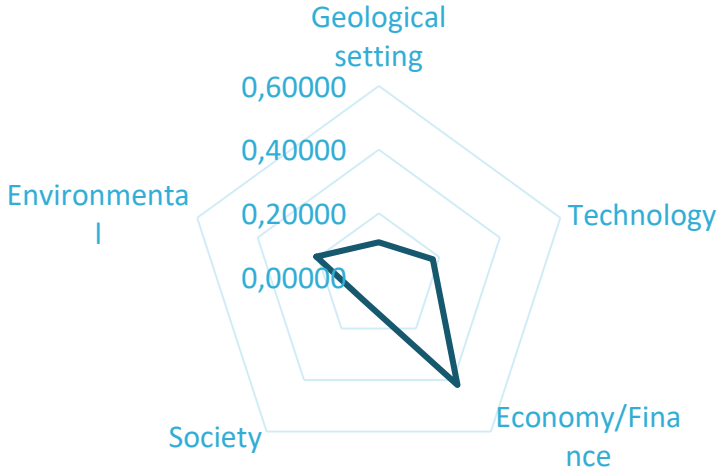
SME



Local community



Other



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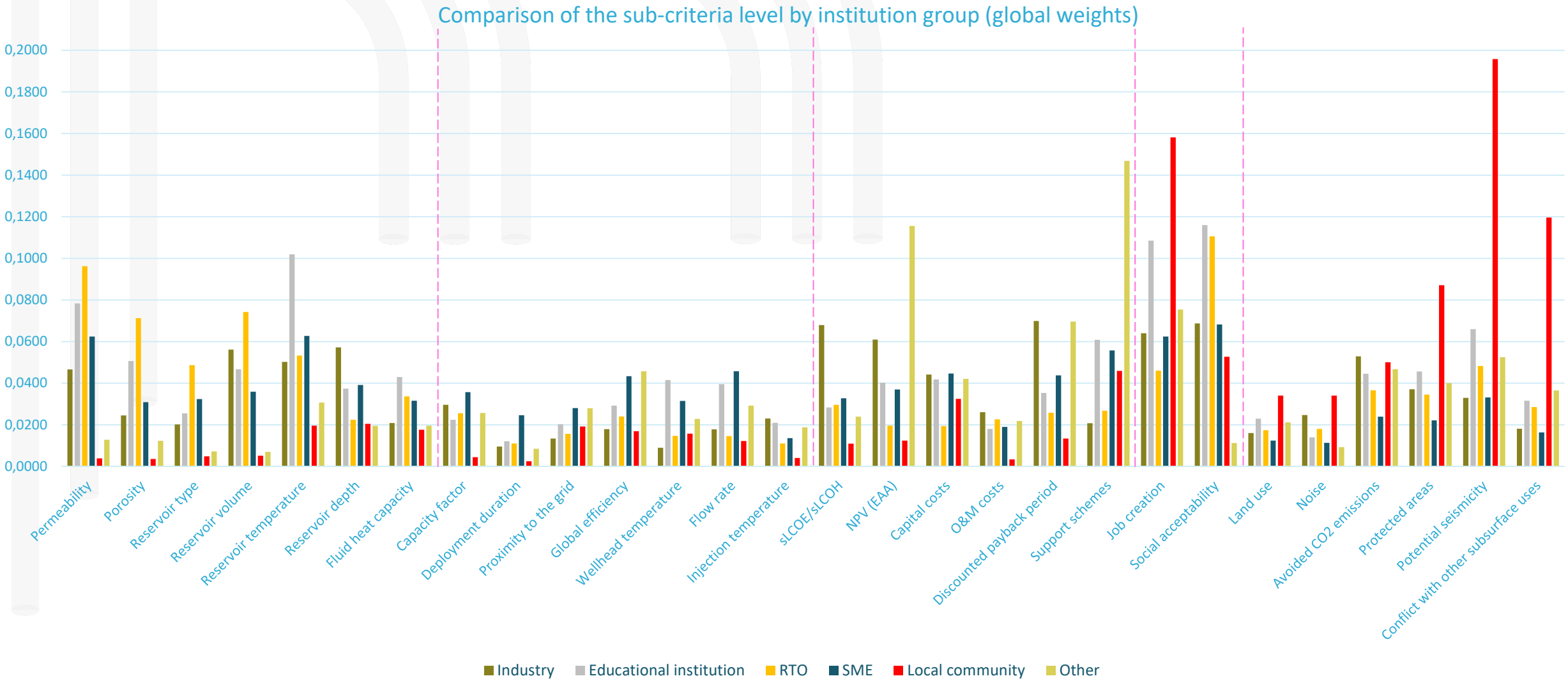
AHP SURVEY

Results



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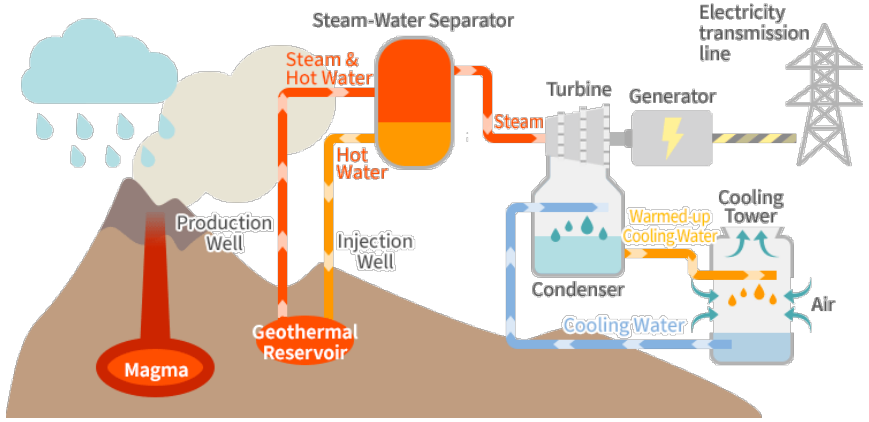
O2W

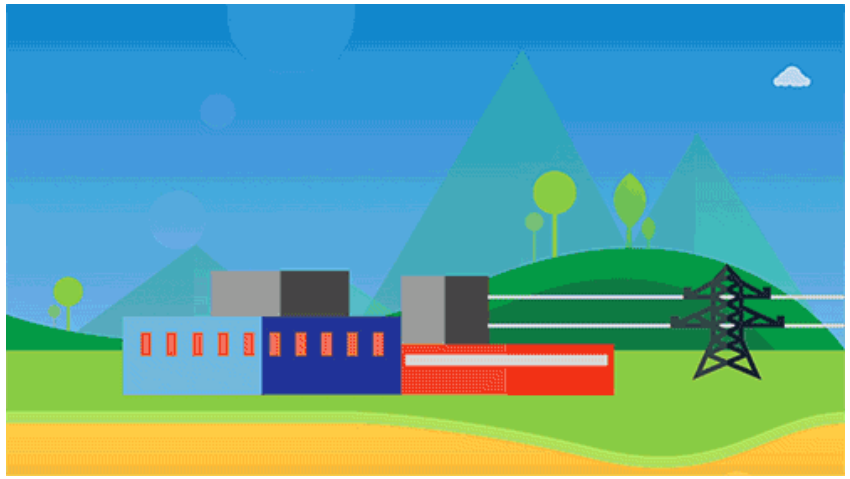
Methodology for an economic evaluation of end-of-life conversion

Comparison of different options for geothermal energy exploitation

Comparison of petroleum asset converted in a geothermal asset which produces energy

- Use of already developed hydrocarbon reservoirs with high temperature and water-cut
- Avoiding the capital cost by using existing infrastructure
- Avoiding the cost of deccomissioning of oil and gas wells





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Methodology and scenarios

Input data for each scenario

Properties of geothermal fluid and reservoir

Geographical location of the wells

Energy demand

CAPEX & OPEX

Emission factors

Share of each fossil fuel in total fossil fuel energy generation for each EU country

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Methodology and scenarios

Comparison of the scenarios based on

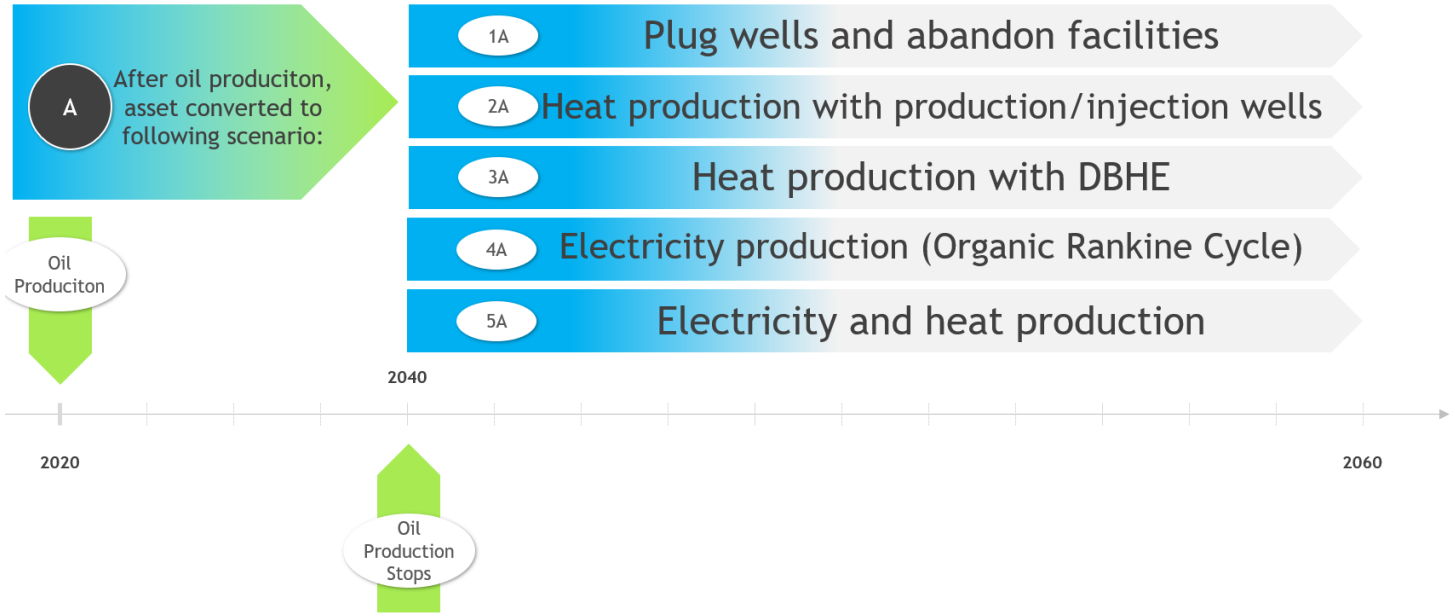
Production quantities

Net present value

LCOE & LCOH

Energy efficiency

Carbon intensity



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Q & A

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Thank you very much for your attention

Geothermal Winter School 2021

MEET
Multi-sites EGS Demonstration

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