INTEGRATED DECISION SUPPORT TOOL FOR OPTIMAL EXPLOITATION OF GEOTHERMAL RESOURCES. A THERMODYNAMIC, THERMO-ECONOMIC, AND ENVIRONMENTAL APPROACH

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WP9 GAA– UNIVERSITY OF FLORENCE (UNIFI)

LEAP-RE STAKEHOLDER FORUM
KIGALI, 10-13 OCTOBER 2023

LEAP-RE
Long-Term Joint EU-AU Research and Innovation Partnership on Renewable Energy

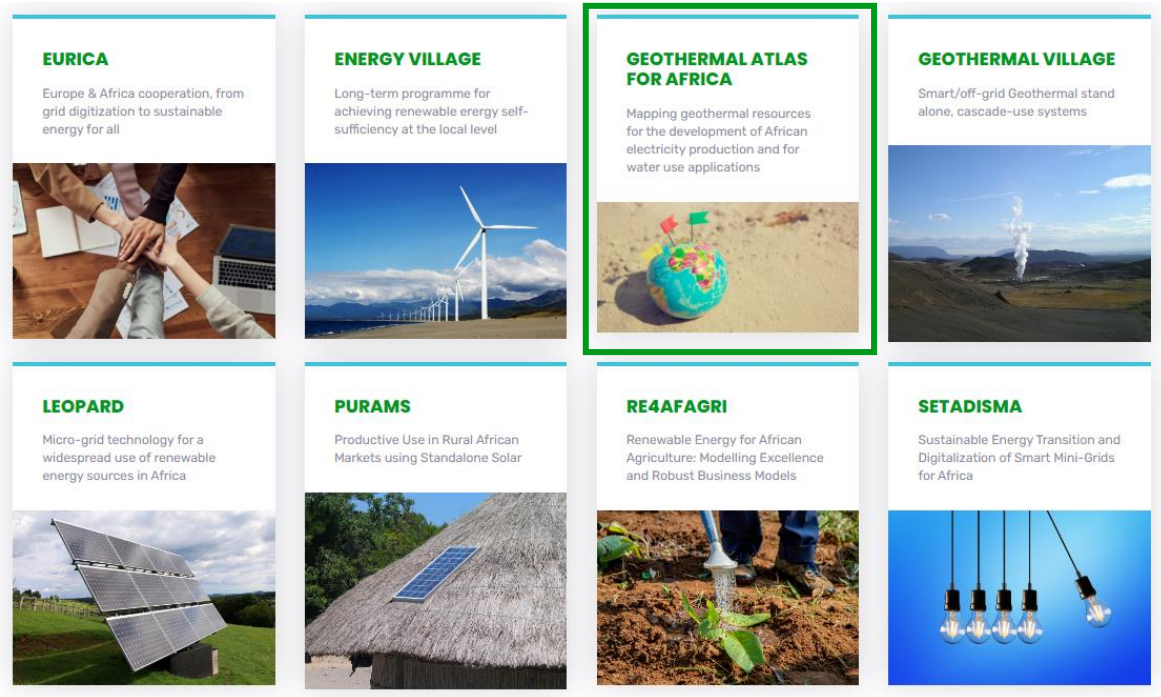
The LEAP-RE project has received funding from the European Union's Horizon 2020 Research and Innovation Program under Grant Agreement 963530.

Introduction

LEAP – RE project

WP9 - Geothermal Atlas for Africa

Location and characteristic of **low to high enthalpy geothermal** resources for the development of African **electricity production**, plus a range of **direct heat/cold use applications**



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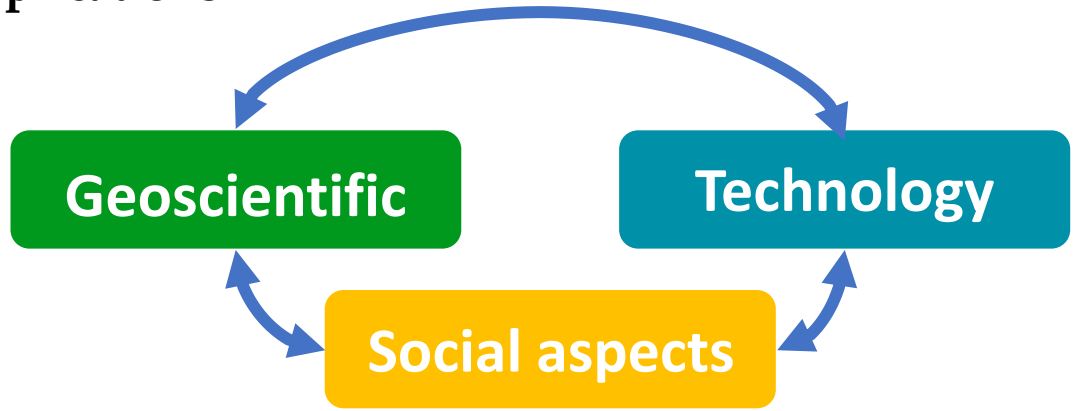
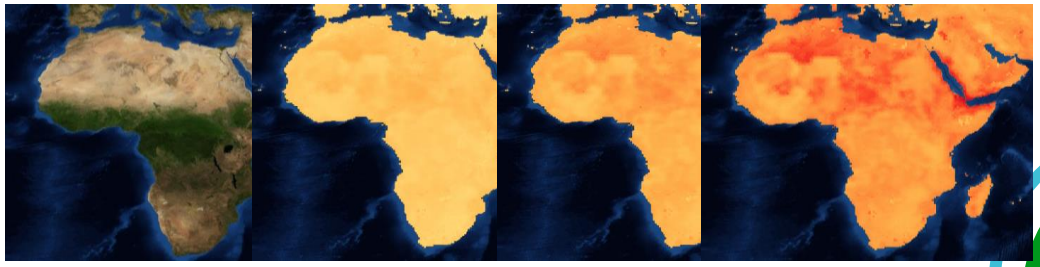
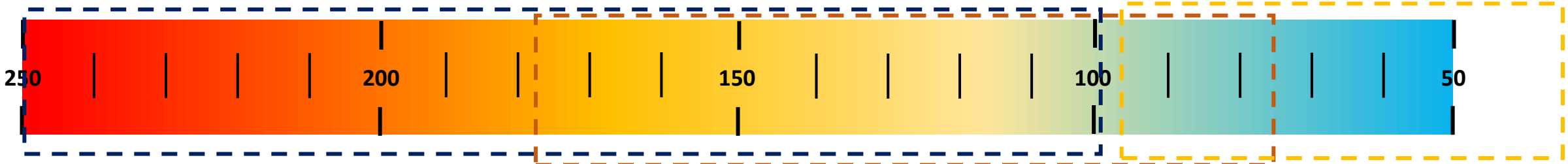




Context Analysis

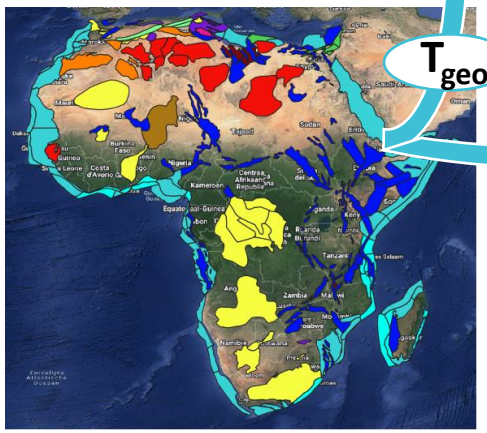
Development of a **decision-making tool** to define which is the best system for the exploitation of geothermal resources in terms of **thermodynamic performance** , **economic** costs and **environmental impacts**



ELECTRICITY PRODUCTION

HEAT / COLD PRODUCTION

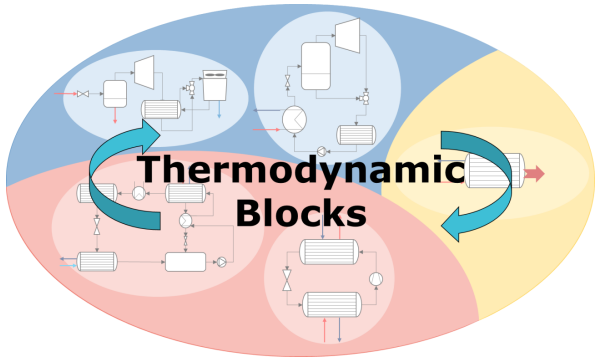
DIRECT USE



T_{geo}

T_{geo}
m_{geo}
x_{geo}

Geothermal Atlas for Africa



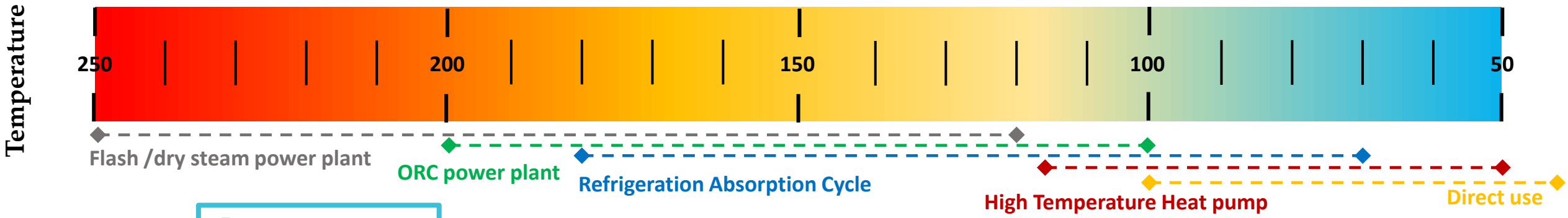
Metamodel

Thermodynamic Performance

Economic cost

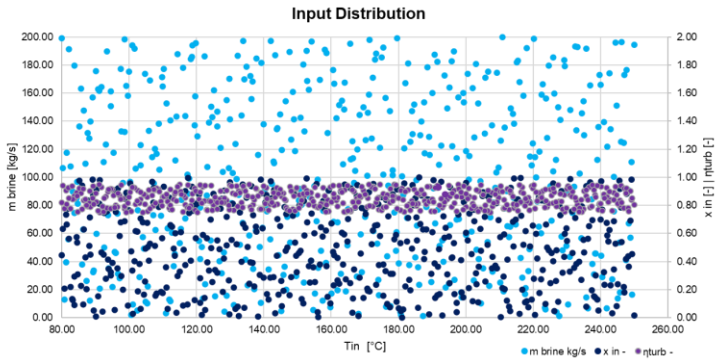
Environmental Impact

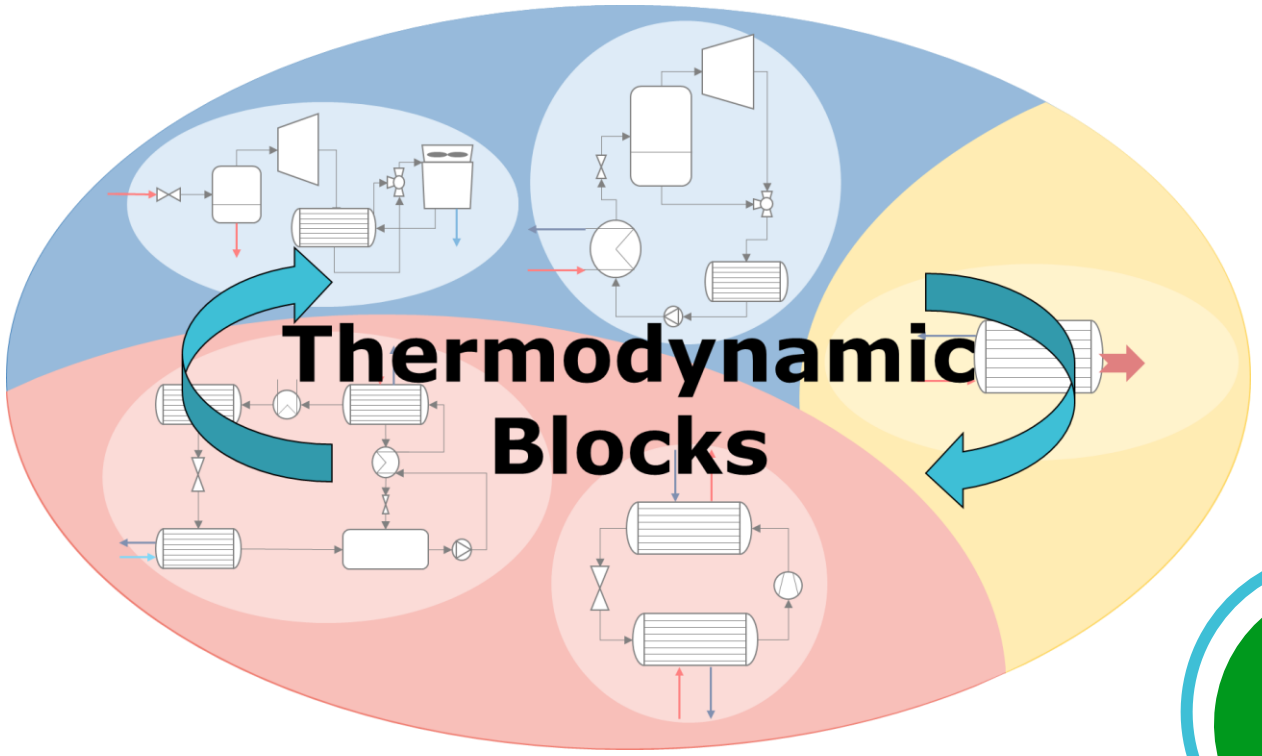
Methodology



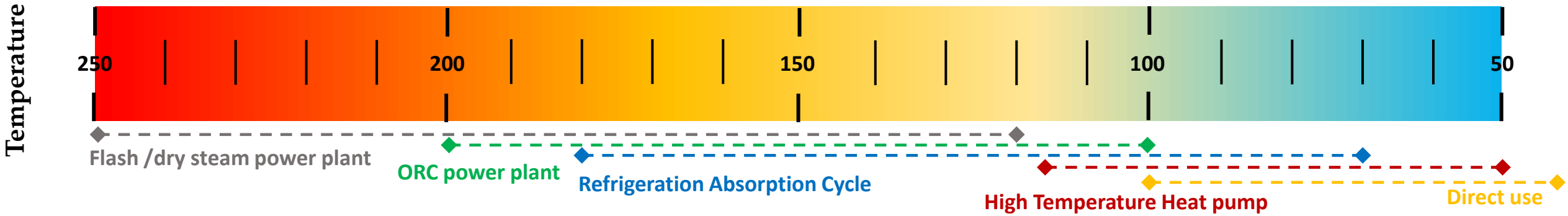
Input parameter

Parameter	Range	Units
T_{geo}	30-200	° C
$\dot{m}_{geo}$	1-200	kg/s
x_{geo}	0-1	-





Methodology



ELECTRICITY PRODUCTION:

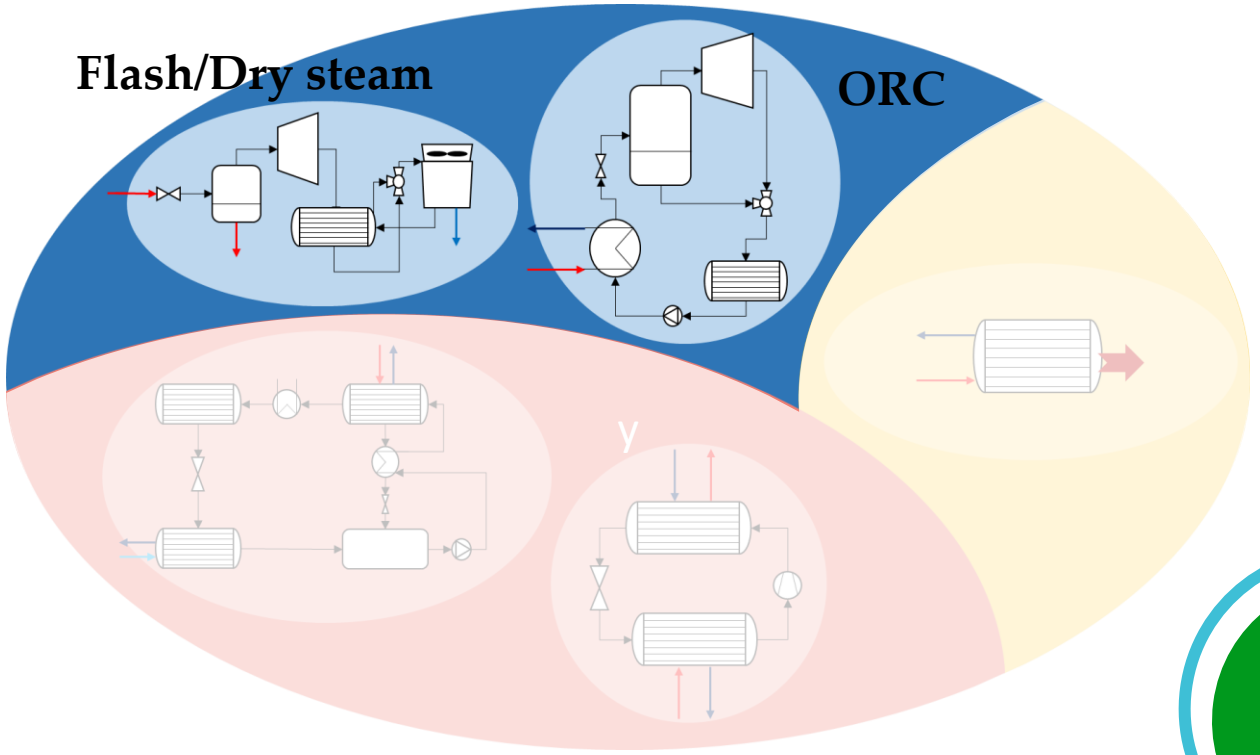
- **Flash/Dry steam power plant**
- **Binary Organic Rankine Cycle ORC power plant**

HEAT / COLD PRODUCTION:

- **High Temperature Heat Pump HTHP.**
- **Refrigerator absorption system R-ABS(absorption water-ammonia).**

DIRECT USE:

- **Heat Exchangers HE.**



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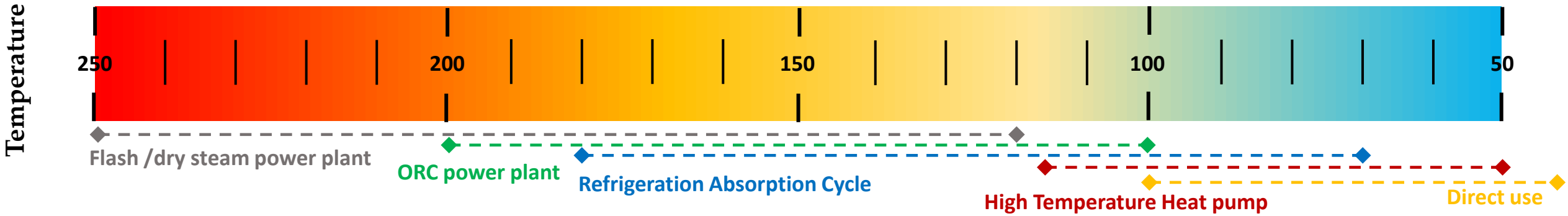

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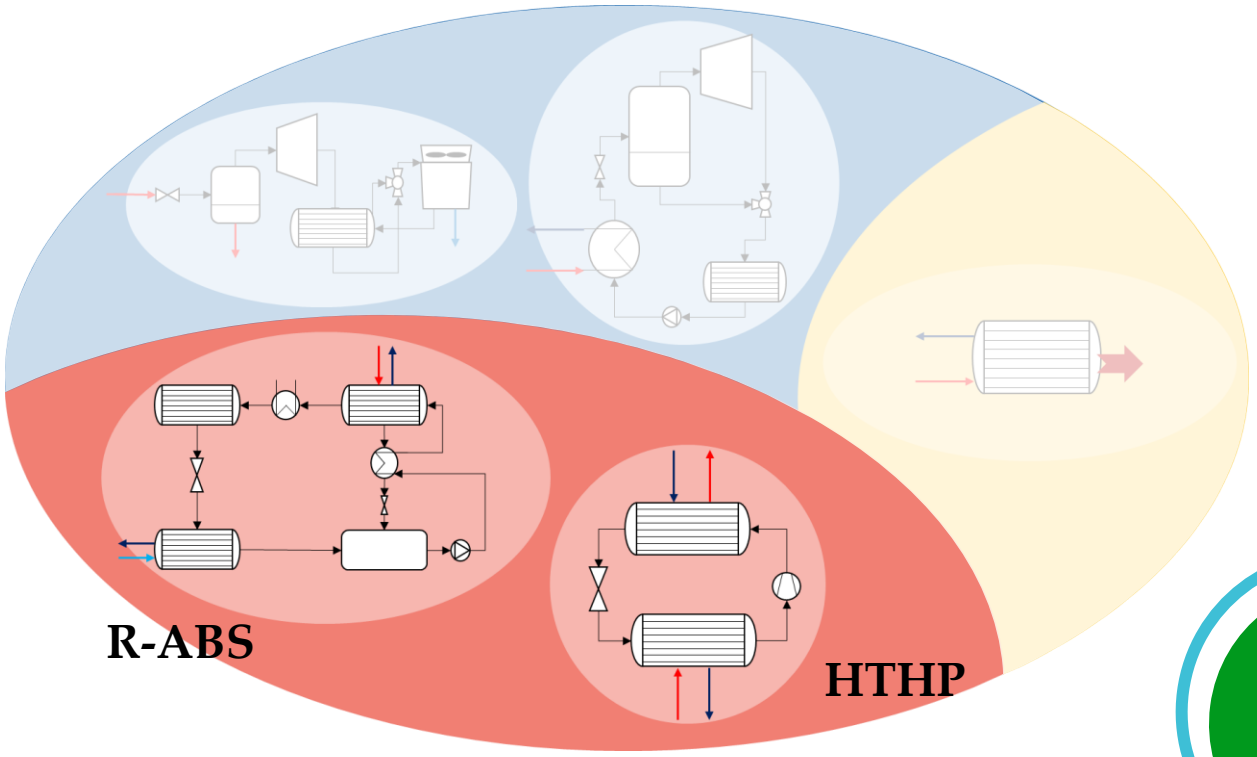

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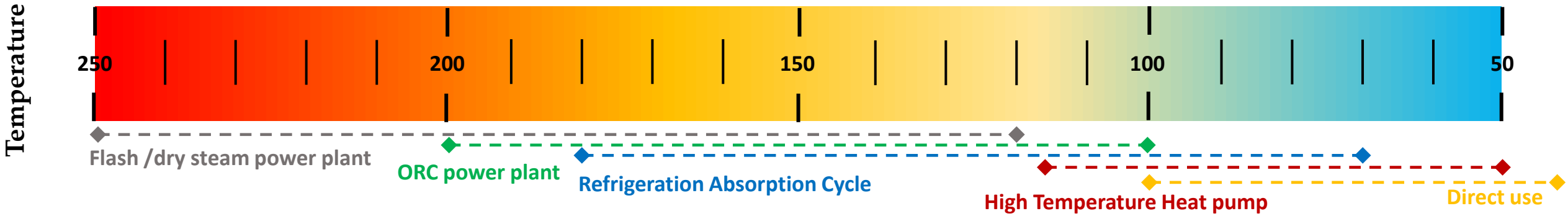

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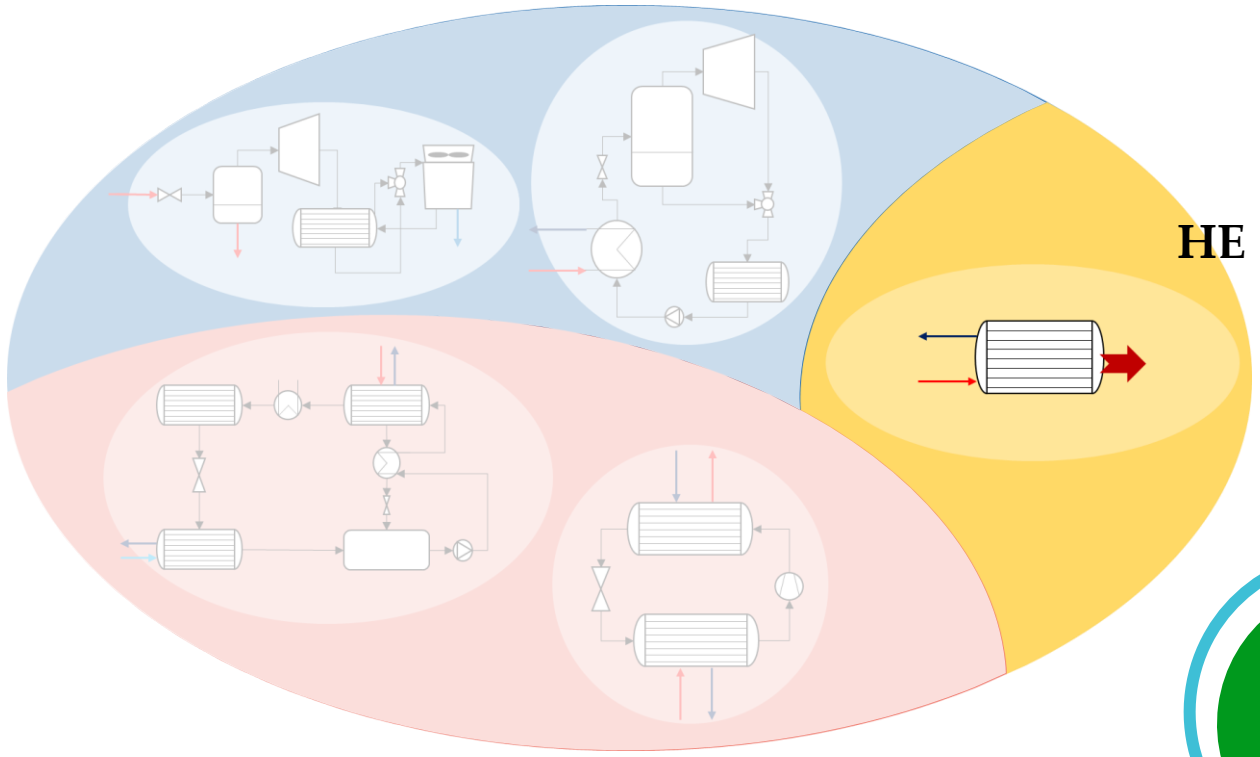
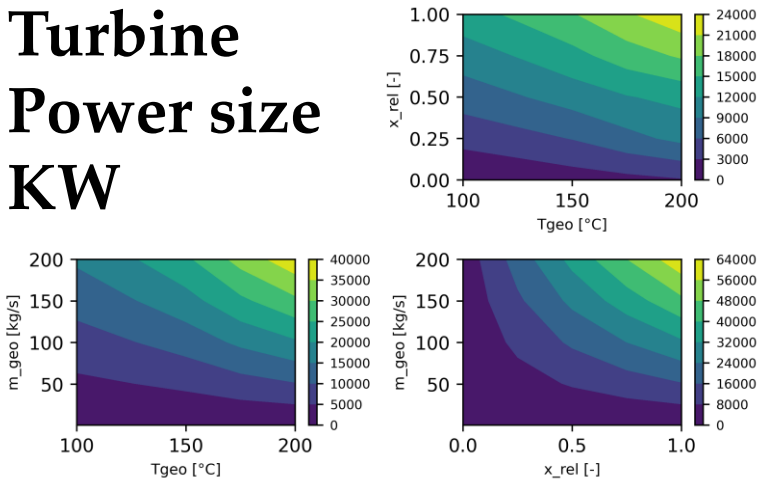


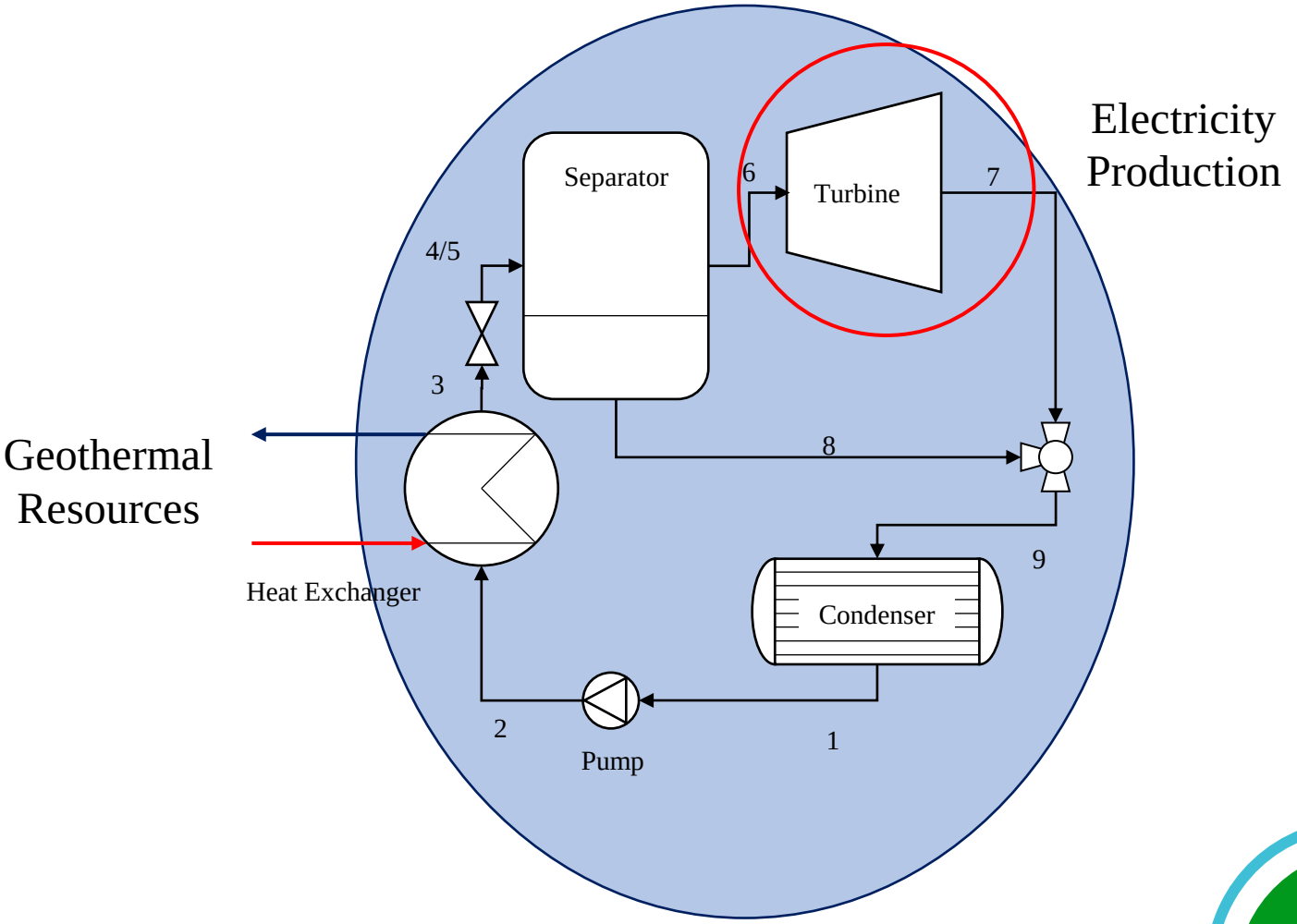
Methodology

Thermodynamic performance

Evaluation of **wide range input**, it has been obtained a network of output conerning **system sizing** and **resource condition** (Installed Power, heat level, T_{out}, m_{out}, x_{out},….). Interpolating the obtained ouputs enables us to generate **metamodels**.

Turbine Power size KW





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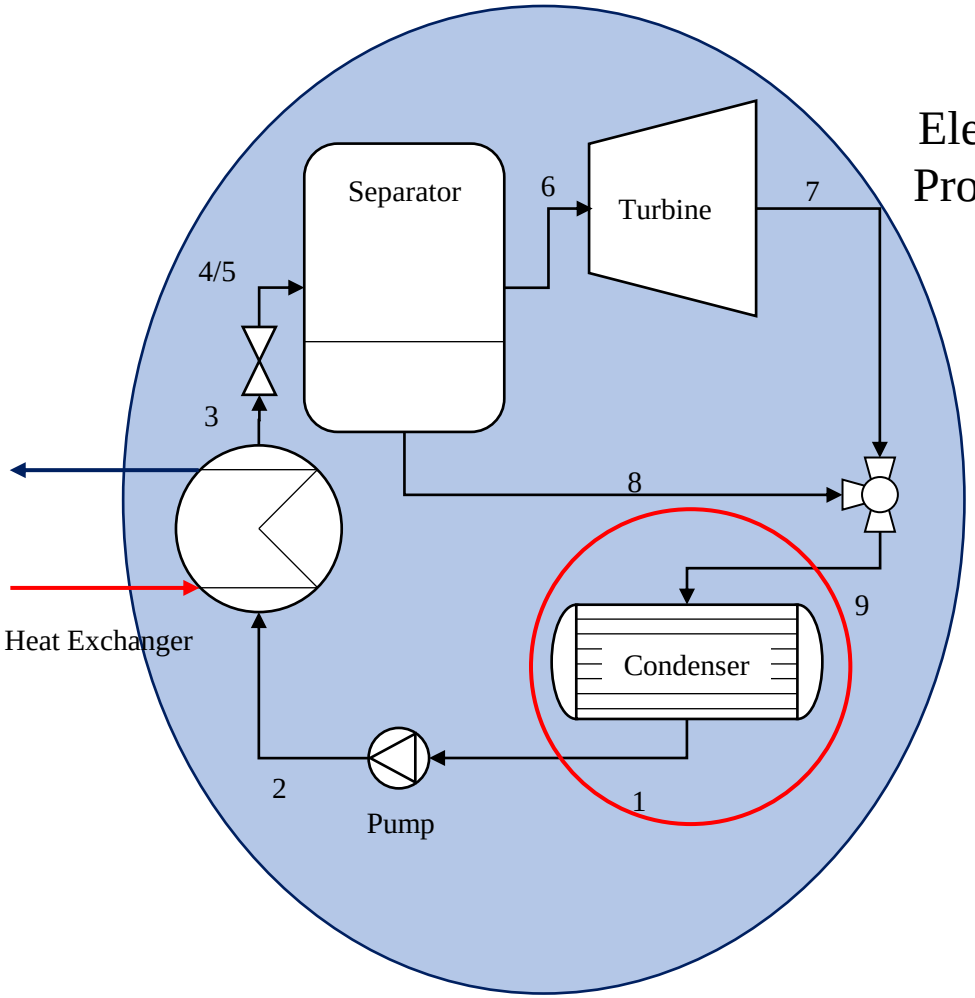
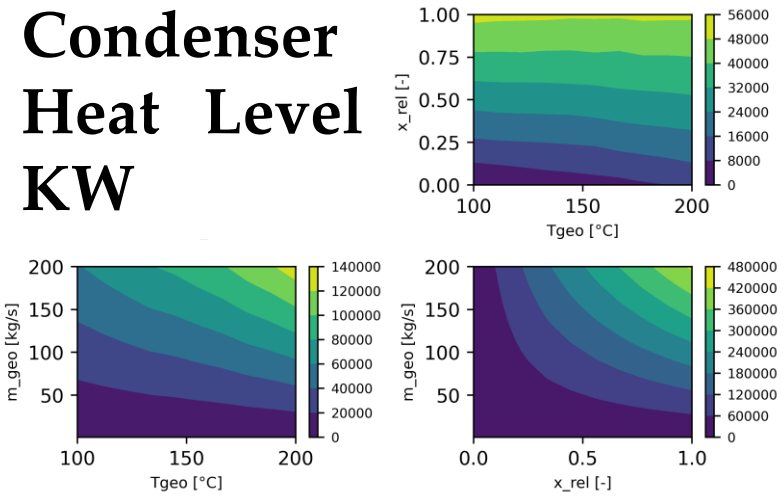


Condenser Heat Level KW



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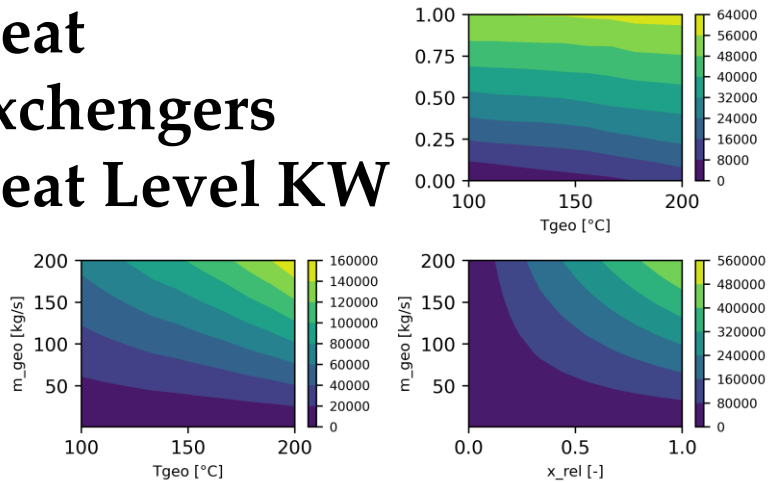
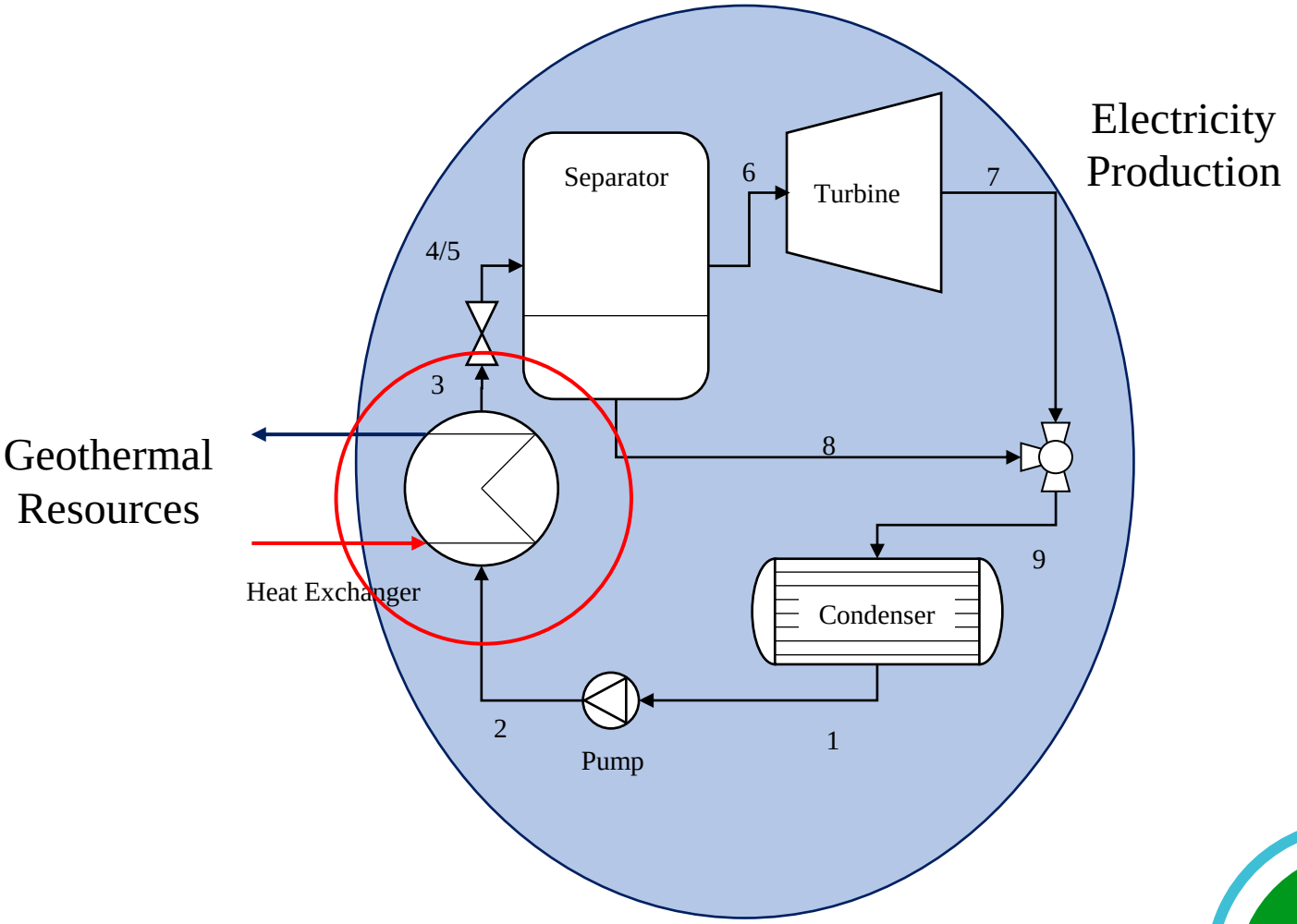
Heat Exchengers Heat Level KW





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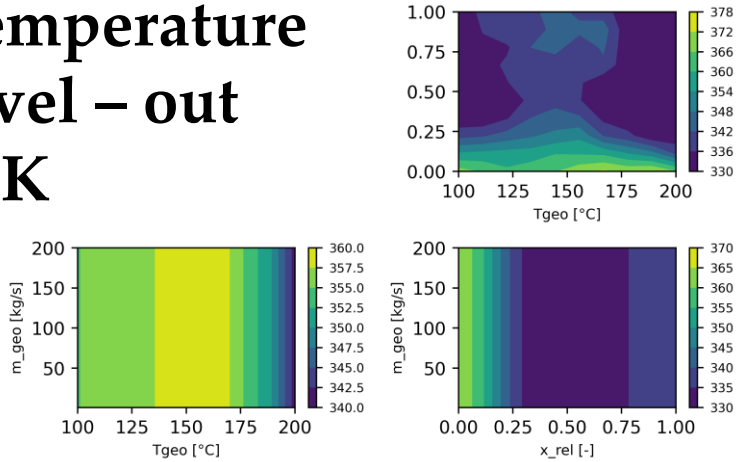
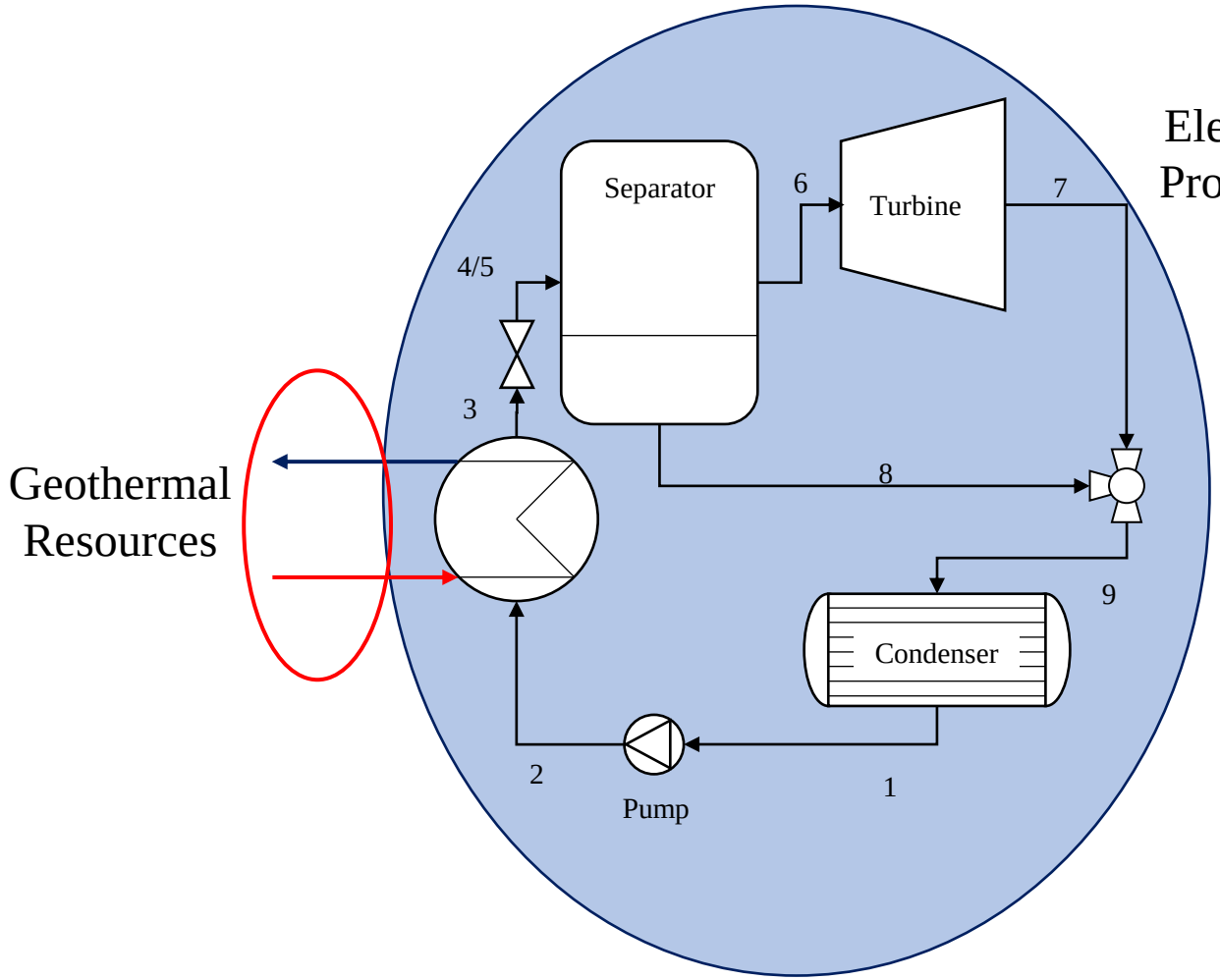
Temperature level – out

° K





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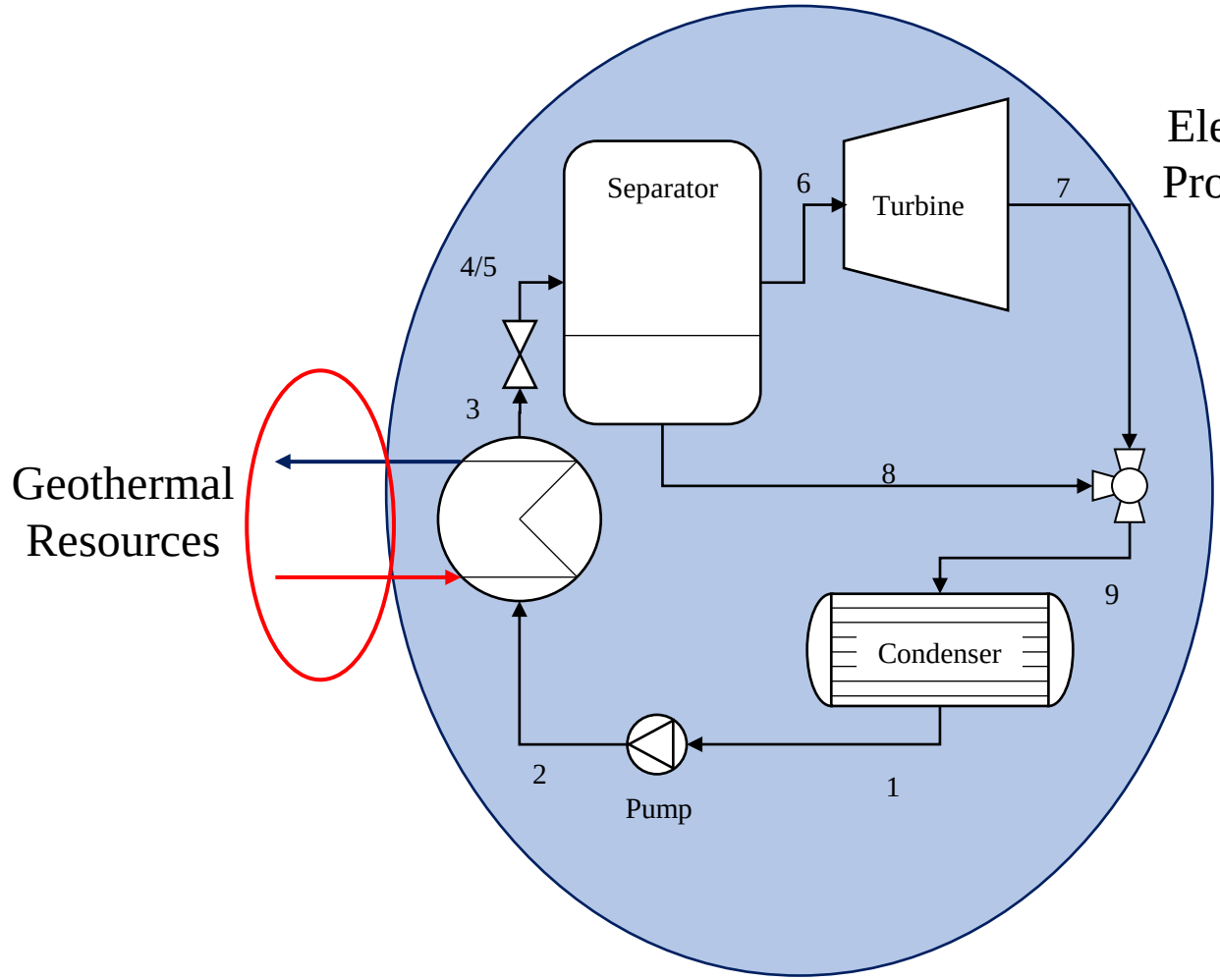
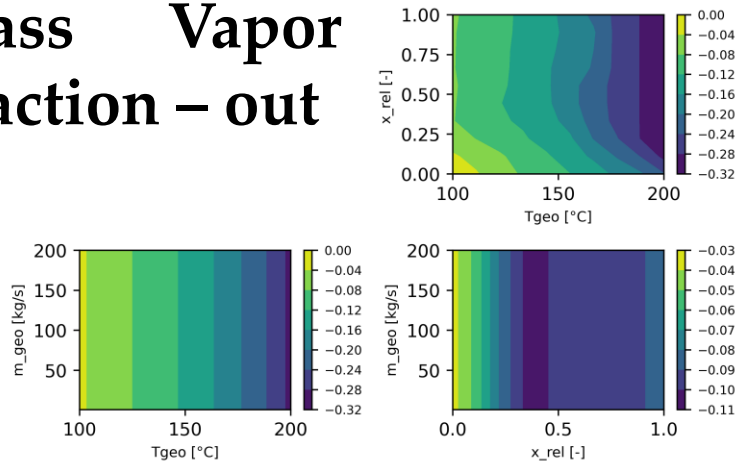


Mass Vapor Fraction – out



Methodology

Economic cost

Data collection and **economic correlations** regarding the energy systems sector, for the **surface plant**, and economic correlations for other necessary elements such as **geothermal wells**:

Equation for the purchase cost of the equipment, ambient pressure

$$log_{10}C_p^0 = K_1 + K_2\ log_{10}(\mathrm{A}) + K_3\ [log_{10}(\mathrm{A})]^2$$

K_1, K_2, K_3 = correction parameter K

A = capacity or size of the equipment

Equation for the Pressure factors

$$log_{10}\ F_p = C_1 + C_2\ log_{10}(\mathrm{P}) + C_3\ [log_{10}(\mathrm{P})]^2$$

C_1, C_2, C_3 = correction parameter C

P = Pressure level [bar gauge]

Equation for the Bare module factors

$$C_{BM} = C_p^0 * F_{BM} = C_p^0 * (B_1 + B_2 F_M F_P)$$

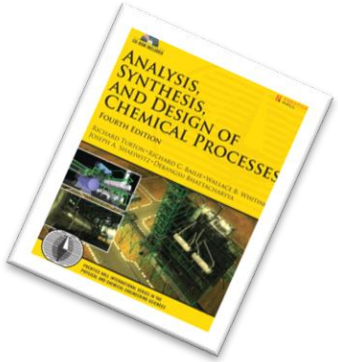
F_M = Material factor

B_1, B_2 = Correction parameter B

Economic Cost

$$LCOE = \frac{sum\ of\ costs\ over\ lifetime}{sum\ of\ electrical\ energy\ produced\ over\ life\ time}$$

Machinery



[1] **Turton, Richard**. *Analysis, Synthesis, and Design of Chemical Processes*. Upper Saddle River, N.J: Prentice Hall, 2003.

Geothermal wells

INTERNATIONAL JOURNAL OF ENVIRONMENTAL STUDIES
2021, VOL. 78, NO. 6, 1022–1036
https://doi.org/10.1080/00207233.2021.1905309

Routledge
Taylor & Francis Group

ARTICLE

Check for updates

Feasibility study and economic analysis of geothermal well drilling

Moein Shamoushaki, Daniele Fiaschi, Giampaolo Manfrida, Pouriya H. Niknam and Lorenzo Talluri

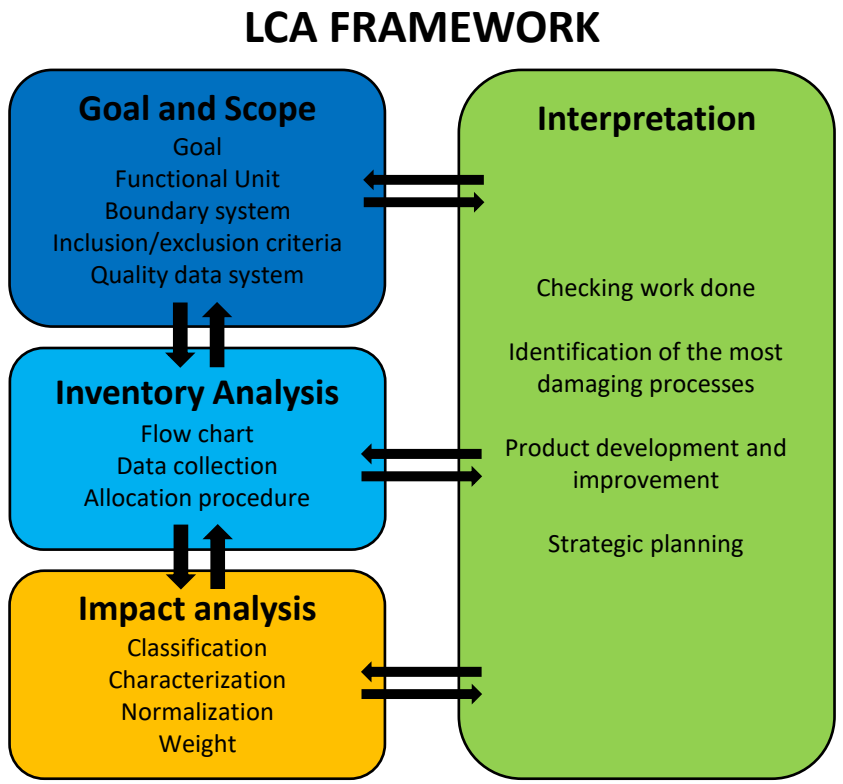
Department of Industrial Engineering, University of Florence, Firenze, Italy

Methodology

Environmental impact

Life Cycle Assessment approach. ISO14040 and ISO14044 standard

- No available correlation between system and environemntal impact
- Different systems need different LCI
- No many available inventories



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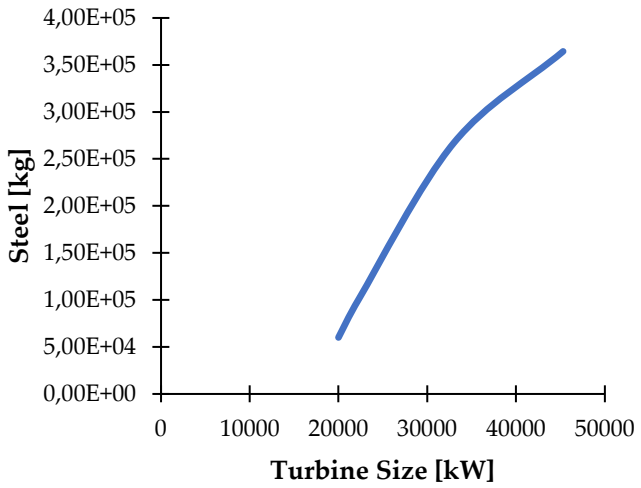


Data collection

Correlation

LCA

Environmental Impact

LCA FRAMEWORK

Goal and Scope
Goal
Functional Unit
Boundary system
Inclusion/exclusion criteria
Quality data system

Inventory Analysis
Flow chart
Data collection
Allocation procedure

Impact analysis
Classification
Characterization
Normalization
Weight

Interpretation
Checking work done
Identification of the most damaging processes
Product development and improvement
Strategic planning

Methodology

Work progress….

		Thermodynamic model	Metamodel	Economic evaluation	Environmental evaluation
Power plant	Flash/dry steam	✓	✓	✗	–
	ORC	✓	✓	✗	–
Heat or cold production	HTHP	✓	–	✗	✓
	R-ABS	✓	✓	✗	✓
Direct use	HE	✓	✗	✗	✗

Results / Preliminary Results - 1

Validation of thermodynamic metamodel

Qualtra is an ORC system of 10 MW. The geothermal resource condition are:
T_{geo}= 180°C; m_{geo} = 32.9 kg/s; x_{geo} = 1

Bagnore is an Flash power plant of 60 MW (three turbine of 20 MW). The geothermal resource condition are:
T_{geo}= 155°C; m_{geo} = 118.4 kg/s; x_{geo} = 0

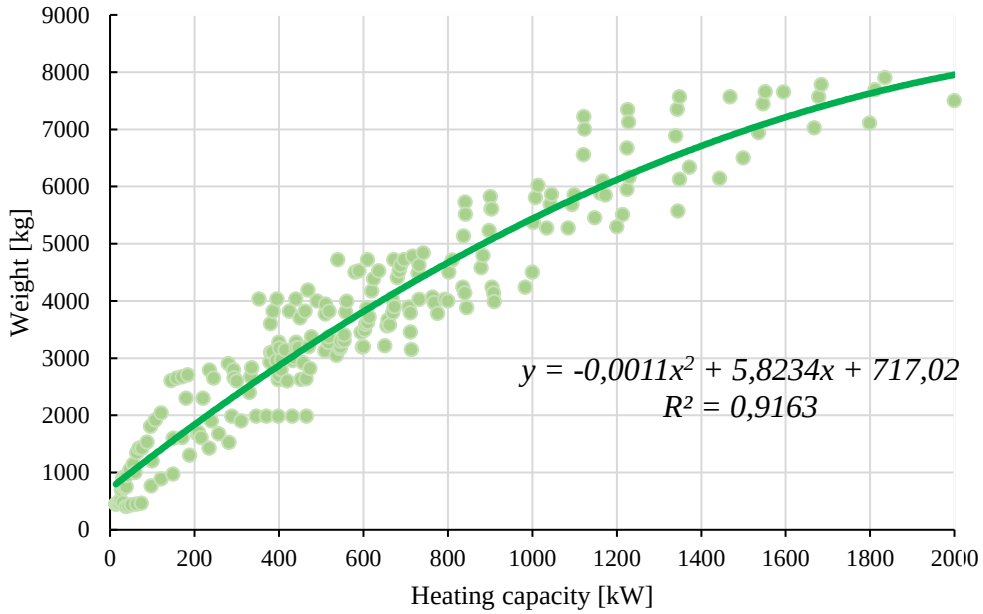
Chiusdino is a Dry Steam Power plant of 20 MW. The Geothermal resource condition are:
T_{geo}= 299°C; m_{geo} =117.6 kg/s; x_{geo} = 1

	Power plant name	Real case [MW]	Metamodel [MW]	Error [%]
Power plant - ORC	**Qualtra**	12.7	12.9	1.57%
Power plant - Flash	**Bagnore**	22.7	22.1	2.64%
Power plant - Dry steam	**Chiusdino**	22.3	23.035	3.30%

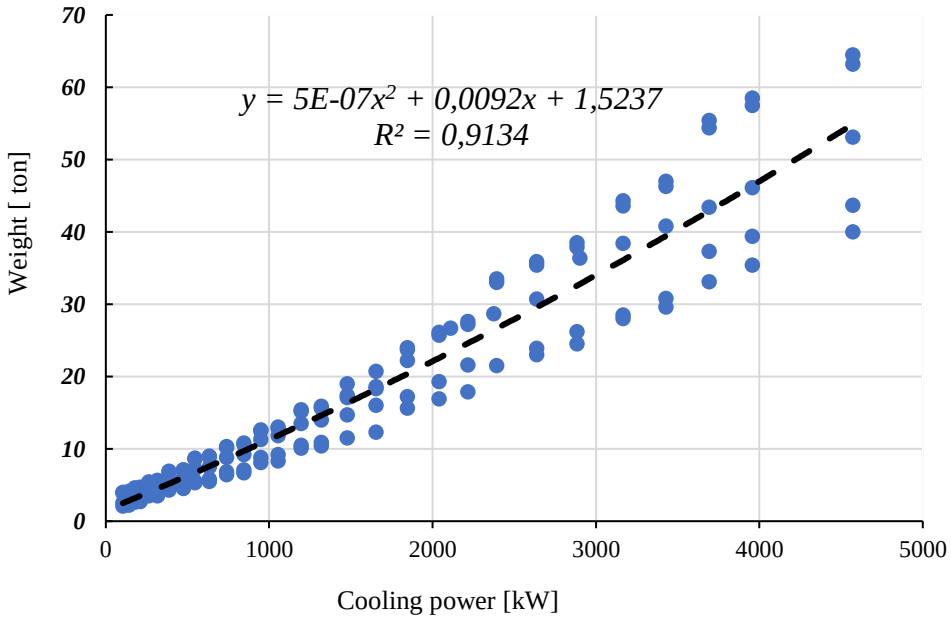
Results / Preliminary Results - 2

Evaluation of environmental impact

High Temperature Heat Pump



Absorption Refrigeration System



Conclusions

- Development of a decision-making tool for finding the best solution for exploiting the geothermal resource with respect to thermodynamic, economic, and environmental performance indicators
- The metamodels of the power plants have been validated
- The environmental model has been completed for medium and low enthalpy uses

Next steps..

- We are working on the metamodels of HTHP and HE for different target uses
- Economic evaluation of different systems
- The environmental model of the wells and power plants is in the process of data collection for the development of the final model. [University College of London]

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THANKS FOR YOUR ATTENTION!

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