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|---|---|---|---|
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| **WP 1** | **Demonstration requirements and specifications** | | |

# D1.8 – Updated End User spec & document agreed with users, including KPI for two case study sites

| | | |
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| **Abstract** | The deliverable is a *living* document and in its second version reports on the key performance indicators (KPIs) identified to measure the performance of the GeoSmart system. The document also included the end user specification of the demonstration sites. | |

## REVISION HISTORY

| Version | Date | Main Authors/Contributors | Description of changes |
|---|---|---|---|
| | | | |
| | | | |
| | | | |

[*] Dissemination level security:

**PU** – Public (e.g. on website, for publication etc.) / **PP** – Restricted to other programme participants (incl. Commission services) /

**RE** – Restricted to a group specified by the consortium (incl. Commission services) / **CO** – confidential, only for members of the consortium (incl. Commission services)

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**Document: D1.8 Updated End user spec and document agreed with users, including KPIs for two case study sites**

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# Acronyms and definitions

DC – Direct Current

FRP – Fiberglass Reinforced Plastic

HV – High Voltage

HVAC – Heating, Ventilation and Air Conditioning

$H_2S$ – Hydrogen Sulphide

HP – High Pressure Steam

IP – Intermediate Pressure Steam

LP – Low Pressure Steam

NCG – Non-Condensable Gas

PVC – Polyvinyl Chloride

SH – Superheat

TBD – To Be Determined

TEFC – Totally Enclosed Fan Cooled

UPS – Uninterrupted Power Supply

UV – Ultraviolet

# 1 EXECUTIVE SUMMARY

The current deliverable reports on the key performance indicators (KPIs) identified to evaluate the functionalities of the GeoSmart system. This is a working document and will be continually updated and referred to for the consortium to maintain focus on the key factors and measure project outcome against these at a) sub-system level; and b) for the overall GeoSmart system. The document outlines the concept, methodology, definitions and calculation methods (as applicable) to monitor the performance of the systems in the demonstration sites.

In addition, the end-user requirements for the sites have been captured and a formal Quality Function Deployment (QFD) technique has been used to determine what aspects of the project have relatively strong links to the end user requirements

# 2 OBJECTIVES MET

The deliverable contributes towards the following work package objectives:

- To develop the detailed key performance indicators for the project success, and for the detailed final designs for the demonstration systems for each demo site. These will be maintained as working documents, updated throughout the project as knowledge and situations change, to ensure that all partners are working from the same set of success criteria.

# 3 KPI DESCRIPTION

## 3.1 Methodology

Key Performance Indicators are a set of quantifiable values used to demonstrate performance of the proposed technological solution. The GeoSmart consortium intends to use these KPIs at multiple levels to measure the performance outcome. The relevance of the KPIs has been established by use of the SMART (**S**pecific, **M**easurable, **A**ttainable, **R**elevant and **T**ime-bound) criteria. A template was prepared comprising the main elements that needed to be developed for each KPI (see Table 1).

**Table 1. Template for capturing KPI**

| | |
|---|---|
| **Rationale**<br>Reasoning for use of the indicator and how it can be used to demonstrate the performance of the system. The objectives that would be targeted as a measurement for improvement. | **Target**<br>Measuring improvement compared with the current state of the art. |
| **Source**<br>Equations/formulas used to calculate, monitor and measure the KPI | **Method of measuring**<br>Specific conditions under which the KPI will be measured or needs to measured |

The template was completed by all work package (WP) leaders and discussions were held to clarify the definitions of the KPIs identified, to complete missing information, and to ensure consistent terminology across all WPs. Workshops and other meetings conducted in March/April 2021 project to establish and finalise KPIs for the two demonstration sites — KZD2 (Figure 1) and Insheim (Figure 2) respectively.

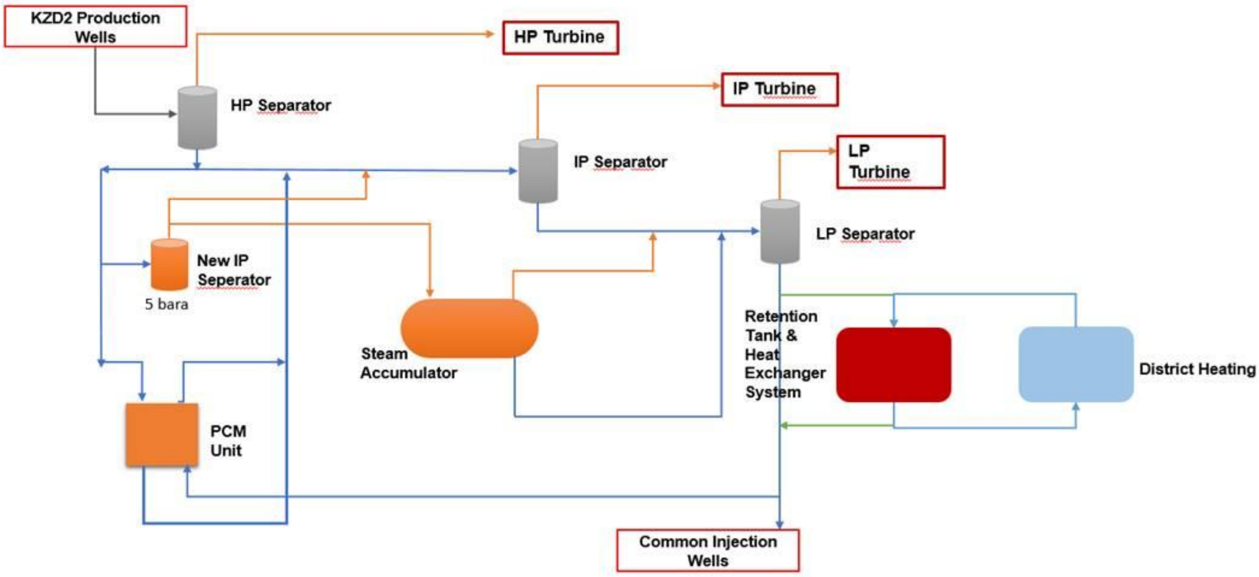



Figure 1. Description of proposed system (KZD2 site)

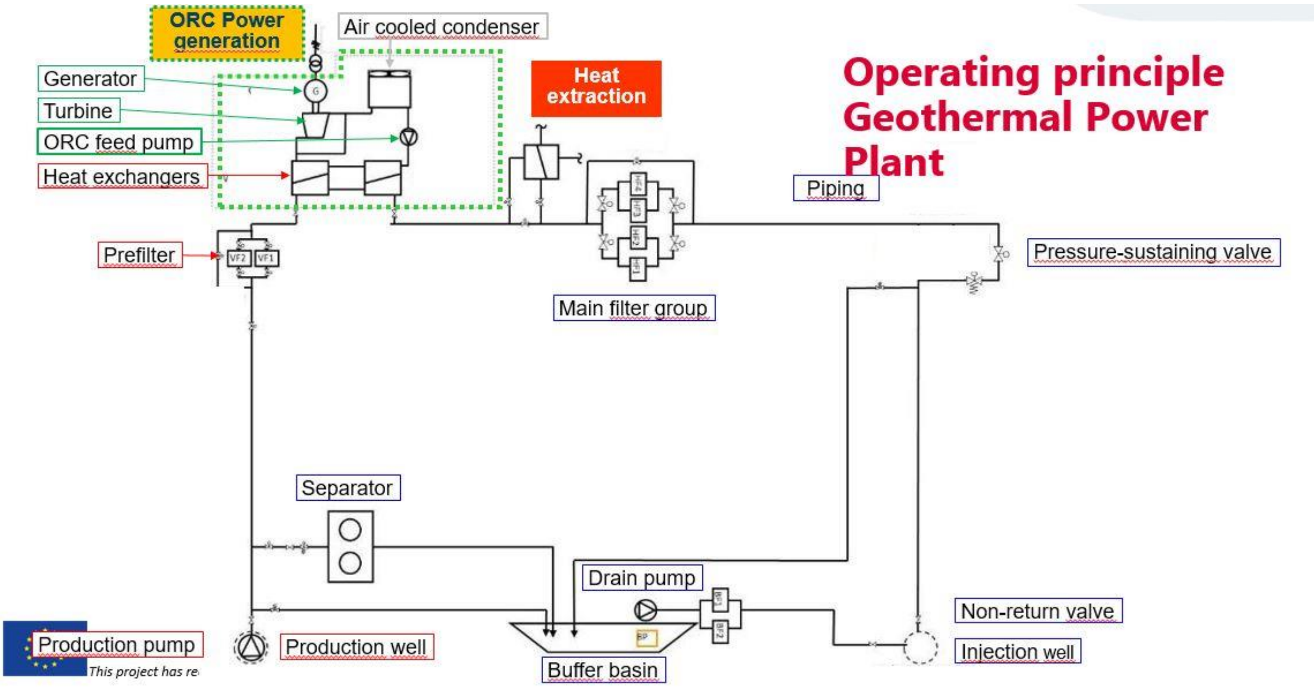



Figure 2. Description of proposed system (Insheim site)

The KPIs have been identified at the following levels:

- **KPIs at technology level**

  These are specific KPIs defined to characterise the innovative technologies developed in the project. The definitions of these KPIs are important to demonstrate the desired level of performance outcome at a sub-system level:

  - Thermal storage which includes the thermal storage units at KZD2 and Insheim;
  - Heat exchanger system at KZD2;
  - Retention tank at KZD2;
  - Flexible Organic Rankine Cycle (ORC) at Insheim;
  - The GeoSmart simulator suite.

- **Non-technical KPIs**

  These include the environmental and general KPIs at business and dissemination level[2].

**Categorisation of KPIs**

GeoSmart KPIs have been categorised to effectively express one or more aspects of performance assessment. Table 2 gives an overview of the KPI categories used in the project.

**Table 2 Overview of the KPI categories in GeoSmart**

| KPI category | Description |
|---|---|
| Technical | • Heat storage density<br>• Heat storage design ratio<br>• Heat storage capacity ratio<br>• Response Time<br>• Cumulative stored energy or number of full cycles<br>• Heat-exchanger power ratio<br>• Heat-exchanger differential pressure ratio<br>• Heat-exchanger effectiveness<br>• Heat-exchanger scaling risk<br>• Efficiency of Silica Removal System with respect to the Solubility Value at the chosen temperature<br>• Efficiency of Silica Scale Suppression System<br>• Reduction rate of melting enthalpy<br>• Corrosion rate (CR) of PCM module material<br>• Adhesion of coating to substrate |
| Non-Technical | • Heat Storage cost<br>• Obtainable Economic Gain from the overall HX + RT system<br>• Number of Open Access Journal Articles<br>• Number of Trained Early Stage Researchers<br>• Master level theses related to Work Package 8 |

[2] The dissemination KPIs has been be included in D9.7 A dissemination plan due M10.

## 3.2 Technical KPIs

1. **KPI: Heat storage density (HSD) in kWh/m3 (HSD)**

**Relevant Work Packages:** WP2, WP6, WP7

**Rationale:** This criteria is important because heat storage systems have generally a large volume, the higher density the better in this case.

**Target:** The target is different for each principle of storage system. For sensible storage 10 to 50 kWh/m3, for latent heat storage 30 to 150 kWh/m3, for chemical heat storage 80 to 400 kWh/m3. Therefore the target will be different for a steam accumulator (sensible), a thermocline (sensible) or a PCM module (latent). For sensible storage, the storage density is sensitive to the variation of temperature , the smaller DT the larger module.

**Source/Formula:**

$$HSD = \frac{Edischarge,design}{Volume} \ or \ \frac{Edischarge,measured}{Volume}$$

**Method for measuring:** Edischarge, design (kWh) is the energy calculated with a model after a full discharge at nominal conditions and new materials after cycling stabilisation. It can be done before testing the module. Edischarge, measured (kWh) is the energy measured during a discharge at nominal conditions after cycling stabilisation. It is more realistic but can be done only after some tests.

Volume ($m^3$) is the volume of the module after design including metallic parts (not only storage material). We can calculate 3 volumes:

1- The module : it will be the reference case for the KPI because most of the scientific articles refer to this criteria
2- The module with insulation
3- The module with insulation + auxiliaries

**Additional comments, if any:** This criteria is valid for all storage systems type, i.e. sensible, latent and chemical.

2. **KPI: Heat storage design ratio in % (HSDR)**

**Relevant Work Packages:** WP2, WP6, WP7

**Rationale:** This ratio gives the difference between the real stored energy at nominal conditions of full discharge and the design energy. This factor can vary during time because of material aging, for example phase change materials (PCMs). It should be done at year zero (gives then the uncertainties of design model), then every year. Therefore, this indicator gives both the margin between the theoretical design conditions and the operating conditions at initial state and after a few years of operation.

**Target:** The target must be close to 100% when starting, it may eventually be higher than 100% (design safety margin). When the storage material may age (case of a PCM module or a chemical storage), the target must be higher than 100%, then will decrease to a minimal level for which the module is not efficient enough, this value is process dependant and economy dependant. For instance, for a PCM module, the material may age and should be changed from time to time (every X years), this will be included in the OPEX costs.

**Source/Formula:**

$$HSDR = \frac{Edischarge, measured}{Edischarge, design}.100$$

**Method for measuring:** Edischarge,measured (kWh) is the energy stored during a full discharge at nominal conditions with new or aged materials after cycling stabilisation.

Edischarge,design (kWh) is the energy calculated during a full discharge at nominal conditions and new materials after cycling stabilisation..

**Additional comments, if any:** This criteria is valid for all storage systems type, i.e. sensible, latent and chemical.

3. **KPI:** **Heat storage capacity ratio in % (HSCR)**

**Relevant Work Packages:** WP2, WP6, WP7

**Rationale:** This ratio compares the stored energy at nominal conditions and the maximum energy that could be stored (for instance PCM melted 100% or sensible material fully charged at maximal temperature) in a stable state (after a few thermal cycles). It is a way to measure the limitations due to the module physics or the process.

**Target:** The target is different for small scale modules and large scale modules. It is also process dependant. As an order of magnitude, HSCR may be in the range 50-70% for a small scale module, and 70-90% for a large scale one

**Source/Formula:**

$$HSCR = \frac{Edischarge, measured}{Edischarge, max}$$

**Method for measuring:** Edischarge,measured (kWh) is the energy stored during a full discharge at nominal conditions with new or aged materials after cycling stabilisation.

Edischarge,max in kWh is the maximum energy that could be stored in the module (sensible and latent). It is calculated from the weight of each part (for instance metallic part, filling material, HTF inside the module), their physical properties and the two nominal temperatures of charge and discharge. For PCM module, it includes PCM and metallic parts. The thermal losses are not taken into account.

**Additional comments, if any: This criteria is valid for all storage systems type, i.e. sensible, latent and chemical.**

4. **KPIs:** **Response Time in Seconds (RS)**

**Relevant Work Packages:** WP2, WP6, WP7

**Rationale:** RS measures the difference between request for extra heat from heat storage to time for extra energy production. It gives an idea of the reactivity of the heat storage. *This KPI does not integrate the whole system response, for instance the electricity production increase.*

**Target:** The response time of a thermal storage is in the range of the minute (1-10 minutes).

**Source/Formula:**

$$RS = t\ Output - t\ input$$

**Method for measuring:** t input is the time of request to the storage system.

t output is the time at which heat production from the storage system increases and reaches a % of the target, for instance 90%. It is measured by the outlet conditions that increase, for instance flowrate and/or temperature. In the case of a steam accumulator, we measure the outlet steam flowrate and we can calculate the corresponding heat power increase. In the case of a thermocline or a PCM module with single phase on HTF side, we measure the inlet or outlet flowrate, the inlet and outlet temperatures and we can calculate the corresponding heat power increase.

**Additional comments, if any: This criterion is valid for all storage systems type, i.e. sensible, latent and chemical.**

5. **KPI: <u>Cumulative stored energy or number of full cycles (NFC) of storage equivalence in kWh/kWh</u>**

**Relevant Work Packages:** WP2, WP6, WP7

**Rationale:** This KPI is an indicator of the economic interest of a storage system, it will allow studying it on an economic point of view. A storage may be expensive, but the return on investment fast if the NFC is very high. It may be also a technical indicator, especially for sensible storage, the module may have a degraded performance if the NFC is too low because the stand-by periods will be very long.

**Target:** The target is highly process and storage technology dependent. For batch processes in the industry, it may be as high as 1000 cycles per year. For district heating or greenhouses applications, the target is 50 to 150 cycles per year. For the application at site KZD2 the target is between 150 and 200 cycles per year. For seasonal storage, it may be very low, one to a few cycles per year.

**Source/Formula:**

$$NFC = \frac{Ecum}{Edischarge}$$

**Method for measuring:** Edischarge is the energy (kWh) discharged in the module in nominal conditions after cycling stabilisation. It can be the design energy (during studies) or the measured energy (when the module is installed and operated ).

The cumulative stored energy Ecum (kWh) is the energy discharged from the module during a given period of time (day/month/year). If the geothermal site has an annual cycle, it is better to do the calculation on a one-year period. This energy cumulates full and partial discharges. It can be the cumulative design energy (during studies) or the cumulative measured energy (in operation).

**Additional comments, if any: This criterion is valid for all storage systems type, i.e. sensible, latent and chemical, but has a low interest for seasonal storage.**

## 6. KPI: Heat-exchanger power ratio in % (HEPR)

**Relevant Work Packages:** WP4, WP6, WP7

**Rationale:** This ratio gives the difference between the real heat power and the design power delivered by the heat-exchanger at nominal conditions. This factor can vary during time because of fouling. It should be done at year zero (gives then the uncertainties of design model), then monitored during operation.

**Target:** HEPR should be close to 100% or higher than 100% when starting if fouling is probable. It may decrease in operation and is an indicator of fouling. Cleaning must be decided when the value is too low.

**Source/Formula:**

$$HEPR = \frac{P_{heatexchanger,measured}}{P_{heatexchanger,design}}.100$$

**Method for measuring:** Pheatexchanger,measured is the power (W) measured in the heat exchanger in the nominal conditions (clean or after some scaling). This power is measured on primary circuit side, and requires the measure of the flowrate, inlet and outlet pressures and temperatures, and a model of the HTF properties (enthalpy or specific heat capacity) versus pressure and temperature. It is also recommended for redundancy to do the same measure on the secondary side, using the same types of sensors.

Pheatexchanger,design is the power (W) calculated in the heat exchanger in the nominal conditions and for a clean surface (initial surface state).

## 7. KPI: Heat-exchanger differential pressure ratio in % (HEDPR)

**Relevant Work Packages:** WP4, WP6, WP7

**Rationale:** This ratio gives the difference between the real pressure drop in the heat-exchanger on primary side at nominal conditions and the design pressure drop. This factor can vary during time because of fouling. It should be done at year zero (gives then the uncertainties of design model), then monitored during operation.

**Target:** HEDPR should be close to 100% or lower than 100% when starting if fouling is probable. It may increase in operation and is an indicator of fouling. Cleaning must be decided when the value is too high.

**Source/Formula:**

$$HEDPR = \frac{DP_{heatexchanger,measured}}{DP_{heatexchanger,design}}.100$$

**Method for measuring:** DPheatexchanger,measured is the pressure drop (Pa) measured in the heat exchanger in the nominal conditions on brine side (clean or after some scaling). It is measured by a differential pressure sensor.

DPheatexchanger,design is the pressure drop ( Pa) calculated in the heat exchanger in the nominal conditions on brine side for a clean surface.

## 8. KPI: Heat-exchanger effectiveness in % (HEE)

**Relevant Work Packages:** WP4, WP6, WP7

**Rationale:** The effectiveness of a counter-flow heat exchanger represents the ratio between the thermal power actually exchanged and the maximum power theoretically exchangeable with the same inlet conditions if the heat-exchanger had an infinite surface of exchange.

**Target:** This criterion is very important when it is important to minimize the pinch DT of the heat-exchanger ($T_{hot,inlet}$-$T_{cold,outlet}$ or $T_{hot,outlet}$-$T_{cold,inlet}$) and can be in the range 80 to 90% in that case, but it means that the heat-exchanger will have a large surface and will be expensive. The criterion for KZD2's site is not so severe and will be in the range 65-75%.

**Source/Formula:**

$$HEE = \frac{(\dot{m}c_p)_{hot}(T_{hot\ inlet} - T_{hot\ outlet})}{(\dot{m}c_p)_{min}(T_{hot\ inlet} - T_{cold\ inlet})} * 100$$

$$with\ (\dot{m}c_p)_{min} = \min[(\dot{m}c_p)_{hot}, (\dot{m}c_p)_{cold}]$$

**Method for measuring:** $\dot{m}$ is the mass flowrate on hot (brine) or cold (water) side (kg/s). Cp is the fluid specific heat capacity (J/kg/K) on hot (brine) or cold (water) side. T is the temperature (K or °C) respectively on hot or cold side and inlet or outlet.

We need to measure the flowrates on brine and water side, pressure and temperature at the inlet and outlet on brine and water side. We need to have the thermal properties (enthalpy or specific heat capacity) versus P and T for the brine and the water.

## 9. KPI: Heat-exchanger scaling risk in % (HESR)

**Relevant Work Packages:** WP4, WP6, WP7

**Rationale:** This ratio between the residence time inside the heat-exchanger and the maximal allowed residence time provides the scaling risk in the heat-exchanger.

**Target:** This criteria should be far under 100%, in the range 0.5-5%, in order to be far away from the scaling conditions.

**Source/Formula:**

$$HESR = \frac{t_{heat-exchanger}}{t_{max,kinetics}} * 100$$

**Method for measuring:** theat-exchanger is the mean residence time in second in the heat-exchanger on brine side. It is calculated thanks to the nominal flowrate and the heat-exchanger brine volume provided by the heat-exchanger design.

tmax,kinetics is the maximal time in seconds before significant scaling at the outlet temperature, calculated from the brine content and the kinetics model developed in WP4.

**Additional comments, if any:** Through 3D modelling, it would be interesting to have also the local velocity and residence time and risk of local deposit.

10. **KPI: Efficiency of Silica Removal System with respect to the Solubility Value at the chosen temperature % (SRS_SV)**

**Relevant Work Packages:** WP4, WP7

**Rationale:** Reaching a $SiO_2$ value equal to the solubility limit would require a retention time with order of magnitude of days. In the silica removal system, there needs to be a balance between lower $SiO_2$ concentration and retention time needed and, consequently, the capacity of the system. To make the process both effective and scalable for further application, it has to be compact enough to be easily reproducible in full load plants

**Target:** Having a retention time of a few hours the target for the SRS_SV efficiency is set at 60%.

**Source/Formula:**

$$SRS_{SV} = \frac{SiO_{2\,input} - SiO_{2\,output}}{SiO_{2\,input} - SiO_{2\,solubility}(T)}$$

**Method for measuring:** The solubility of SiO2 with respect to temperature is a known value; the values of SiO2 concentration at the inlet and at the outlet of the retention system will be obtained collecting samples of fluid in sample ports that will be provided in the system.

11. **KPI: Efficiency of Silica Scale Suppression System % (SSSS)**

**Relevant Work Packages:** WP4

**Rationale:** Silica Scaling should not occur in down stream piping and reinjection well.

**Target:** SSSS needs to be near to 100% as much as possible.

**Source/Formula:**

$$SSSS = \frac{SiO_2\ scaling\ A - SiO_2 scaling\ B}{SiO_2\ scaling\ A}.100$$

Where, Scaling A = without SSSS, Scaling B = with SSSS

**Method of Measuring:** There are two methods: 1) Direct method. Scaling products are extracted, at the end of testing period or maintenance inspection from the material (stream piping, reinjection well etc.), and quantified with standard analytical instruments (common in failure analyses). The amount of scaling product is compared to the reference sample without SSSS. 2) Indirect method. Change in aqueous SiO2 concentration can be measured before and after SSSS. This indicates how much of SiO2 is contributing towards formation of silica scaling and how efficient is SSSS.

### 12. KPI: <u>Reduction rate of melting enthalpy % (RRME)</u>

**Relevant Work Packages:** WP2

**Rationale:** Degradation causes reduction rate of melting enthalpy.

**Target:** <10%/year.

**Source/Formula:**

$$RRME = \frac{\Delta h_{initial} - \Delta h}{\Delta h_{initial} \cdot \Delta t_{liquid}} \cdot 100$$

Where,
$\Delta h_{initial}$ is the initial melting enthalpy of the PCM
$\Delta h$ is the melting enthalpy of the PCM after an amount of time $\Delta t_{liquid}$ in liquid state of the PCM
**Method of Measuring:** Samples of the PCM are taken after filling the storage tank and during operation. The melting enthalpy of the samples is determined by DSC measurement. The time amount in the liquid state is determined from the previous operating temperatures of the storage up to sampling.

### 13. KPI: <u>Corrosion rate (CR) of PCM module material</u>

**Relevant Work Packages:** WP2

**Rationale:** Corrosion rate is a significant KPI.

**Target:** <1mm/year.

**Source/Formula:**

$$CR = \frac{(K \times W)}{A \times T \times D}$$

Where,

*T* is the time of exposure in hours

*A* is the area in $cm^2$

*W* is the mass loss in grams

*D* is the density in $g/cm^2$

*K* is a constant

**Method of Measuring:** The total surface area of the specimen (making corrections for the areas associated with mounting holes) and the mass lost during the tests are determined. This measurement is done following the ASTM G1-03 standard.

14. **KPI: Adhesion of coating to substrate (MPa)**

**Relevant Work Packages:** WP4

**Rationale:** Adhesion of coating to substrate is applicable when continuous layer of scale is formed.

**Target:** <4 MPa

**Source/Formula:**

$$Adhesion = \frac{Load\ at\ failure}{Area}$$

**Method of Measuring:** Adhesion of coating to substrate is measured using Portable Adhesion Testing (PAT) following the standard ASTM D4541 – 17. Dollies are glued to the coated surface and a perpendicular force to the surface is exerted in an effort to remove both the dolly and the coating from the substrate. The load at failure is recorded as well as the type of failure.

## 3.3 Non- Technical KPIs

1. **KPI: Heat storage cost in €/kWh (HSC)**

**Relevant Work Packages:** WP2, WP6, WP7

**Rationale:** This KPI is an indicator of the economic interest of a storage system, it will allow studying it on an economic point of view. A storage may be performant but too expensive.

**Target:** The target is scale dependant; the cost versus energy has an exponential shape towards very small scales. It is also technology dependant. For the module alone, the target is 30-50 €/kWh for thermoclines and 50-70 €/ kWh for steam accumulators (with no $CO_2$ impact) and for size larger than 5 MWh. For PCM modules, the target is 100-200 €/kWh. For the modules fully installed on site, it is more difficult to propose a target because it is site dependent.

**Source/Formula:**

$$HSC = \frac{Cost, design}{Edischarge, design} \; or \; \frac{Cost, measured}{Edischarge, measured}$$

**Method for measuring:** We can define 2 costs. One is the cost of the module alone, it will be the reference cost for this KPI. In the case of PCM module, it includes the cost of the module and of the PCM material. The second one is the cost (€) of the module ready for operation (including site preparation, auxiliaries, measures, insulation, control….etc) provided by a model (during studies) or by real costs (after manufacture and installation).

Edischarge is the energy (kWh) discharged from the module in nominal conditions after cycling stabilisation. It can be the design energy (during studies) or the measured energy after commissioning.

**Additional comments, if any: This criterion is valid for all storage systems type, i.e. sensible, latent and chemical.**

2. **KPI: Obtainable Economic Gain from the overall HX + RT system (OEG index )**

**Relevant Work Packages:** WP4, WP7

**Rationale:** Ratio between the economic value of the amount of energy saved and the cost of the system.

**Target:** OEG should be at least 1.2 to justify the investment.

**Source/Formula:**

$$OEG = \frac{Energy\,Price * MWh_{obtained}}{Cost\;\; overall\, system}$$

**Method for measuring:** The KPI should be evaluated on a period of 10 years, where the income is the value of heat recovered during the chosen period and the overall cost is the CAPEX and OPEX. It is important to highlight that scaling up the system will result in an higher OEG index: with higher amount of brine the energy obtained increases linearly while costs increase less.

3. **Number of Open Access Journal Articles**

**KPI:** Number of open access journal publications on novel concepts for the synergistic hybridization of geothermal systems with biomass and concentrating solar thermal.

**Rationale:** The synergistic hybridization of geothermal with biomass and concentrating solar thermal has the potential to reduce capital costs by the sharing of components (e.g. the power block), prolong the usefulness of declining geothermal fields through the addition of additional heat (e.g. to restore the enthalpy to the power block to its design conditions), and to compensate for seasonal variations inherent to each technology (e.g. the electrical output from geothermal power plants tends to peak in the winter while that from concentrating solar thermal power plants tends to peak in the summer).

Current challenges to hybridization include the need for co-location of geothermal and biomass and/or solar resources, and the need for methods to integrate these resources in a manner that does not lead to the large destruction of exergy due to very different characteristic temperatures (e.g. using biomass to drive a Organic Rankine Cycle with a relatively low Turbine Inlet Temperature and thermal efficiency as opposed to a Gas Turbine with a relatively high Turbine Inlet Temperature and thermal efficiency).

**Target:** 2

**Source/Formula:** Count

**Method for measuring:** Number of open access journal articles on this topic.

### 4. Number of Trained Early Stage Researchers

**KPI:** Number of Early Stage Researchers (ESRs) trained on geothermal hybridization, integration, and policy.

**Rationale:** The extent to which geothermal contributes to Europe's energy and economic transitions will in part depend on the extent to which new European ESRs with expertise in geothermal hybridization, integration, and policy are trained to world class standards.

**Target:** 1

**Source/Formula:** Count

**Method for measuring:** Number of PhD degrees in the area of geothermal hybridization, integration, and policy resulting from GeoSmart research.

### 5. Master level theses related to WP8

**KPI:** Master level theses related to WP8.

**Rationale:** The exposure to graduate students in these type of research projects is vital to further enhance the relevant skills to thrive in the renewable energy industry.

**Target:** 2

**Source/Formula:** Count

**Method for measuring:** Number of master level theses submitted.

# 4 END USER SPECIFICATIONS

A Geothermal Energy Product is an energy commodity that is saleable in an established market. Examples of Geothermal Energy Products are electricity and heat. Other products, such as inorganic materials (e.g silica, lithium, manganese, sulphur, zinc), gases or water extracted from the Geothermal Energy Source in the same extraction process do not qualify as Geothermal Energy Products.

The following sections cover the end user specifications for Kizildere II site and Insheim site.

## 4.1 Kizildere II site

The objective of this section is to define the basis for the design of the power plant for the Kizildere II Geothermal Power Plant. The details mentioned will ensure that the plant design and construction will meet specific goals such as a high level of reliability through component redundancy, quality construction implementation, quality equipment selection, plant maintainability, safety, and operational flexibility and efficiency through equipment arrangement and convenient access.

The project is a nominal 80 MW gross geothermal power plant in Denizli Province, Turkey. The project is located in western Turkey, approximately 185 km from the Aegean Sea. The nearest major port is Izmir. Good road and rail transportation are available in close proximity to the site. Site elevation is 155 meters above sea level. Ambient wet and dry bulb temperatures at the site vary from approximately -1 C to 41 C. Annual average rainfall is approximately 572 mm. Structural design is based on the greater of calculated static and dynamic loads imposed throughout the potential operating range of the equipment, and also incorporate additive live, wind, and seismic loads. Power will be generated at 15 kV at the turbine generator terminals and stepped up through the GSU Transformer to utility transmission voltage of 154 kV. Power factor at the generator terminals will be between 0.95 leading and 0.85 lagging.

Project major equipment and/or systems will include the following:

- Gathering and Separation System
- Turbine Generator and Lube Oil System
- Main Steam System
- Non-Condensable Gas Removal System
- Cooling Tower and Circulating Water System
- Component Cooling Water System
- Compressed Air System
- Fire Detection and Protection
- Chemical Treatment System
- Miscellaneous Process Drains
- 154kV System and 154 kV breaker
- Generator Step-up Transformer
- Generator Breaker
- Generator and Exciter
- Relay Protection and Metering
- Auxiliary Transformers
- Medium Voltage and Low Voltage Distribution System

- Critical Power DC and Secure AC Power System
- Plant Control System
- Building Structure
- Other Balance of Plant Equipment

### 4.1.1 Codes and Standards

As a minimum the Works shall comply with the current editions, at the Effective Date, of relevant internationally recognized Codes, Standards and Regulations. Specific dates and revisions of Codes, Standards and Regulations shall be identified on issued drawings and specifications. The Architectural portion of the project will comply with the Turkish Building Code. Codes and specifications from the following list will be preferred over alternative codes:

| Designation | Regulatory Body, Administering Association, Society or Institution |
|---|---|
| ACI | American Concrete Institute |
| AFBMA | Antifriction Bearing Manufacturer's Association |
| AGMA | American Gear Manufacturer's Association |
| AISC | American Institute of Steel Construction |
| ANSI | American National Standards Institute |
| API | American Petroleum Institute |
| ASCE | American Society of Civil Engineers |
| ASHRAE | American Society for Heating, Refrigeration and Air Conditioning Engineers |
| ASME | American Society of Mechanical Engineers Boiler and Pressure Vessel Codes |
| ASNT | American Society for Non-destructive Testing |
| ASTM | American Society for Testing and Materials |
| AWS | American Welding Society |
| AWWA | American Water Works Association |
| BS | British Standard |
| CTI | Cooling Tower Institute |
| EJMA | Expansion Joint Manufacturer's Association |
| HEI | Heat Exchanger Institute |
| HI | Hydraulic Institute |
| IEC | International Electrotechnical Commission |
| IPCEA | Insulated Power Cable Engineers Association |
| ISA | Instrument Society of America |
| ISO | International Organisation for Standardisation |
| JEC | Japanese Electrotechnical Committee |
| JEM | Japan Electrical Manufacturers' Association |
| JIS | Japanese Industrial Standards |
| NACE | National Association for Corrosion Engineers |
| NEC | National Electrical Code |
| NEMA | National Electrical Manufacturer's Association |
| NESC | National Electric Safety Code |
| NETA | National Electrical Testing Association |
| NFPA | National Fire Protection Association |
| OSHA | USA Department of Labour Occupational Safety and Health Act |
| SSPC | Steel Structures Painting Council |
| TEMA | Tubular Exchanger Manufacturer Association |
| TS | Turkish Standard |
| UBC | Uniform Building Code |

| | |
|---|---|
| UFC | Uniform Fire Code |
| UL | Underwriters Laboratories Inc. |
| UPC | Uniform Plumbing Code, International Association of Plumbing and Mechanic Officials |

## 4.1.2 Site Specific Conditions

All equipment supplied will be suitable for installation and service under the following conditions.

| **Meteorological Information** | |
|---|---|
| Dry Bulb Temperature<br>Design Temperature, Minimum Design<br>Temperature, Maximum | <br>-1 C<br>41 C |
| Wet Bulb Temperature<br>Range<br>Cooling Tower Design | <br>-1 to 24 C<br>13.0 C |
| Altitude of Site Above Sea Level | 155 meters |
| Atmospheric Pressure | 0.995 bara |
| Average Annual Rainfall | 572 mm |
| | |
| **Temperature & Humidity Controlled Environment Conditions** | |
| Design Temperature | |
| Office, Electrical Equipment Rooms | 23.5 C dry bulb |
| Battery Room | 25 C dry bulb |
| Max Temperature Variance (all rooms) | $\pm 2$ C |
| Humidity | |
| Design Humidity | 55 % RH maximum |
| Max Particulate Concentration | $30 \times 10^{-6}$ g/m$^3$ |
| **Electrical & Control Equipment Room Filtration** | |
| Maximum Gaseous Levels | |
| $H_2S$ | 0.003 ppm TWA (time weighted average) |
| $Cl_2$ | 0.002 ppm TWA |
| $SO_2$ | 0.001 ppm TWA |

## 4.1.3 Plant Performance

Following criteria covers the plant performance indicators:

### 4.1.3.1 Performance Guarantees

The plant will be designed to run on a continuous basis for a gross power output of not less than 60,000 kW at the generator terminals at the following design conditions:

- Gathering system interface enthalpy equal to 978 KJ/kg and flow of 3.6 tons/h

- Wet bulb temperature of 13 C
- Interface non-condensable gas (NCG) content in brine of 2.5 wt% NCG of the total brine plus NCG flow.
- Power factor of 0.85 at the generator terminals.

#### 4.1.3.2 Design Life

All equipment will be designed and selected for continuous duty service with an anticipated plant operational life of 30 years. The expected wear life of expendable, consumable and wear parts will be consistent with good design practice for the particular service and fluid handled.

#### 4.1.3.3 Operating Conditions

For the purpose of analyzing system components the produced geothermal fluids and circulating water are expected to exhibit the following characteristics:

| Brine Characteristics | |
|---|---|
| NCG in Brine | 0.6 % wt |
| Salt content | 5000 mg/kg |
| | |
| HP Steam | |
| NCG in HP Steam | 5.5 % wt |
| | |
| IP/LP Steam | |
| NCG in IP Steam | 0.5 % wt |
| NCG in LP Steam | 0.01 % wt |
| Noncondensible Gas (NCG) Composition | |
| Carbon Dioxide ($CO_2$) | 99.5 % |
| Hydrogen Sulfide ($H_2S$) | 0.03 % |
| Molecular Weight | 19.44 g/mol |

Conditions that will impact the performance of the plant are brine inlet enthalpy, ambient wet bulb temperature and NCG content in the brine.

Ambient wet bulb temperature fluctuation will impact the performance of the cooling tower and thus the cooling water temperature. Higher wet bulb temperatures will result in higher cooling water temperature to the condenser and therefore a higher condenser pressure and lower turbine generator output and vice versa.

NCG content above the design point will reduce the evacuating capability of the NCG system resulting in higher condenser pressure and lower turbine generator output.

### 4.1.4 Plant Design

Following criteria covers the plant design indicators:

#### 4.1.4.1 Equipment Design Considerations for Geothermal Environments

$H_2S$ is likely to be present around the site in concentrations of some 5-10 ppm. Concentrations above 0.3 ppm are unacceptable for exposed copper conductors, and concentrations down to 0.1 ppm have adverse effect on silver-plated connectors and conductors. Rapid tarnishing of these and other materials occurs in this atmosphere.

Enclosures for electrical and instrumentation equipment shall be as follows:

- Inside air conditioned, H2S-filtered spaces - IP 41
- All other locations - IP 65

Where any enclosure is located outdoors, such cabinet or enclosure shall be manufactured from stainless steel (type 316), and shall be provided with stainless steel door clamps on three sides of the door to assure a watertight seal.

A cabinet or enclosure for the purpose of this definition shall include the cabinet panels, cabinet fasteners, cabinet hardware (including hinges, locks, handles, cable glands or pipe glands) and any support structure or cabinet sub-frame assembly. Such cabinets or enclosures include, but are not limited to, instrument cabinets and electrical cabinets. Holding-down bolts, nuts and washers for cabinets, instrument stands and the like, shall be hot dip galvanised carbon steel, except on the cooling tower where they shall be stainless steel type 316. Holding down bolts shall be installed into concrete using an epoxy chemical set anchor system. Mechanically fixed anchor bolts shall not be used.

No equipment including bus-bars, links, terminals, fittings, circuit breakers, contactors, relays, contacts, and the like, is to be made in whole or in part of silver, nickel-silver, copper, phosphor-bronze, brass, or other copper or silver alloy, unless hermetically sealed or tin plated to a minimum thickness of 0.005 mm, or otherwise suitably plated. Cadmium plating shall not be used for any purposes including screws and fastenings.

Circuit boards shall be tinned and lacquered, except over gold-plated areas used as connectors. The lacquer shall be applied to both sides to an approved (preferably international) standard to give the best possible protection against hydrogen sulfide, humidity and dampness. The lacquer used shall be inert to attack from fungi, bacteria, atmospheric conditions and sunlight (including UV component) and shall have proven suitable and stable properties for at least 15 years maintenance-free service under the conditions specified.

Where any equipment is to be located outside the main powerhouse and utilises a fastener or fasteners which must be removed or undone to allow access to the equipment for servicing or maintenance, such fastener or fasteners shall be manufactured from stainless steel type 316. This includes equipment which will be located inside outdoor cabinets. Fasteners for the purpose of this definition include, but are not limited to, nuts, bolts, machine screws, set screws, washers, clamps, U-bolts and the like. Typical items which must meet this requirement are:

- Motors
- Valve actuators
- Instruments, including transmitters
- Fire fighting equipment
- Lighting

- Electrical outlets
- HVAC heat rejection modules, and
- Public address and telecommunications systems equipment

"ZeRust", or equal, corrosion inhibitor capsules shall be placed in all enclosures, junction boxes, instruments, size to suit in each case. 100% spare capsules shall be provided.

The use of proven corrosion protection fluids to protect exposed metallic surfaces on valves, motors etc. is required, where applicable.

#### 4.1.4.2 System Outlines

The following are the major systems of the plant:

- Gathering and Separation System

The gathering system collects brine from the production wells. Brine is flashed to high pressure (HP), intermediate pressure (IP), and low pressure (LP) steam, with the flashed steam passed to the turbine and the flashed brine returned to injection wells.

- Turbine Generator and Lube Oil System

The turbine-generator will have an HP section as well as separate IP/LP section, each section top exhausting to separate condensers. Each HP, IP and LP inlet is equipped with main stop valves (MSVs) and governing valves (GVs).

The oil system provides low-pressure lube oil at the appropriate temperature to the journal bearings of the turbine, generator, turbine thrust bearing, and turbine turning gear. In addition, the oil supply system provides high-pressure oil to hydraulically operate the MSVs and GVs. High-pressure oil is also used for the control oil system at a reduced pressure. The control oil system provides a hydraulic trip circuit for the turbine. Oil is stored in a main oil tank. Under normal operation, a turbine shaft-driven oil pump provides high-pressure oil; low-pressure lube oil is provided by passing the high-pressure oil through an ejector within the main oil tank. Under startup conditions, a backup two- stage AC-motor-driven oil pump provides both high-pressure control oil and low- pressure lube oil. During emergency conditions, a backup DC-motor-driven oil pump provides low-pressure lube oil. An oil purifier keeps the oil system water free.

- Main Steam System

The Main Steam System receives HP, IP and LP steam from the gathering system and transports it to the turbine, gland steam and non-condensable gas removal ejectors at the designed pressure and quality. Steam piping and system components are protected from overpressure by a series of pressure control valves and rupture disks at the steam pressure control station. The main steam HP, IP and LP flows are metered by venturis. Steam traps placed at appropriate intervals remove condensation from the piping. There will be provision for future water injection into the main steam line to scrub out contaminants or wash the turbine blades.

- Non-Condensable Gas Removal System

Non-Condensable Gas (NCG) Removal System consists of a single train where the NCG is drawn from the gas cooler sections of the LP main condenser using steam jet ejectors and vacuum pumps (or compressors), in series. 100% load is defined as NCG content in brine of 3 weight % NCG of the total brine plus NCG flow. A two-stage removal process transitions the gas pressure from a vacuum to above atmospheric pressure. The first stage consists of ejectors and associated intercondenser(s), where the ejector motive steam is condensed by a cooling water spray. Condensed steam and cooling water is returned to the condenser via control valves to maintain an appropriate level in the intercondenser. The second stage consists of vacuum pumps with a backup ejector. The discharge pressure of the second stage is sufficient to allow the non- condensable gases to be routed to the atmosphere by the cooling tower exhaust fans.

- Cooling Tower and Circulating Water System

The circulating water system consists of an evaporative cooling tower, which serves to supply cooling water to condense steam exhaust from the turbine in the steam condensing and gas cooling zones, and to cool auxiliary plant systems. Condensate drops to the hotwells while the cooled NCG is extracted from the top of the gas cooling zone with steam jet ejectors. Hotwell pumps transfer hot water from the condenser to the cooling tower, where the water is cooled and returned to the condenser. Steam exhaust from the turbine is condensed in a direct contact, spray-jet-type main condenser. Cooling water is drawn in by the IP/LP condenser vacuum and is directly sprayed into the condenser by vertical columns housing spray nozzles. The HP condenser operates above atmospheric pressure, and thus the cooling water for the HP condenser is supplied from the IP/LP hotwell pumps. A condenser cooling water control valve admits cooling water flow into the condenser and water level is maintained by the hotwell pumps. The cooling tower will be a mechanically induced draft, counterflow design utilizing low clog film fill. Structural members will be FRP.

- Component Cooling Water System

In addition to the circulating water system, the cooling tower basin serves to supply and return cooling water for the Component Cooling Water (CCW) System. Two 100- percent capacity CCW pumps provide sufficient cooling water pressure to all components in the system consisting of NCG system intercondensers, compressors, vacuum pump, and heat exchangers. One pump operates continuously; with the redundant pump capable of automatic start should the operating pump fail or the system pressure become abnormally low. Manually operated valves are used to balance pressure and flow at the individual components of the system.

- Compressed Air System

Two 100 percent capacity air-cooled, oil-free, rotary air compressors provide instrument and service air to the plant. The compressor integral control packages will be capable of alternating lead/lag roles.

The air compressor takes in air through an inlet dust-and-chemical filter to reduce the quantity of hydrogen sulfide ($H_2S$) entering the compressed air system. Compressed air is stored in a receiver which supply air based on the demands from the plant systems and a single twin desiccant dryer treats the instrument air from the air receiver. The dryer is equipped with pre-filters and after-filters. Instrument air will be dried to dew point -40 $^{o}$C. The service air header is automatically isolated from the system by a control valve if the instrument air header pressure drop below a set point. This preserves the air pressure within the station air receivers for the instrument air system during an emergency.

- Fire Detection and Protection System

The fire detection and protection system provides a means to detect, extinguish and control fires within the plant. A firewater tank and NFPA designed fire pump system will be required. A manually actuated spray nozzle system protects the turbine generator bearing areas. A wet pipe sprinkler system protects the turbine lube oil tank, hydraulic power unit area, and GSU transformer. Strategically located hydrants and stand pipes on and around the cooling tower and within the power house provide additional protection. Dry chemical portable extinguishers are supplied to provide coverage of areas such as the electrical rooms, relay, and battery rooms in accordance with NFPA guidelines. A stand alone fire detection and alarm system that is capable of interfacing with the Control System will be provided for all building areas. The non-flammable fiberglass cooling tower will not require a fire protection system.

- Chemical Injection System

The Chemical Injection System is designed to control the microbiological activity and pH of the circulating, auxiliary cooling water, and condensate reinjection systems to maintain their optimum performance and material protection. Treatment of the cooling water is achieved by metered injection of organic biocide and sodium hypochlorite (bleach) for microbiological control, caustic soda solution for pH control, and oxygen scavenging or corrosion inhibitor for corrosion control.

- Condensate Reinjection System

The condensate reinjection system will consist of “cold” injection to control the cooling tower water level. Condensate at the discharge of the hotwell pumps will be pumped to a dedicated injection well.

- Miscellaneous Process Drains

The Miscellaneous Drains system transports and disposes of process and drainage fluids from the power plant to various locations. Liquids collected upstream of the turbine generator main stop valves (MSV) in either the low point condensate drip pots and steam traps will be discharged to a flash pipe, which is cooled by CCW. Liquids collected downstream of the MSV and gland steam pressure control valve will be discharged to the condenser drain and flash tank.

- Domestic and Waste Water System

All process drains will be recovered and recycled through the circulating water system and will eventually be reinjected through the injection wells. Oily water and wastes from containment areas such as transformers, turbine lube oil, utility station sinks, and housekeeping floor drains will be directed through an oily water separator where the effluent will be discharge through the leach field and the separated oily waste temporary stored on site and eventually taken off site for treatment and/or disposal through approved facility contracted by the Owner.

Drains from bathrooms and sinks are led to a septic tank. This drains to a leach field.

Drinking and usage water will be supplied from the Kizildere Village drinking water network and the amount of water consumption is estimated as 3000 L/day.

- 154kV System

Provides equipment necessary for connection to the grid so that power can be exported to the grid as well as importing power during startup operations. Equipment includes transmission line takeoff structure, disconnect and earthing switches, voltage and current transformers, surge arresters, 154kV breaker with associated bus work connecting to the HV terminals of the GSU Transformer. Redundant revenue metering, protection relaying and associated synchronizing control for the 154kV breaker are included within this system. The 154KV system will be designed by others.

- Generator Step-up Transformer

Generator Step-up Transformer provides transformation of 15kV generator voltage to 154kV interface. Planning studies by utility will provide upper limits for the impedance. Transformer temperature rise will be 65 degrees C. Transformer rating will accommodate requirements of spare capacity.

- Generator Breaker

This equipment will provide for connection of the low voltage side of the GSU Transformer to the Generator Line terminals and will be designed to accommodate the systems short circuit duty as well as the full load ampacity requirements. Generator breaker will be provided with earthing switch and associated current and voltage transformers necessary for the protection, metering and synchronizing of the system.

- Generator and Exciter

Generator will be provided with Turbine appropriately sized to deliver 60 MW at generator terminals. Generator auxiliary equipment will be provided with machine sized and rated to assure equipment reliability and protection of operating equipment as per Contract requirements. These auxiliaries will include Line Side and Neutral Side Termination Compartments, Neutral Earthing Transformer with associated resistor, Line Side Potential Transformers and Surge Arrestor.

- Relay Protection and Metering

Relay systems will be designed to be consistent with recommended practices. Any specific requirement detailed for protection will be included in the protection scheme. Synchronizing will be provided across the generator breaker and the 154kV breaker with consideration for control interlocks of the Generator Step-up Transformer load tap changer. Revenue metering will be provided at the 154 kV point of interconnection.

- Auxiliary Transformers

Transformers will be provided to transform from the 15 kV system to 6300 volts and from 6300 volts to 400 volts. Transformers will be provided with spare capacity as required as a percentage of calculated normal operating loads. Auxiliary transformers primary and secondary terminals will be connected to their respective distribution equipment via cable systems.

- MV and LV Distribution System

All MV and LV Distribution Equipment will be located in the electrical building. Conditioned air will be provided for this space to mitigate the $H_2S$ environmental concerns for electric equipment and devices.

Medium voltage distribution equipment will include Switchgear and Motor Control Centers rated for the calculated load currents and short circuit capability as required. Switchgear will be provided with arc resistant features and coordinated with building design for adequate venting. Low voltage distribution equipment will include Switchboards and Motor Control Centers rated for the calculated load currents and short circuit capability as required.

- Critical Power Systems

Project critical power systems will include AC UPS power supply for control system components requiring clean and reliable power. DC power will be provided for control system components as well as plant protection system which requires DC power (Emergency Oil Pump). Batteries will be located in separate room from the Electric Equipment Room, where redundant battery chargers are located.

- Plant Control System (PCS)

Plant Control System will be based on a (TBD) platform. Upon completion of the programming there should be spare capacity per Multi-Loop controller and spare I/O capacity per control unit. The control system uses redundant power supplies, redundant multi-function processors, and redundant data highways. Refer to the I&C Design Criteria for additional information.

Plant design will encompass those practical features that will enhance the availability and reliability of each system and of the plant as a whole. Factors to be taken into consideration will be the ability to isolate components for maintenance, accessibility of equipment for maintenance and local, as well as remote, control stations.

Adequate redundancy or standby capability shall be provided for auxiliary components that would cause an electrical shutdown by their failure. Redundancy for the facility electrical system will be compatible with the mechanical systems. The following table specifies major equipment redundancy required:

| **Component** | **Number Required/Redundancy** |
|---|---|
| Hotwell Pump | 2 – 50%, each condenser |
| Component Cooling Water | 2 – 100% |
| Condensate Reinjection Pump | 2 – 100% |
| Air Compressors | 2 – 100% |
| Instrument Air Dryer | 1 – 100% (Dual Tower Unit) |
| Air Receiver | 1 – 100% (minimum 20 minutes operating reserve) |
| Chemical Injection Pumps | 2 – 100% |
| Turbine Lubricating Oil Pump | 1 – 100% (Turbine Shaft Driven)<br>1 – 100% (AC Power)<br>1 – 100% (DC Power) |

| | |
|---|---|
| Cooling Tower Basin | 5 hours at zero blowdown reserve |
| Main Transformer | 1 x 100% |
| Control System | Redundant processors for each drop<br>Redundant power supplies for each drop<br>Redundant power sources for each drop |
| Battery Chargers | Redundant sources |

#### 4.1.4.3 Materials

All materials and equipment furnished

1. Shall be new, unused, and undamaged when installed or otherwise incorporated into the Works and properly identified by appropriate stampings and markings and shall be accompanied with original manufacturer's documentation where appropriate.
2. Shall be of industrial type suited for their intended function, specifically geothermal service.
3. Shall possess acceptable resistance to the type of corrosion generally encountered in geothermal facilities and a marine environment.

The following materials shall not be used under any circumstances:

- Cadmium
- Silver
- Electroplated zinc coated carbon steel (if outside)
- Asbestos
- Cupronickel
- Chromium
- Paint containing lead or chromates
- Chlorinated solvents and thinners
- Halon and other chlorinated fluorocarbons
- Heavy metals, including mercury and arsenic
- PCBs or other similarly hazardous materials

All components exposed to the circulating water will be stainless steel, FRP, or other materials not susceptible to corrosion. MSDS sheets will be provided for chemicals that will be used in the plant. Exposed FRP and PVC will be provided with UV protection.

#### 4.1.4.4 Tie-ins and Interfaces

The primary electrical interconnections with the plant will be the 154kV interconnection with the utility.

The primary mechanical interconnections with the plant will be the gathering system, condensate injection and electrical power transmission system and Plant Power Distribution system interfaces.

#### 4.1.4.5 Health, Safety and Environment

Near field noise level for the power plant and balance of plant equipment at 1 meter and no less than 1.2 meters above floor level from any surface of operating plant item shall not exceed an A-weighted sound pressure level of 85 dBA.

Buildings, process areas, work areas and outlying areas including roadways will be provided with minimum lighting levels in accordance with IES guidelines. Lighting will generally be designed to be efficient as well as provided a safe and comfortable work environment.

The plant shall be designed such that hazards to operators are to be avoided utilizing industry guidelines and good engineering practice.

Platforms shall be provided at all major pieces of equipment requiring regular operational and maintenance. Platforms shall be sized and positioned that no routine maintenance task requires an operator to reach off the platform or to step off the platform onto equipment or piping. Platforms shall be access either by ladder or stairway. Any platform used for routine tasks shall be provided with stairway access. A routine task shall be any task which requires one or more operators to use the platform daily.

All platforms, stairs, and ladders shall be in accordance with the requirements of the Occupational Safety and Health Administration. Platforms, stairs, and ladders shall be constructed of hot dip galvanized steel.

Plant design shall avoid interference with walkways, particularly from structural steel, piping, and equipment which cause trip hazards and narrow passageways.

Site roadways shall be clearly defined. Plant equipment shall be sufficiently set-back from transportation and access routes to avoid interference with site traffic. If this is not possible, warning signs for workers and visitors for these areas shall be clearly defined. Sufficient measures shall be taken to protect any equipment that must be located close to a transportation route (i.e. bollards, parking curbs, fencing, etc.).

All newly constructed open concrete storm ditch and all existing ditch that will be demolished and reconstructed will be supplied with grating cover over the opening. For storm ditches that cross roadways, the grating will be traffic rated. For all other storm ditch, the grating will be rated for pedestrian traffic.

Electrical equipment spacing in switchgear rooms will be in accordance with IEC standards.

Standard requirements for operations' personnel's use of Personal Protective Equipment (PPE) will be given consideration in plant design and requirements will be so noted in operation manuals as well as necessary signage provided in the affected areas requiring PPE.

Electrical distribution equipment which incorporates explosion venting for the safe operation of interrupting fault currents will provide appropriate duct work to direct the blast to a safe area.

Transformers will be provided with adequate oil containment in the event that a leak should occur. Containments will be sized with appropriate safety factors and proper consideration will be given for the drainage of such containments.

$H_2S$ carried with the steam is removed in the condenser and passed to the gas removal system. Approximately 4.9 kg/h of $H_2S$ is discharged into the atmosphere by mixing it with air exhausted by the cooling tower fans. All process drains will be recycled into the circulating water system and eventually reinjected through the condensate reinjection system. Oily water will be directed through an oily water separator before the effluent is discharged through the existing leach field while the separated oil will be temporary stored on site and then taken off-site for treatment. Sanitary waste will flow to a septic tank and the effluent is discharge to the leach field. Stormwater will be collected through trenches and directed to existing settling basins.

Siltation, runoff and erosion of soils shall be adequately controlled. Earthworks and spoil disposal shall be carried out in a manner to minimize erosion and siltation.

Plant fire protection and life safety features will be considered in the plant layout and be designed in accordance with local codes and permits requirements.

#### 4.1.4.6 Constructability, Maintainability and Operability

The facility will be laid out to accommodate the spaces required to service equipment as well as to maintain and operate the plant. Access aisles and clearance will be provided for operation, maintenance, inspection , and equipment removal. Provisions will be made for personnel walkways including doors, stairs, landings, ladders, and other approved access means.

The plant will be arranged to facilitate the economic performance of maintenance activities with appropriate use of:

- Overhead Bridge Crane
- Mobile Cranes
- Forklifts
- Monorails

#### 4.1.4.7 Shutdown Philosophy

Shutdown philosophies will be followed during design to provide failsafe features and allow an orderly and safe shutdown of the various systems and equipment.

Plant tripping logic will be identified in the Interlock Logic diagrams.

Electrical system does not provide redundant equipment for the 154kV, 15 kV, 6300 volt and 400 volt equipments. Upon loss of any of this equipment, means will be provided to safely disconnect the generator as well as shutdown the plant in a safe manner.

### 4.1.5 Construction Specifications

All construction specifications will be issued in accordance with PEI standards and will be in either CSI or PEI format. All codes and standards referenced will be from US standards organizations following the guidelines set forth in this document. If the contractor requests substitutions to the codes, the Owner will determine if they are equivalent to their US counterpart and acceptable as an alternative.

The contractor shall submit project or "Product" documents according to the relevant submittal schedules contained in the equipment and construction specifications. These submittals will be reviewed and accepted by the Owner. If the Contractor should choose to use suppliers that are not pre-approved, the Owner will determine if they are acceptable alternatives.

Construction or "Execution" procedures contained within the construction specifications are based on US industry standard practices. Any alternative procedures proposed by the Contractor will be reviewed and accepted by the Owner.

Civil construction specifications will be developed for the project contractor to use during project execution. The Specification will be in CSI or PEI format and will be based on PEI standards. U.S. codes and standards will be referenced. Contractor request for substitution of codes and standards will be determined by ZORLU to be acceptable or unacceptable; products indicated in specifications will be based on U.S. suppliers. ZORLU will determine if alternative product submittals are equivalent and/or acceptable. Construction methods indicated in specifications will be based on U.S. practices. ZORLU will review proposed deviations from specified methods and determine if the deviation meets the intent of the specification.

Minimum requirements for the geotechnical investigation and report are included in the attached design criteria document and the geotechnical evaluation specification. The aspects of the geotechnical report that are most relevant from the civil perspective are any recommendations for road section construction, drainage, excavation and shoring, and general earthwork including, backfill materials and compaction. The geotechnical evaluation will present the recommendations for the items mentioned above and other relevant civil aspects will be incorporated into the overall civil plant design.

A topographic map of the entire project area will be prepared with additional detailed topographic mapping done at specific sites as required for design. A network of horizontal and vertical control monuments will be established throughout the project area.

#### 4.1.5.1 Instrumentation and Control Construction Specification

An Instrumentation and Control (I&C) construction specification will be developed by PEI for the project contractor to use during project execution. The specification shall outline required codes and standards to follow, allowable vendors to supply I&C equipment and instrumentation products and requirements for those products, and required installation practices to follow while installing I&C equipment and instrumentation. The I&C construction specification shall be based on PEI or CSI standard format.

The construction specification will reference US codes and standards. If the contractor requests a substitution to these standards Engineer will request Zorlu's assistance to verify if the substitution is equivalent and acceptable per Turkish standards. I&C equipment and instrumentation product selection within the construction spec will reference industry standard suppliers. Product submittals by contractor from non-industry standard products will require Zorlu's assistance for review of product compliance with the specification requirements.. If contractor submits an alternate supplier to those listed in the specification Engineer will request Zorlu's assistance to verify if the alternate supplier and their product is equivalent to the one specified based on Zorlu's experience. The execution and installation practices defined within the specification will conform to industry standard practices. If the contractor recommends different execution practices than those defined within the spec Engineer will request Zorlu's assistance to confirm that the modified practices meet the intent of the specification and conform to local practices.

## 4.1.6 Electrical Installation Specifications

An electrical construction specification will be developed by PEI for the project contractor to use during project execution. The specification shall outline required codes and standards to follow, allowable vendors to supply electrical products and requirements for those products, and required installation practices to follow. The construction specification shall be based on PEI or CSI standard format.

The construction specification will reference US codes and standards and if the contractor requests a substitution to these standards it will be Zorlu's responsibility to verify if the substitution is equivalent and acceptable. Product selection within the construction spec will reference US suppliers. Product submittals by contractor will be reviewed and accepted by Zorlu. If contractor submits alternate supplier to those listed in specification it will be Zorlu's responsibility to verify if the alternate supplier and their product is equivalent to the one specified. The execution and installation practices defined within the specification will conform to US standard practices. If the contractor recommends different execution practices that those defined within the spec it will be Zorlu's responsibility to confirm that the modified practices meet the intent of the specification.

The site conditions consist of, "Pollution level III – Heavy" per IEC 60137 for heavily polluted atmospheres, $H_2S$ laden environment. All equipment specifications must consider these conditions with proper consideration for the installation location of each piece of equipment. Vendors shall provide a statement of the suitability of each piece of equipment to withstand the environment in which the equipment will be located.

Electrical equipment rooms shall be supplied with conditioned air that is dust and chemically filtered, to mitigate the $H_2S$ in the atmosphere. Electrical equipment enclosures for Plant distribution and control equipment will be located in the environmentally conditioned electrical equipment rooms to minimize the effects of $H_2S$ when practical. Electrical equipment and devices other than generators and motors located outside of the electrical equipment rooms will be provided with IP65 or better enclosures. Environmental specification requirements for each piece of electrical equipment will be communicated to vendors to ensure that all requirements are met.

All equipment will be specified to meet seismic requirements and vendor documentation will be received to confirm equipment complies with specifications. Overload factors per the contract will be utilized for calculations to ensure that structural integrity is maintained for any switchyard structure designs. The seismic requirements will be communicated to all equipment vendors who will provide seismic certification documentation to ensure that the provided equipment is acceptable for use. Equipment foundation and anchoring requirements will be coordinated between equipment vendor data and structural design.

Materials and equipment used will be such that maintenance cycle of three years will be acceptable. Where practical, manufacturers' standard equipment which is capable of performance and operation in a geothermal environment for the 30 year expected plant life, will be used in accordance with the Design Criteria requirements.

All switchyard electric equipment (breakers and switches) will be provided with sufficient limit/position switches (both primary and secondary) to allow all necessary protection interlocks and status requirements. In addition to the switches necessary for the protection and status requirements, spare contacts will be included in the equipment specifications.

Generator breaker will be provided with sufficient limit/position switches (both primary and secondary) to allow all necessary protection interlocks and status requirements. In addition to the switches necessary for the protection and status requirements, spare contacts will be included in the equipment specifications.

All Medium Voltage Switchgear and Switchboards will be provided with sufficient limit/position switches to allow all necessary protection interlocks and status requirements. In addition to the switches necessary for the protection and status requirements, spare contacts will be included in the equipment specifications.

All Low voltage Switchgear/Switchboard/Motor Control Centres will be provided with sufficient limit/position switches to allow all necessary protection interlocks and status requirements. In addition to the switches necessary for the protection and status requirements, spare contacts will be included in the equipment specifications.

### 4.1.7 Material Specifications - Process Piping

| **Material Specifications - Process Piping** | |
|---|---|
| **Fluid/Service:** | **Materials** |
| Air – Utility: | Carbon Steel |
| Air – Instrument: | 316L Stainless Steel < 2" NPS<br>Carbon Steel >/= 2" NPS |
| Chemical – Caustic Soda: | Carbon Steel |
| Chemical – Biocide | PVC |
| Chemical – Oxygen Scavenger | PVC |
| Gas - Non-condensable (NCG): | 316L Stainless Steel / FRP |
| Oil - Control and Lubricating: | 316L Stainless Steel |
| Oil – Transfer: | Carbon Steel |
| Steam: | Carbon Steel |
| Water - Cooling Tower Fire Suppression: | HDPE/FRP/PVC |
| Water - Condensate/Reinjection: | FRP/316L Stainless St (Power Plant)<br>Carbon Steel (Steamfield) |
| Water – Domestic (aboveground) | Carbon Steel (galvanized) |
| Water - Fire Main: | HDPE/PVC/Ductile Iron |
| Water - Fire Suppression: | Carbon Steel (galvanized) |
| Water - NCG Removal Cooling: | FRP/316L Stainless Steel |
| Water - Main Cooling: | FRP/316L Stainless Steel |
| Water – Potable: | HDPE/PVC / Stainless Steel |
| Water – Seal: | 316L Stainless Steel |
| Water - Component Cooling: | FRP/316L Stainless Steel |
| Corrosion allowance for carbon steel piping: | 3 mm |
| Corrosion allowance for stainless steel piping: | 0 mm |
| | |
| | |
| **Plant Area or Element** | |
| Condenser shell, nozzles and piping: | ASTM 316L SS |
| Hotwell pump metallic components in contact with pumped fluid: | ASTM 316 SS |

| | |
|---|---|
| Liquid ring vacuum pump or compressor metallic component in contact with water or NCGs: | ASTM 316LSS |
| Steam jet ejectors: | ASTM 316LSS |
| Gas extraction system material: | ASTM 316LSS |
| Gas extraction system aftercondensers material: | ASTM 316LSS |
| Main cooling water system, water risers and distribution pipework: | FRP or ASTM 316L |
| Main cooling water system buried pipework: | FRP |
| Cooling tower fasteners and hardware: | ASTM 316LSS |
| Cooling tower materials fire combustibility rating : | Less than 25, per NFPA |

## 4.2 PG GmbH site at Insheim

The Insheim Geothermal Power Station is a geothermal power station in Rhineland-Palatinate, Germany. Since 2008, two wells with depths of 3,500 m have been drilled, and circulation and hydraulic testing, conducted between 2009 and 2010, was completed successfully. The plant has been operated by Pfalzwerke geofuture GmbH since November 2012. The system converts thermal energy from the deep water into electricity. The plant is supplying electrical power to approximately 8,000 households generated by its 4.8 MW geothermal power plant.

Key features of the plant is summarized below:

| | |
|---|---|
| **Objective** | > 4 MW electrical power |
| **Wells** | 2, Sidetrack |
| **Vertical Depth** | 3,500 m |
| **Temperature** | 165°C |
| **Flow Rate** | 80 l/s |
| **Reservoir** | EGS/hydrothermal |
| **Power Plant** | ORC |
| **Construction** | 2008 to 2012 |
| **Status** | feed-in of up to 4.8 MWe |
| **Optional maximum thermal output** | 6–10 MW |

The power plant, with an average electrical output of around 4.3 megawatts, is capable of generating around 33,000 megawatt hours of electrical energy with around 8,000 operating hours per year when it reaches the design output. Mathematically, around 8,000 households can be supplied with electricity. The residual heat is sufficient to supply an additional 600 to 800 households with heat. The establishment of a local heating network in Insheim is currently being examined.

The conditions in Insheim are particularly favorable for the extraction of geothermal energy due to the geological situation in the Upper Rhine Graben , with water temperatures of more than 160 degrees Celsius at a depth of around 4000 meters.

Investigations and analyzes in advance led to the selection of the location between the town of Insheim and the A 65 motorway . From 2008 to 2012, two boreholes were sunk and the complete power plant installation was carried out.

The electricity is generated by an ORC system, which transfers the energy to a turbine using the carrier medium isopentane .The process used in the geothermal plant in Insheim uses the heat from the thermal water, which is pumped through deep boreholes and cooled back into the ground through reinjection boreholes. Due to insufficient discovery, a side arm (sidetrack) was drilled to improve the hydraulic properties, but the original borehole was not filled, so that a borehole with two arms is now available for reinjection. With such a deflection hole, the water can be distributed more quickly and more spaciously underground. This means that less pressure is required during operation. There are regular earthquakes around the facility , up to June 19, 2020, 154 quakes were registered directly below Insheim, the maximum magnitude was 2.4. In the area around the plant there are more earthquakes that are not always directly under Insheim, but are caused by the operation of the power plant. On May 20, 2020, an earthquake with a magnitude of around 2.2 was registered.

End-user specifications could cover (but not limited to):

**(1) Specifications relating to heat production**

- Heat load for industry
- Specific heat capacity

**(2) Specifications relating to Electricity production**

**(3) Specifications relating to costs**

- Grid connection costs

**(4) Legal and policy related specifications**

- Relevant site-specific regulations

**<u>In addition following aspects could be considered while defining end user specifications</u>**

- Injection of geothermal fluid (associated parameters)
- Requirements pertaining to protection of wildlife and vegetation
- Drilling requirements
- Reliability assessment requirements
- Life Cycle assessment related requirements
- Miscellaneous technical specifications
- Electrical efficiency

- Gross Capacity
- Net Capacity
- Usable Heat Output
- Capital Cost
- Opex cost

Stratigraphy, Thermal gradient , Depths (reservoir thickness), Reservoir Temperature ,Geothermal (reservoir) fluid type, Geothermal (reservoir) fluid density , Geothermal (reservoir) fluid viscosity, Permeability ,Transmissivity, Reservoir index (productivity / injectivity), Injection pressure, Flow rate , Volumetric heat capacity (Granite) , Recovery factor , Conversion coefficient , Plant capacity factor, Economic life of project ,Heat reservoir volume, Power generation (gross), Parasitic load (pump for pressure difference) , Power generation (net)

- **System definition rules for optimised flexible efficiency**

PG GmbH will improve the existing ORC models, taking the performance models of the major components as expander, pump and heat exchangers into account. The focus is on off-design performance modelling, taking extra constraints (outlet temperature limitation) into account. The goal is to obtain a model, able to maximize the electricity generation efficiency, taking extra constraints into account.

- **Control system strategy for combined ORC and TES system**

The control strategy will be designed to integrate information from long term weather forecasting, and will base its decisions on the results of dynamic simulations covering a minimum time window of 15 days. The site-specific requirements for the controllers will be identified and provided as the following:

1) The expected characteristics of the stochastic information for the intended sites, such as the variation over time of thermal load of the condenser and of the weather conditions;
2) The prescribed range of extension of the temperature anomaly in the aquifer after one year of operation
3) The inputs from the submodels it has to integrate, namely a model for the water supply/aquifer, estimate of the temperature anomaly extension, a model for the power block operational characteristics, to optimize the condensing temperature. A parametric grey-box model will be used to characterize the power system, to be fast and sufficiently accurate to capture the relations existing between electricity production, ORC condensing temperature and air.

- **Wet cooling system for binary plant**

The preliminary design of a hybrid cooling system based on a combination of a CT and closed loop GWC will be accomplished (PG GmbH), so as to define the optimal configuration of the well field and the integration of the groundwater loop(s) with the water circuit of the air coolers. Different layout configurations will be explored to minimize the extra CAPEX of the binary plant. To this end, PG GmbH will use an in-house tool for the simulation of the shallow aquifer and the wells field coupled with a simplified off-design model of the ORC unit and of the geothermal network. The deliverables of this task will provide the basis for the definition of the controller of the hybrid cooling system and the design of the related DEMO at the Insheim CHP plant.

- **Flexible energy management controller for hybrid cooling system of Insheim**

Firstly the devices that are to be controlled will be characterized, to the exent required to provide accurate control. A one dimensional 'grey box' parametric model of the heat storage system will then be developed, which includes heat losses, conduction, convection and mixing to characterize the heat buffer. Parameters for the physical processes will be estimated based on temperature sensors placed in the buffer. In addition, the ORC system characteristics will be built in to generate a generic control model applicable on a broad range of systems.

- **Engineering preparation**

The following innovations will be designed and constructed at demonstration scale for the Insheim site, using the development inputs from WPs 2, 3 and 4

- Short term pressurised water storage to increase the flexibility for both heat delivery to the district heating network and electricity production of the ORC including the smart determination of the state of charge Hybrid cooling based on groundwater cooling with one doublet to increase the efficiency of the electricity production with the ORC in the summer months and the control of the hybrid cooling system taking into account the weather forecast, the planning of the electricity production and the state of the aquifer storage in order to increase the electrical efficiency without compromising the underground energy balance.
- Improved control of the ORC and storage tank and communication link with the existing controller for the district heating network in order to reduce the energy consumption of the back-up heating installation of the district heating network and to increase the revenues of the electricity production.
- Internal control of the flexible ORC to deliver the desired outlet temperature The engineering works for each innovation will be detailed at the Insheim site.

- **System design and build**

The Demo will have one groundwater doublet to provide extra part-cooling capacity to one of the ORC modules of the ORC power block of the plant.

PG GmbH is responsible for all the activities related to the ORC. The GW loop will interface with the cooling water loop of the plant by a dedicated heat exchanger.

To such a purpose, the DEMO (cooling loop + wells field) and the ORC module will be equipped with the needed instrumentations/devices to continuously record all relevant data for the validation of the simulation tools

- **Installation and commissioning of demonstration plant**

Execution and management of the implementation includes following activities:

Management: the overall technical and economic aspects need to be managed, agreements must be made between partners and subcontractors and, where needed, will include technical and financial and risk control.

Control and supervision: the practical integration and implementation works, control of implementation quality.

Commissioning and initial operation: will be followed in detail.

PG GmbH is responsible for the innovations related to the water storage, the hybrid cooling and the improved control of the overall system.

PG GmbH is responsible for the implementation of the internal control and all activities related to the flexible ORC.

- **Evaluation of demonstration results**

The simulation models developed in WP5 will be updated and validated with test results from demonstration site. LCOE impact calculations:

We will utilise technical data including well temperature, chemistry, productivity and injectivity index; ΔT constraints; heat and power demand curves will be forecast; and financial data such as local power price, tax rate, discount rate, inflation rate gathered andd extrapolated for future market scenarios. Using these data, we will estimate the probable Capex considering the current approach of material selection in geothermal pr oject development.

In the LCOE estimation, we will use parameterised value of Opex in the range of 2 to 3% of the Capex. Considering 30 years of lifespan of power plant, we will determine LCOE for the case study site, comparing the base LCOE with that arising from the levels of GeoSmart application:

- At the first level, we will consider the implementation of storage alone
- In the second level, we will consider the addition of power block flexibility engineering and energy management In the third level, we will consider the full application scope of GeoSmart i.e., including the scaling reduction also LCA calculations:
- To perform LCA study, in addition to the generic approach, we will also use SimaPro LCA software in the assessment using cradle-to-grave life cycle approach.
- We will follow the International Reference Life Cycle Data System (ILCD) Handbook, based on ISO 14040 and 14044 standards on LCA. To comply with the guideline and ensure the credibility of the LCA study, we will make these studies through critical reviewing process by an independent reviewer.

# 5 QUALITY FUNCTION DEPLOYMENT

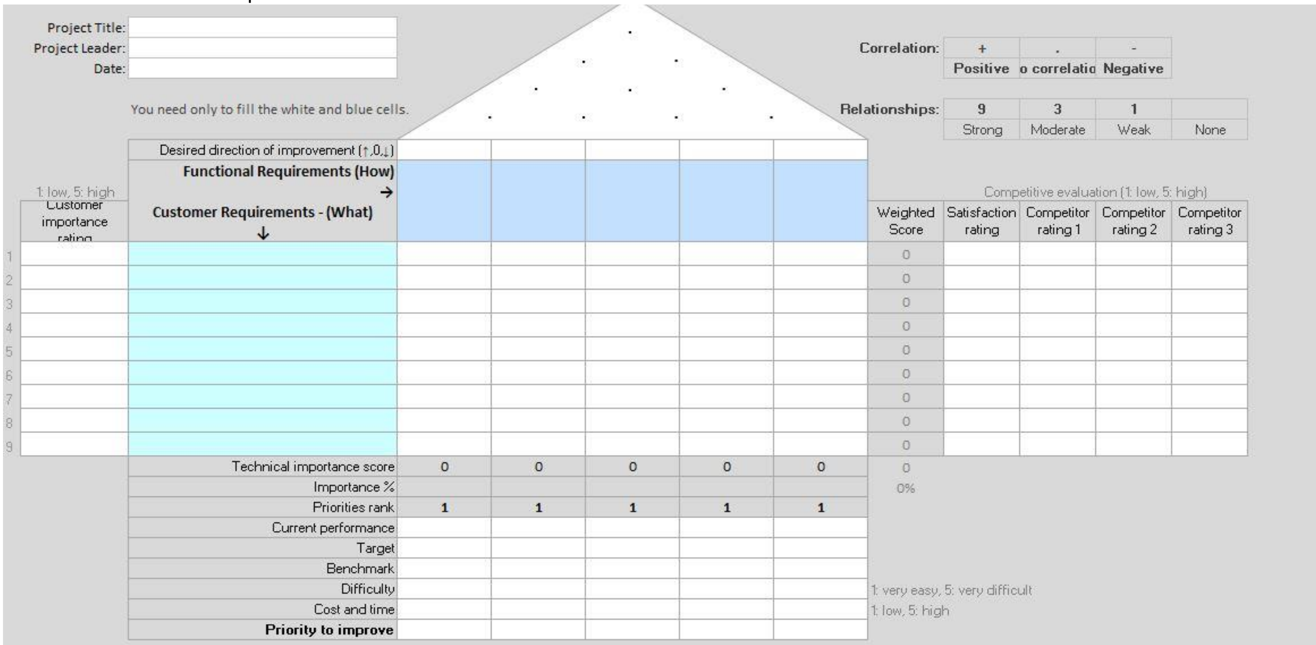
Quality Function Deployment (or QFD, for short) is a basic Total Quality Management (TQM) tool that systematically develops customers' needs and expectations. The tool provides a graphical methodology for unearthing a customer's stated and unstated needs and expectations, for making decisions in cases where these needs and expectations conflict, and for driving these customer-based requirements and expectations into the product development and manufacturing process (Berk, 2000). QFD is driven by what the customer wants, and for this reason, the technique is often described as "deploying the voice of the customer."

The basic QFD sets out the relationship between customer needs and how they will be achieved (the design/functional requirements). Additional information (importance, target values, competitor analysis etc.) can be added as required.

## 5.1 Customer Requirements

The core of QFD approach consists of defining customer requirements and functional requirements.

The template used to carryout QFD for GeoSmart is illustrated below;




The customer requirements are essentially ranked with respect to customer importance ranking with a lowest score of 1 to highest score of 5. The customer requirements currently identified for GeoSmart project are listed below;

- Heat load for industry
- Specific heat capacity
- Heat storage density
- Response Time
- Heat-exchanger effectiveness
- Heat storage cost
- Corrosion rate
- Grid connection costs
- Electrical efficiency
- Net Capacity
- Capital Cost
- Opex cost
- Economic life of project

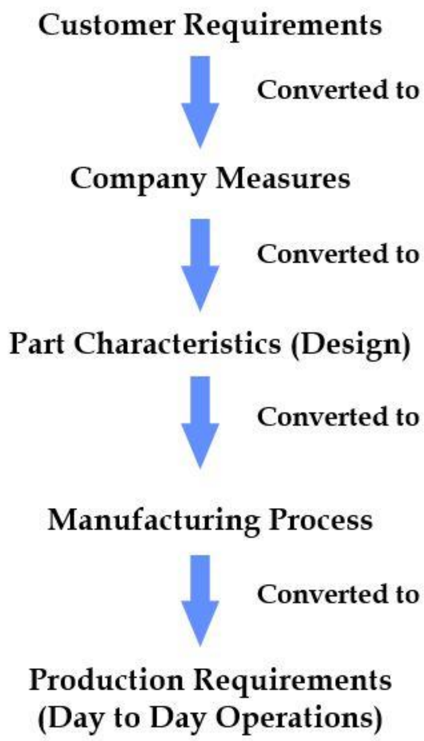
## 5.2 Functional Requirements

Functional requirements or design requirements broadly should cover;

- Descriptions of operations performed by system
- Descriptions of work-flows performed by the system
- Descriptions of system reports or other outputs.

Proactive product development is better than reactive product development. QFD can help an organization/ company move toward a more proactive approach.

To simplify,




Some of the factors contributing to functional requirements in GeoSmart project are

- Discharge (measured in kWh)
- Volume of the module after design including metallic parts
- Flowrate
- Temperature
- Mass flowrate on hot (brine) or cold (water) side (kg/s)
- Fluid specific heat capacity (J/kg/K) on hot (brine) or cold (water) side
- Mass loss in grams
- Time of exposure in hours
- Cost of the module
- Cost of the PCM material
- Energy price
- Power obtained
- Cost of overall system

## 5.3 Initial takeaways from QFD

For the GeoSmart project, an initial set of customer requirements and functional requirements have been identified. Since this is a living document, the QFD template will be updated throughout the course of the project and a final output will be submitted along with D1.7 - Final document of end user spec document agreed with users, including KPIs for two case study sites, which is due at month 57 of the project. The identified customer and functional requirements are mentioned in the previous sections.

| 1: low, 5: high<br>Customer importance rating | Desired direction of improvement (↑,0,↓)<br>Functional Requirements (How) →<br>Customer Requirements - (What) ↓ | Discharge | Volume | Flowrate | Temperature | Time of exposure | Cost of the module | Energy price | Power obtained | Cost of overall sytem | Cost of PCM material | Mass loss |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3 | Specific heat capacity | 9 | 9 | 9 | 9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3 | Heat load for industry | 9 | 9 | 9 | 9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4 | Heat storage density | 9 | 9 | 9 | 9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4 | Response time | | | | | 9 | | | | | | |
| 4 | Heat-exchanger effectiveness | 9 | 9 | 9 | 9 | | | | | | | |
| 5 | Heat storage cost | | | | | | 9 | | | 9 | | |
| 5 | Grid connection costs | 0 | | | | | | | | 9 | | |
| 4 | Corrosion rate | 0 | | | | | | | | | | 9 |
| 3 | Electrical efficiency | 0 | | | | | 9 | 9 | 9 | 9 | 9 | |
| 3 | Net capacity | | | ` | | | | | 9 | | | |
| 5 | Capital cost | 0 | | | | | | | | 9 | 9 | |
| 4 | Operational expenditure cost | 0 | | | | | | | 9 | | | 9 |
| 5 | Economic life of the project | 0 | | | | | | 9 | | 9 | 9 | |

So far, an initial relationship between customer needs and how they will be achieved (the design/functional requirements) have been established. Additional information (importance, target values, competitor analysis etc.) will be added throughout the project duration.

# 6 NEXT STEPS

The current document is a *living* document that has been used to identify KPIs at the technical and global level and will be updated as the project progress. An updated version of the document, listing the final KPIs for the two case studies **D1.7 Final document of the end user spec document agreed with the users including KPIs for two case studies** will be submitted in M57.

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