Cost and Environmental Impact Estimators for Surface Plant utilising hot or superhot geo-resources

Dr Hye Chowdhury

Technovative Solutions Ltd (**TVS**), Unit 1 & 4, Rutherford House,

Manchester Science Park, Manchester, M15 6JJ, UK

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Introduction

TVS role in COMPASS project

- To develop i) the cradle-to-grave LCA model and ii) the parametric cost model
  - for the surface plants, using basic and reference flow data obtained from Icelandic and Italian perspectives in terms of the functional unit of 1 MWh of electrical energy production.
- To estimate the investment cost of the proposed geothermal project or existing geothermal power plant and analyse the LCOE and other financial parameters, TVS has developed ***COMPASS Cost Estimator for surface plant*** based on parametric cost model within the GETEM framework.
- To evaluate the environmental impacts of the proposed geothermal project or existing geothermal power plant, TVS has developed ***COMPASS Environmental Impact Estimator for surface plant*** based on cradle-to-grave LCA modelling following ISO 14040 and 14044 standards on LCA.
- In addition, cost and environmental performance modules for well completion have been developed in this project based on the cradle-to-gate Life Cycle Assessment (LCA) model and ii) the parametric cost model for **well completion** using COMPASS technology components casing and cementing materials and methods in terms of the functional unit of 1m of drilling activities.

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Introduction

- **In the COMPASS project,** TVS developed Cost and Environmental Impact Estimators for Surface Plants utilising hot or superhot geo-resources based on parametric cost and life cycle assessment models.

- **Functionalities of the Cost Estimator** for surface plant software application:
  - Calculating the levelised Cost of Electricity (LCOE) of existing plants utilising hot geo-resources and future proposed plants utilising superhot geo-resources.
  - Evaluating other financial indicators of the plants such as Net Present Value (NPV), Payback Period (PBP), Internal Rate of Return (IRR) and Return on Investment (ROI).
  - Performing sensitivity analysis of various financial parameters of the plants against discount rate, revenue factor or annual cash flow increase/decrease.
- **Functionalities of the Environmental Impact Estimators** for surface plants software application:
  - Estimating the resource consumption of existing and future plants in construction, Operation & maintenance (O&M) and End of Life (EoL) phases.
  - Evaluating the environmental impacts of these plants in three phases.
  - Representing the results of environmental footprints of the plants graphically.

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Methods

Parametric Cost Model for Surface Plants

- A parametric cost model for surface plant based on the Geothermal Electricity Technology Evaluation Model (GETEM)
- This model allows for estimating CAPEX, OPEX and other cost components involved in existing or proposed geothermal project development using user-inputted data or default data of various parameters in exploration, well field, field gathering system and power plant development phases.
- For the calculation of the LCOE of a surface plant, the GETEM model uses the levelised CAPEX, OPEX and royalties.

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Methods

Cradle-to-grave LCA Model for Surface Plants

- The cradle-to-grave LCA modelling of a geothermal power plant (GPP) using hot or superhot geo-resources comprises three phases following ISO LCA standards:
  - Construction phase
  - Operation & Maintenance (O&M) phase
  - End of Life (EoL) phase
- For LCA modelling of a geothermal power plant, basic data and other relevant parameters and components of GPP are collated from Icelandic and Italian representative geothermal power plants using very hot geo-resources, along with the proposed COMPASS geothermal power plant.
- The reference flow data of various materials, energy and processes involved in the three phases of GPP have been gathered from the representative flash-type GPP in Icelandic and Italian perspectives.
- The functional unit of the cradle-to-grave LCA studies is 1 MWh of electrical energy production from GPP.
- For obtaining functional flows of all the resource consumption data, the total mass or energy flows in the construction, O&M and EoL phases of the plants are divided by the total electrical energy production of the respective plant during the lifetime of the plant.
- Using these functional flow data in three phases, LCA tool SimaPro 9.5.0.0 calculates the environmental footprints of the proposed COMPASS GPPs in Icelandic and Italian perspectives and Icelandic and Italian GPPs using hot or superhot geo-resources, considering the life cycle impact assessment methodology IMPACT 2002+ v2.15.

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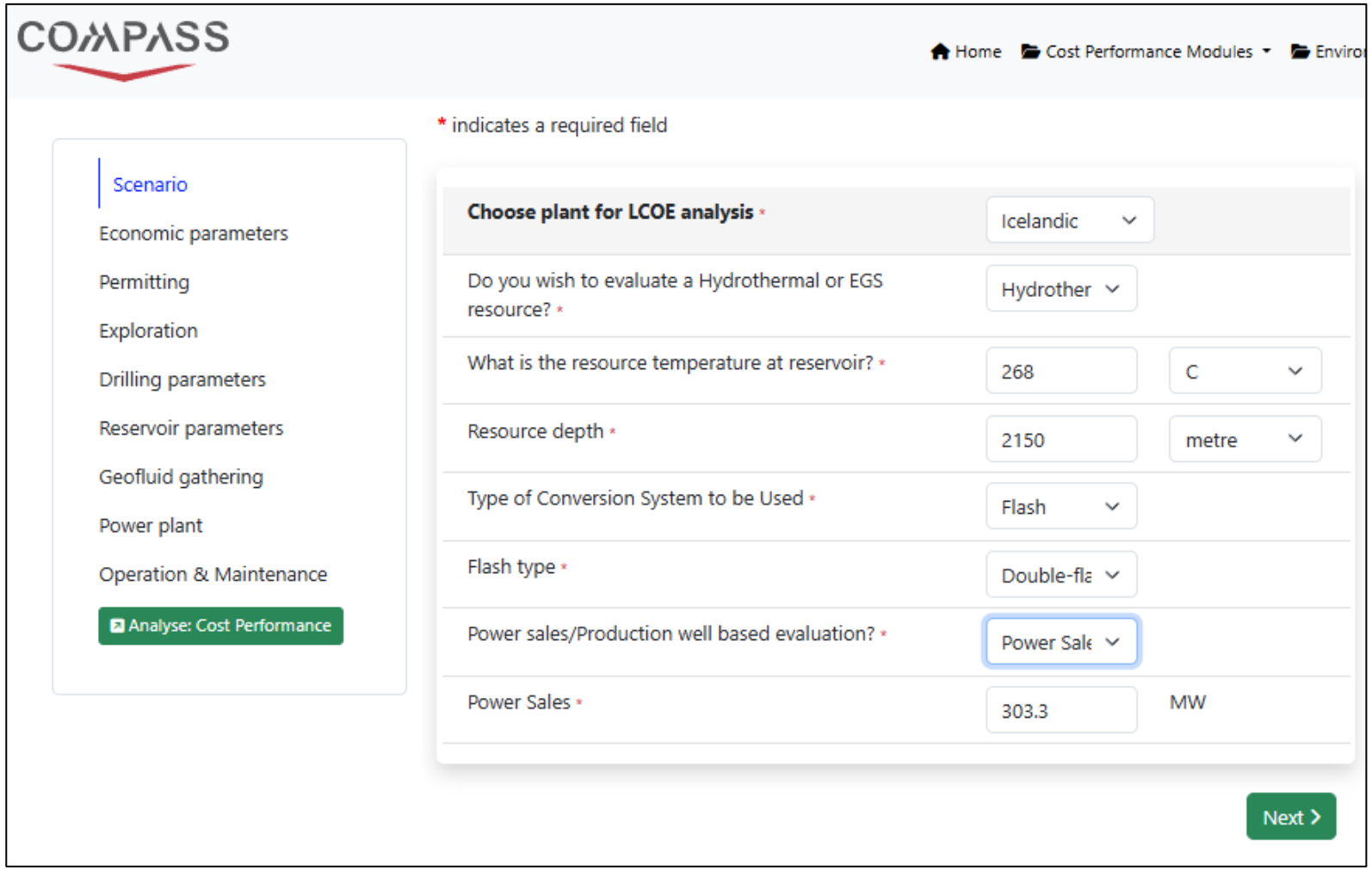
Demonstration of Cost Estimator for Surface Plant

Link to access the **COMPASS Cost Estimator for surface plant** here: https://compass.technovativesolutions.co.uk/surface-plants/cost-performance/surfaceplantsCostPerformance

Plant Characterisation

- The user or plant operator can give the inputs of the mandatory parameters for an existing or future geothermal plant.
- After defining the scenario of the selected plant, click 'Next' for defining the other essential parameters.



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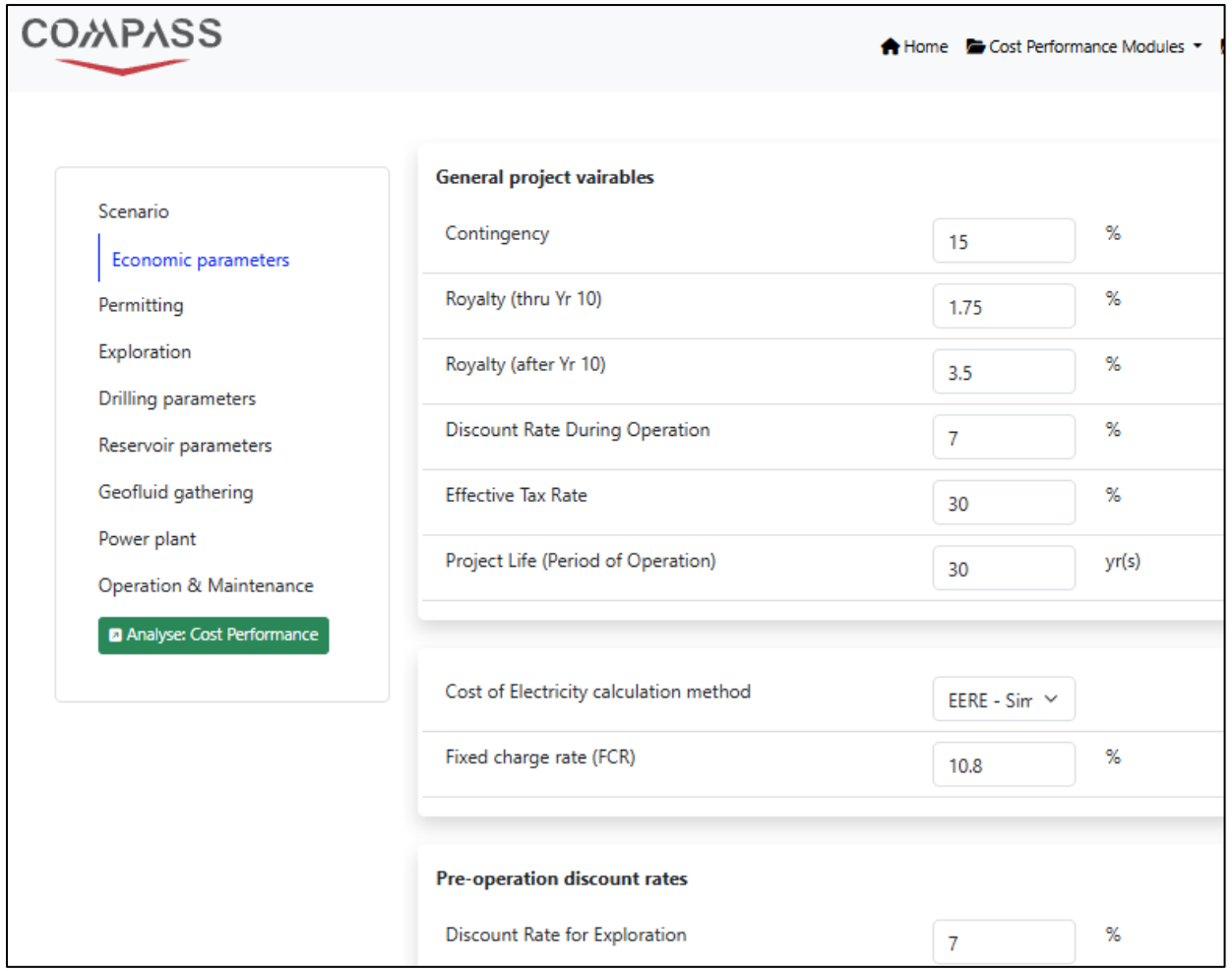
Demonstration of Cost Estimator for Surface Plant

Economic parameters

- On this page, user-inputted or default values (retrieved from DBMS) of various parameters in the following categories:

➢ General project variables
➢ Pre-operation discount rates and
➢ Project duration at different phases

are defined before go into the next stage.



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Demonstration of Cost Estimator for Surface Plant

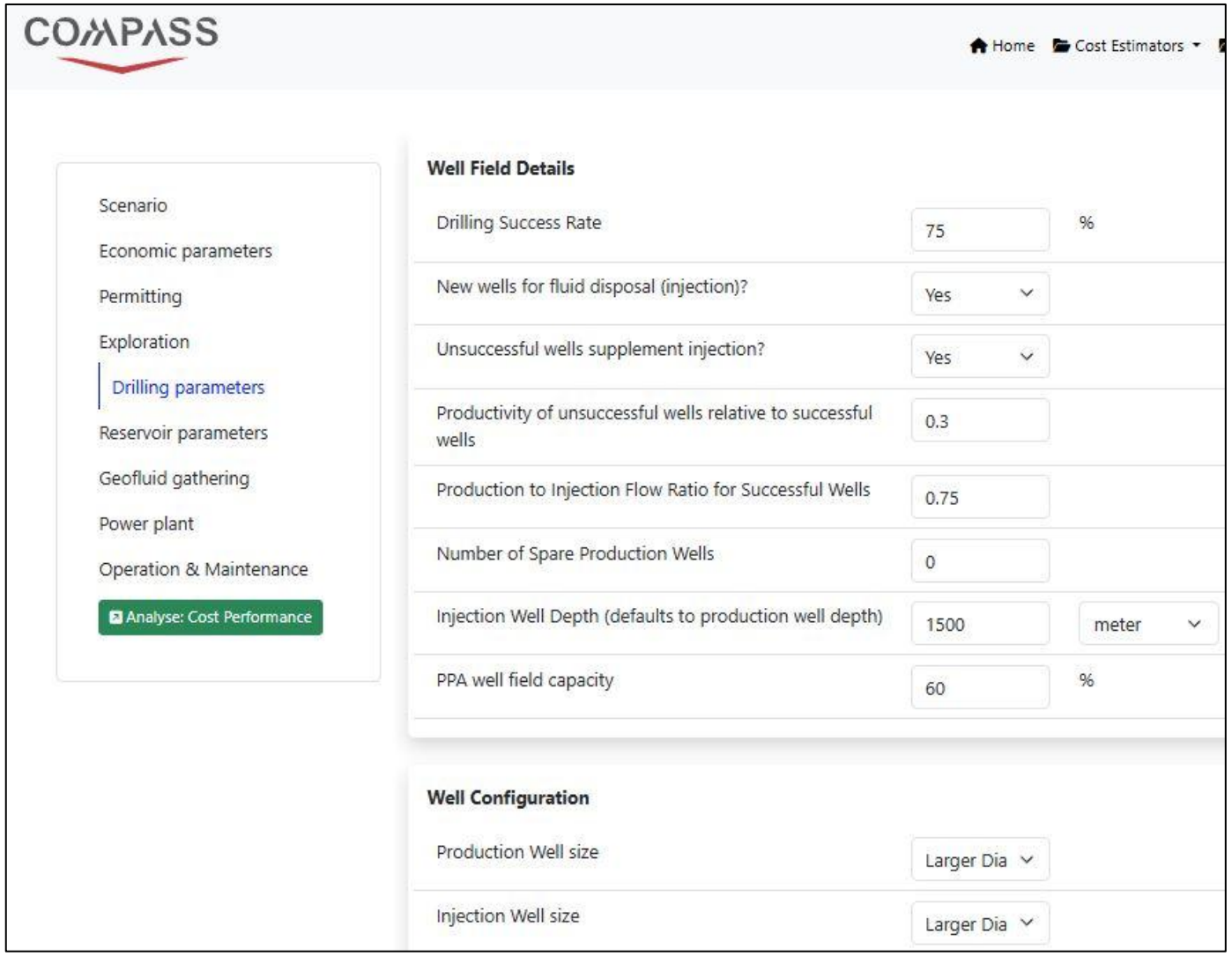
Drilling Parameters

On this page,

- Various drilling parameters at different stages:

➢ Well Field Details
➢ Well Configuration
➢ Well Cost Estimates
➢ Stimulation Costs
➢ Other Costs

of well drilling will be given by the user or retrieved from the DBMS.



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Demonstration of Cost Estimator for Surface Plant

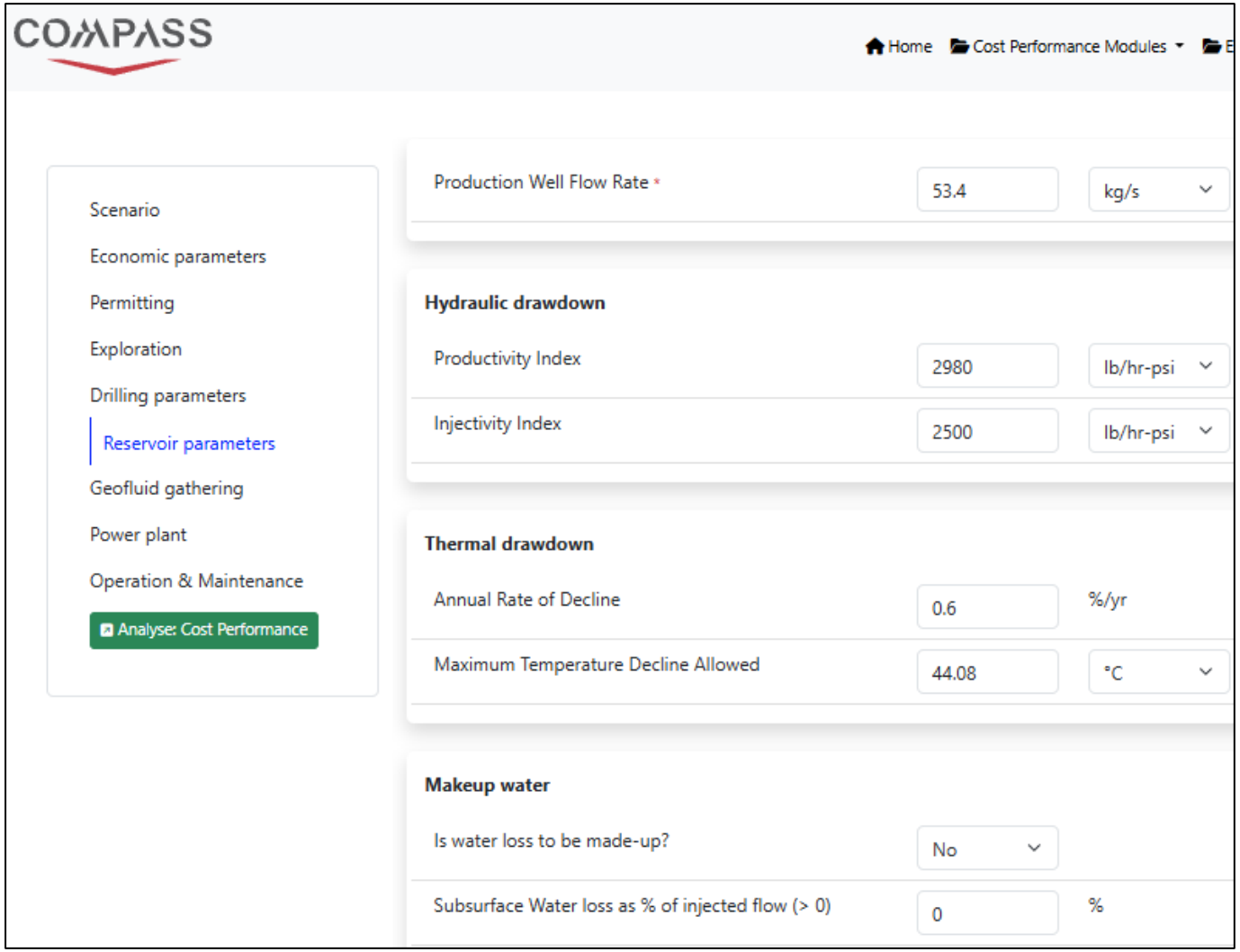
Reservoir Parameters

On this page,

- First, define the geofluid flow rate per well.
- Then user-inputted or default values (retrieved from DBMS) of various parameters in the following categories:

➢ Hydraulic drawdown
➢ Thermal drawdown and
➢ Makeup water

are provided.



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Demonstration of Cost Estimator for Surface Plant

GeoFluid Gathering

On this page,

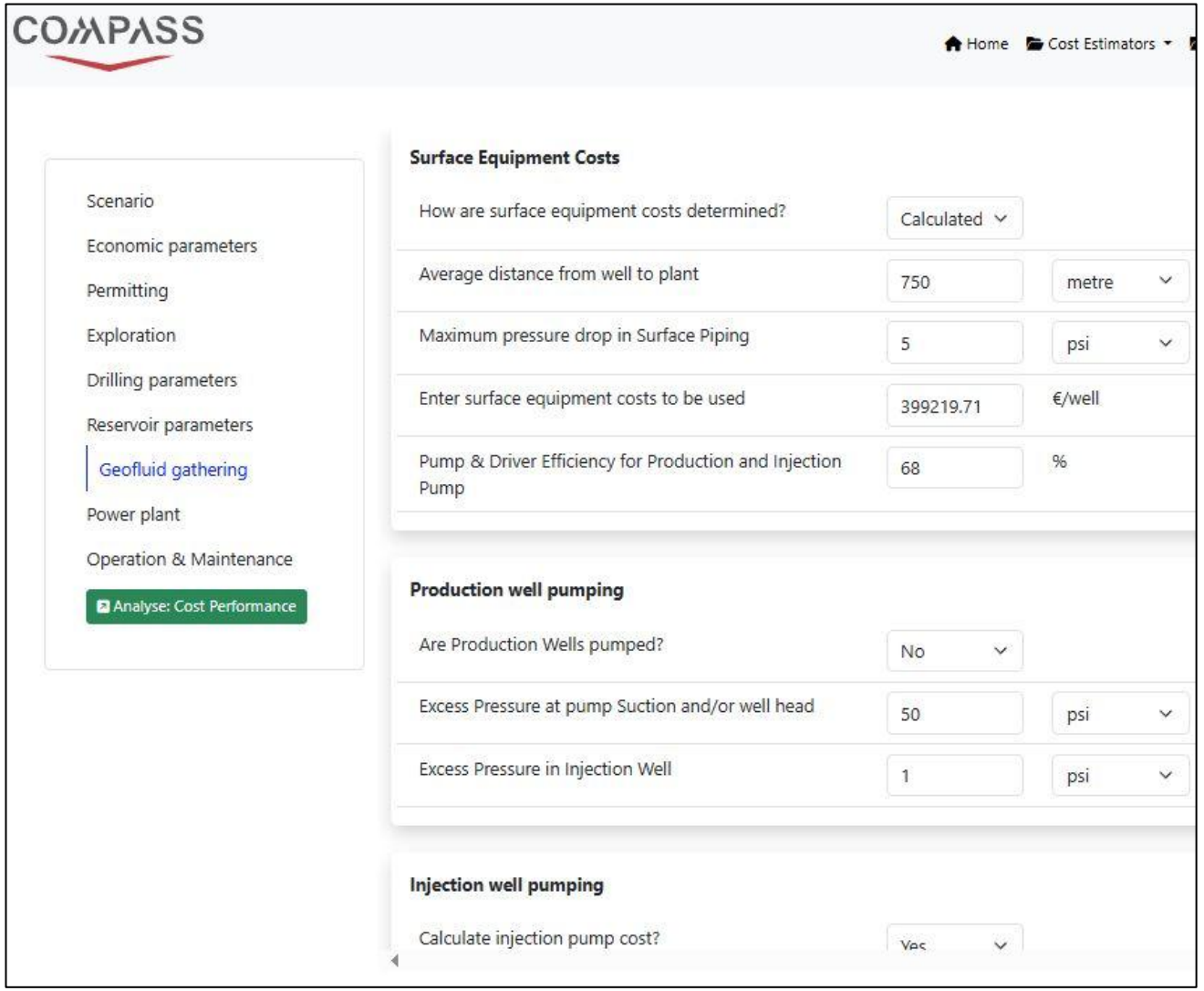
- Several parameters of the following stages:

➢ Surface equipment costs
➢ Production well pumping and
➢ Injection well pumping

of Geofluid gathering are defined by the user or retrieved from the DBMS.

Power Plant and Operation & Maintenance stages

- Several parameters of these two stages are defined by the user or retrieved from the DBMS.



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Demonstration of Cost Estimator for Surface Plant

❑ Using the data of various parameters provided, Cost Estimator for surface plant can estimate LCOE, LCOE impact and other relevant costs for the selected geothermal power plants shown in the Table below:

Table – A part of cost performance results of two existing plants and the future COMPASS plants utilising hot or superhot geo-resources.

Items	Unit	Hellisheidi	Bagnore	COMPASS
LCOE	€/ MWh	53.91	51.39	24.40
LCOE impact as compared with Hellisheidi	%	-	-	+54.7
Power sales	MW_e	303.3	60	350
Total capital cost w/o contingency	M€ /MW	2.61	2.57	1.18
Total capital cost with contingency	M€ /MW	2.82	2.77	1.31
Exploration Drilling Costs (full-sized)	€	20,994,459	21,757,015	27,028,904
Exploration Drilling Costs (small diameter)	€	2,173,366		
Non-Drilling Exploration Costs	€	458,885		
Permitting & Leasing Costs	€	734,111	265,948	248,720
Other Indirect Costs	€	1,104,972	1,145,106	1,422,574
Total exploration cost w/o contingency	€	25,465,793	25,800,321	31,332,449
Total drilling cost w/o contingency	€ / m	2,710	1,755	1,525
Total field gathering system cost w/o contingency	€	42,540,623	4,934,401	10,325,351
Total Power Plant & Transmission cost w/o contingency	€	351,374,342	67,662,365	293,836,265
Total Annual O&M cost	€ /y	24,677,750	5,131,328	15,493,613

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Demonstration of Cost Estimator for Surface Plant

- For Hellisheidi, Bagnore and COMPASS GPPs, other financial parameters such as Net Present Value (NPV), PayBack Period (PBP), Internal Rate of Return (IRR) and Return on Investment (ROI) have been calculated using CAPEX, OPEX, cash flow increase, discount rate and other cost parameters and annual electricity generation shown in Table below.

Items	Unit	Hellisheidi	Bagnore	COMPASS
Annual Electricity Generation	kWh	2.01×10^9	4.26×10^8	2.48×10^9
Annual Revenue	M€	281.54	59.60	347.68
Annual Profit	M€	256.86	54.47	332.19
Net Present Value (NPV)	**M€**	**2080.058**	**494.38**	**3569.45**
Payback Period (PBP)	**Years**	**3.33**	**3.05**	**1.38**
Internal Rate of Return (IRR)	**%**	**32.63**	**35.42**	**75.76**
Return on Investment (ROI)	**%**	**9.01**	**13.11**	**28.93**

- **Annual Electricity Generation & Revenue:** COMPASS plant leads with 2.48×10^9 kWh in generation and €347.68 million in annual revenue, surpassing Hellisheidi and Bagnore plants in Icelandic and Italian perspectives.
- **Annual Profit:** COMPASS plant also leads with €332.19 million, compared to Hellisheidi (€256.86 million) and Bagnore (€54.47 million) plants.
- **NPV:** COMPASS plant's NPV is €3.57 billion, significantly higher than Hellisheidi (€2.08 billion) and Bagnore (€494.38 million) plants' NPV.
- **Payback Period:** COMPASS plant has a shorter payback period at 1.38 years, as compared with Bagnore (3.05 years) and Hellisheidi (3.33 years) plants.
- **IRR & ROI:** COMPASS achieves an IRR of 75.76% and ROI of 28.93%, those outperform Hellisheidi and Bagnore plants' IRR and ROI.

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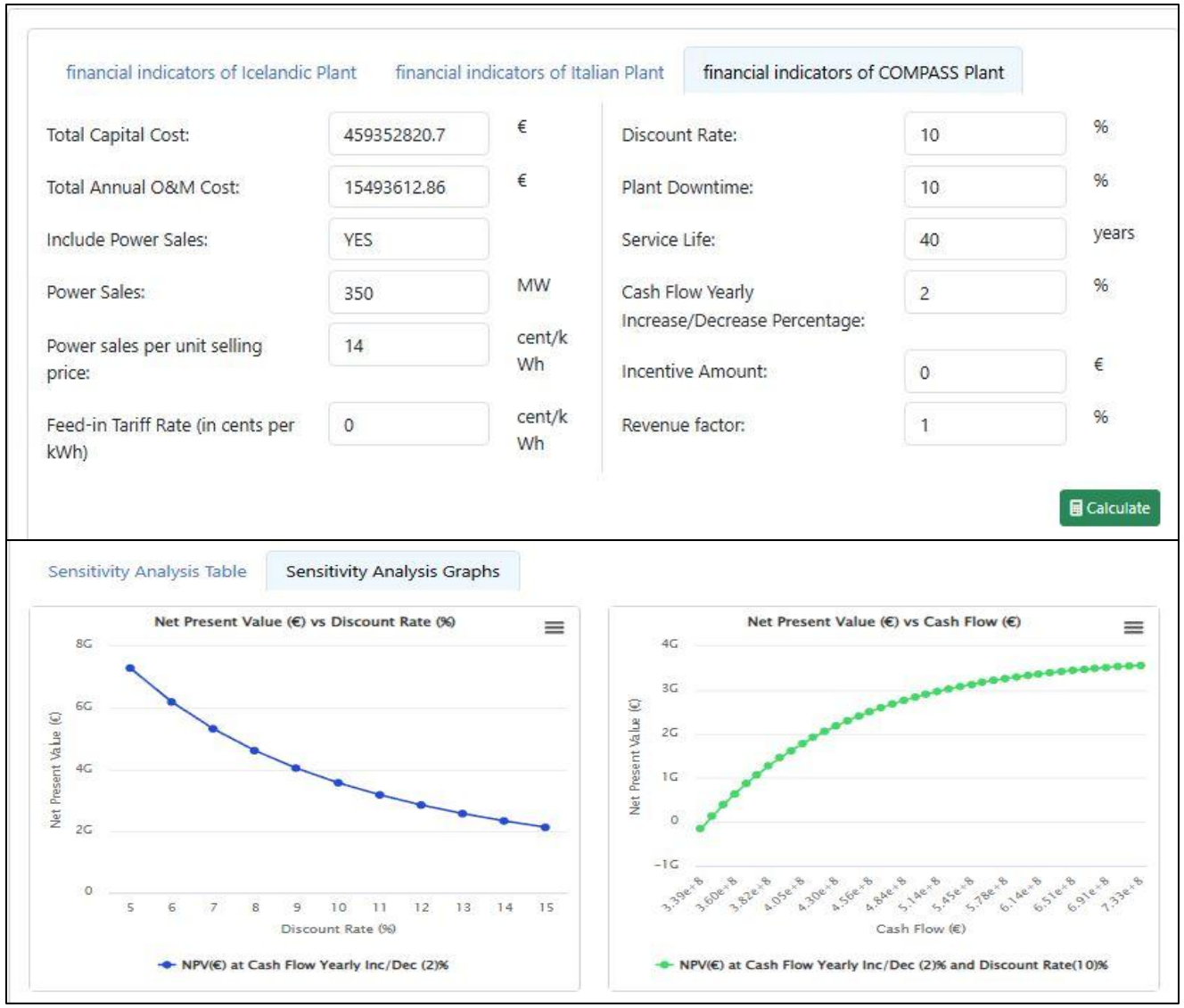
Demonstration of Cost Estimator for Surface Plant

- COMPASS Cost Estimator for Surface Plant can also compute ***sensitivity analysis of*** Net Present Value (NPV), Payback Period (PBP), Internal Rate of Return (IRR), and Return on Investment (ROI) of the chosen plant with variation in user-inputted data.

- The results of sensitivity analyses of these financial parameters against discount rate, revenue factor and cashflow increase/decrease for the chosen plant can be obtained after clicking the button 'Calculate'.



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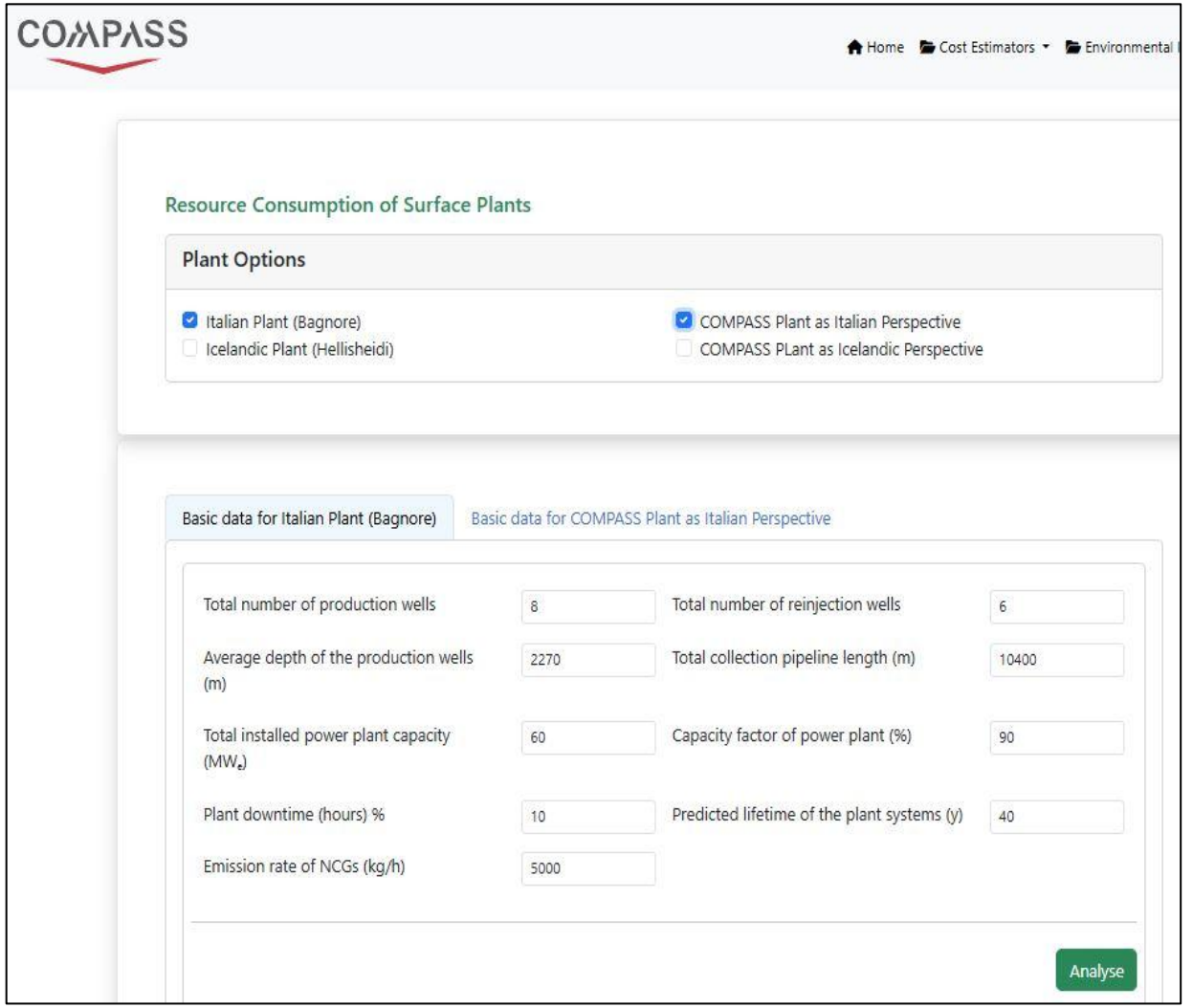
Demonstration of Environmental Impact Estimator for Surface Plant

Link to access the **COMPASS Environmental Impact Estimator** https://compass.technovativesolutions.co.uk/surface-plants/environmental-performance/resource-consumption

- In this Environmental Impact Estimator, users first select the chosen geothermal power plant for estimating the resource consumption in three phases.
- Based on the selected plant, users can populate basic plant data from the COMPASS DBMS module or users can give input their plant data of various important parameters:
  - Total number of production wells
  - Total number of reinjection wells
  - Average depth of the production wells (m)
  - Total collection pipeline length (m)
  - Total installed power plant capacity (MW_e)
  - Capacity factor of the power plant (%)
  - Plant downtime (%)
  - Predicted lifetime of the plant systems (y) and
  - others



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Demonstration of Environmental Impact Estimator for Surface Plant

Resource Consumption Data Estimation

- A part of resource consumption data in construction phase for **COMPASS Plant as Italian perspective** is shown here.
- After calculating the selected plant's resource consumption data in three phases and emission data, this Estimator employs background processes for various materials and processes involved in these phases from databases, such as ecoinvent and other databases available in the SimaPro 9.5.0.0 LCA software tool.

Resource Consumption of COMPASS Plant as Italian Perspective

Construction phase | Maintenance phase | Atmospheric emissions | End of Life

Construction phase

Process Name	Total flow amount	Total flow amount unit	Functional flow amount	Functional flow amount unit
Bentonite	3.48×10^{6}	kg	3.50×10^{-2}	kg/MWh
Cellulose fibre	2.02×10^{5}	kg	2.03×10^{-3}	kg/MWh
Portland cement	3.65×10^{7}	kg	3.67×10^{-1}	kg/MWh
Hydrochloric acid	9.07×10^{5}	kg	9.13×10^{-3}	kg/MWh
Reinforcing steel	5.34×10^{6}	kg	5.38×10^{-2}	kg/MWh
Sodium hydroxide	9.07×10^{5}	kg	9.13×10^{-3}	kg/MWh
Water (unspecified natural origin) IT	3.02×10^{6}	l	3.04×10^{-2}	l/MWh
Lubricating oil	1.51×10^{5}	kg	1.52×10^{-3}	kg/MWh
Diesel (burned in diesel electric generating)	3.20×10^{8}	MJ	3.22×10^{0}	MJ/MWh
Excavation	1.73×10^{4}	m3	1.74×10^{-4}	m3/MWh

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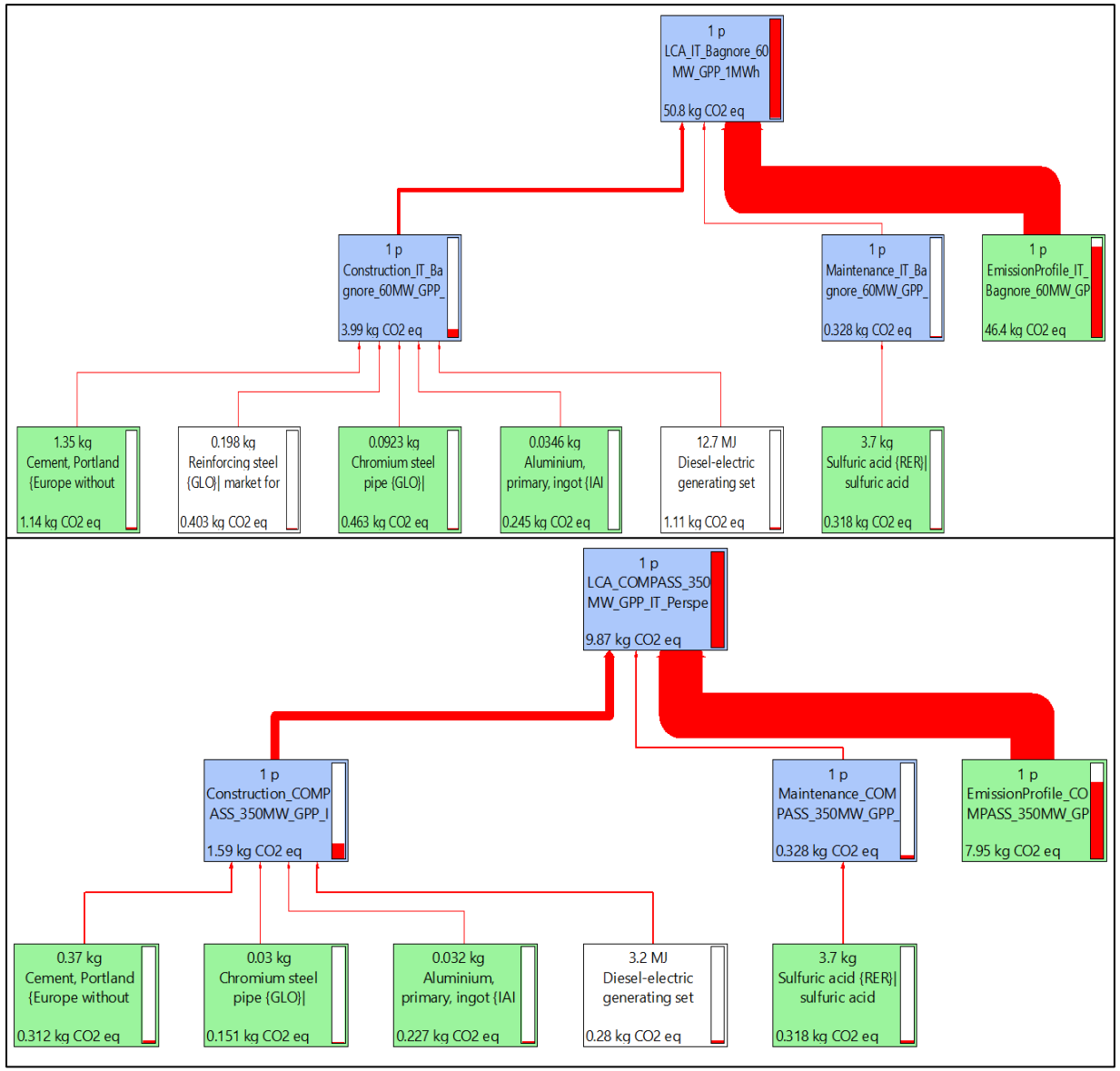
Demonstration of Environmental Impact Estimator for Surface Plant

- The LCIA methodology IMPACT 2002+ v2.15 (available in SimaPro LCA tool) is used to translate these resource consumption and emission data in three phases of a chosen plant into several environmental performance indicators such as ***climate change, human health, ecosystem quality and resources.***
- The carbon footprint (climate change) results of Italian Bagnore plant (50.8 kg CO2 eq / MWh) and COMPASS plant in Italian perspective (9.87 kg CO2 eq / MWh) are shown here:

- The carbon footprint savings of COMPASS plant as an Italian perspective is about 80.6% as compared with the Italian Bagnore Plant.



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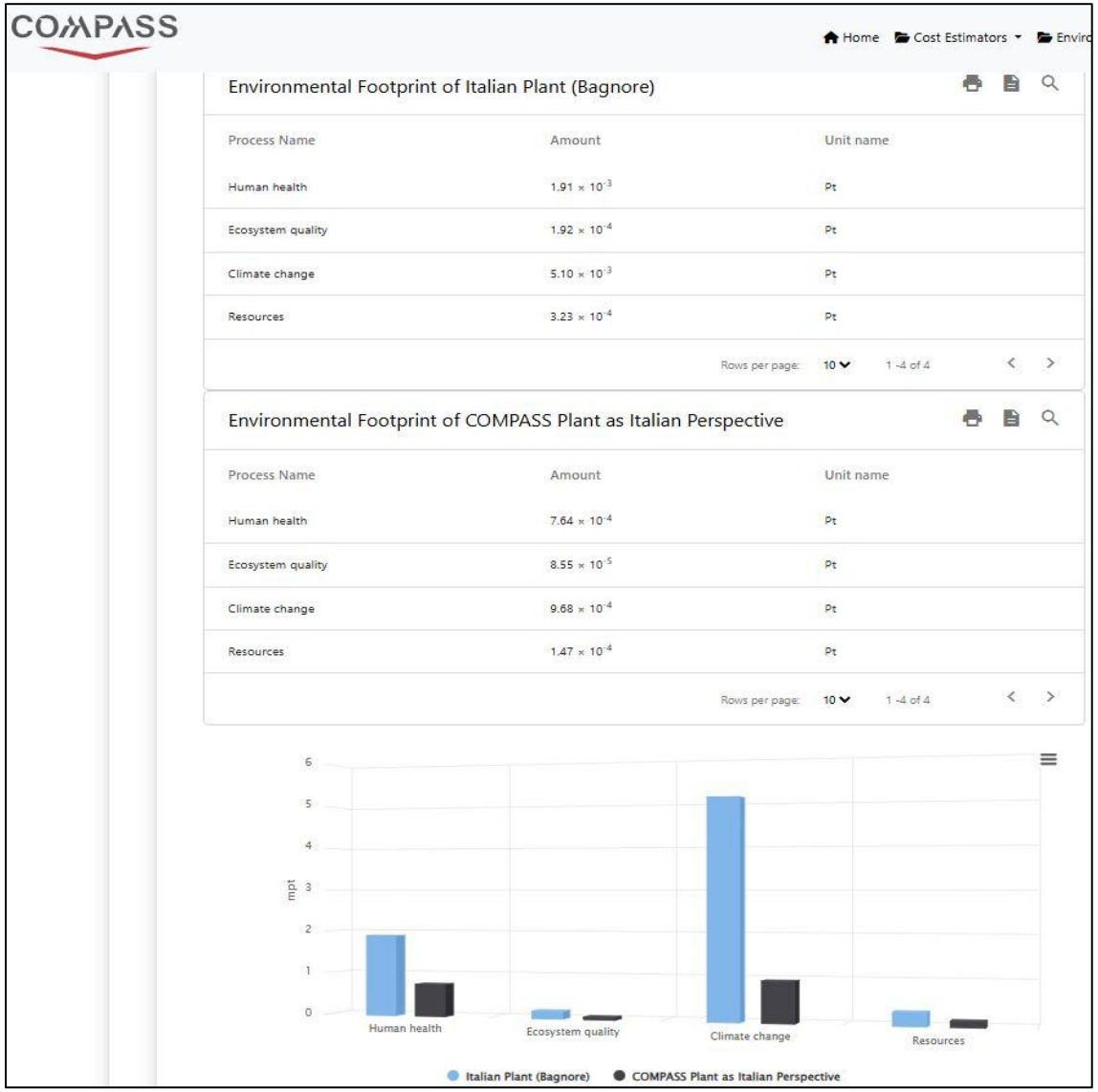
Demonstration of Environmental Impact Estimator for Surface Plant

Environmental Footprint Results

- ❑ Quantitative environmental impact results can be obtained from the Estimator and is shown here
- ❑ Quantification of all four environmental footprints (climate change, human health, ecosystem quality and resources) is expressed in a common scale of measurements, termed as eco-point (Pt).
- ❑ All four environmental footprint results of Italian (Bagnore) and the COMPASS plant an Italian perspective are shown in Tables.
- ❑ It is evident from the graph that all four environmental footprints of the COMPASS plant an Italian perspective are much lower than those of the Italian Plant (Bagnore).



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Conclusions

- **Cost Estimator for Geothermal Project**

The key benefits of this tool are

❑ **Comprehensive Financial Assessment:**
- ➢ Computes key financial metrics: LCOE, NPV, PBP, IRR, and ROI.
- ➢ Helps in investment decision-making.

❑ **Sensitivity Analysis:**
- ➢ Analyse how financial outcomes change with varying parameters.
- ➢ Identifies critical cost drivers and uncertainties.

❑ **Cost Optimisation & Risk Reduction:**
- ➢ Evaluating multiple cost scenarios for better planning/decision-making.
- ➢ Reduce financial risks through data-driven insights.

❑ **Comparison Across Geothermal Plants:**
- ➢ Allows assessment of different plant locations (e.g., Italian, Icelandic perspectives).

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Conclusions

- **Environmental Impact Estimator for Geothermal Project**

❑ This estimator can offer several key benefits

-Performance Benchmarking
-Supporting Sustainability Goals
-Risk Management and Mitigation
-Regulatory Compliance with Environmental standards
-Improving Decision-Making
-Transparency and Stakeholder Communication

Finally, integration of these estimators with COMPASS Decision Support System (DSS) developed by SINTEF:

- ➢ Works seamlessly within the COMPASS DSS.
- ➢ Enhances geothermal project feasibility studies

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About the Organisation: TVS

Who are we?

https://technovativesolutions.co.uk/

Established in 2012, Technovative Solutions Ltd (TVS) specialises in digital innovation, solving global challenges through cutting-edge technologies.

Core Domains:

- Materials & Manufacturing
- Renewable Energy
- Digital Healthcare
- Climate & Disaster Resilience
- Digital Product Passport (DPP)
- Software Development

TVS at a glance

- **30+** EU&UKRI Projects
- **150+** Partners
- **20+** Tools
- **70+** experienced scientists, engineers, and developers
- **12+** years of experience
- **4** Spin-offs

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Questions ? ? ?

hye@technovativesolutions.co.uk

Thank you

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