# ORC Power+

## Feasibility Study for


**B:POWER, a.s.**
U Borové 69 ID: 28925319 info@bpower.cz
CZ 580 01 Havlíčkův Brod VAT ID: CZ28925319 www.bpower.cz
The company is registered in the Commercial Register kept at the Regional Court in Hradec Králové,
Ref. No B 3014

**Client:**

| | |
|---|---|
| **Contracting Authority:** | **ElectraTherm**<br>4750 Turbo Circle<br>Reno, Nevada 89502 |
| **Contractor:** | **B:POWER, a.s.**<br>U Borové 69<br>580 01 Havlíčkův Brod<br>www.bpower.cz |
| **Date of Elaboration:** | **04.10.2016** |
| **Elaborated by:** | **Jiří Musílek, Karel Šmíd** |

**Study Objective:**

The objective of this study is to find the most suitable technical-economical solution for integration of the ORC technology from Electratherm into the newly built power station. To maximize the performance of the ORC unit it is necessary to design the entire system and, in particular, the key components (cooler, flue-gas exchanger, and ORC alone) correctly. Therefore, this study has concentrated on the design and integration of these components.

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# 2 TECHNICAL PART

## 2.1 Input documents from the Contracting Authority

The following input documents were considered within the study:

- Engine datasheet (GE 12V228)
- Site layout
- One line diagram

## 2.2 Limiting factors in solution design

The received input documents implied several facts which significantly limited the possible technical solution for the integration of the heat exchanger and ORC. These limiting factors included;

- Available pressure drop for the installation of the heat exchanger overpressure of the engines used (30 mbar), the pressure loss of the damper and gas ductwork (20 mbar), leaving only 10 mbar available for design of the flue-gas exchanger including the entire flue-gas path.
- The second limiting fact is impossibility or a minimum possibility to change the location of the technology – “engine and accessories.”
- The third limiting fact is a lack of space for ORC and accessories.

All of these facts act against one another and have an adverse influence on the price of work (they make it more expensive). These limiting factors have led to a conclusion that the originally intended technical solution was not feasible.

The original solution counted on a higher pressure loss for the flue-gas exchanger and the ability to move the “skid” with the chimney, compressor and cooler, i.e. increasing the distance between the container with engine and the skid (see Fig. 1). In addition, limitation of the pressure loss of the exchanger and flue-gas path to max. 10 mbar totally excluded connection of two engines into one flue-gas exchanger, as originally planned. It is still possible, however, to use two flue-gas exchangers and to connect them into one ORC at the hot-water side.

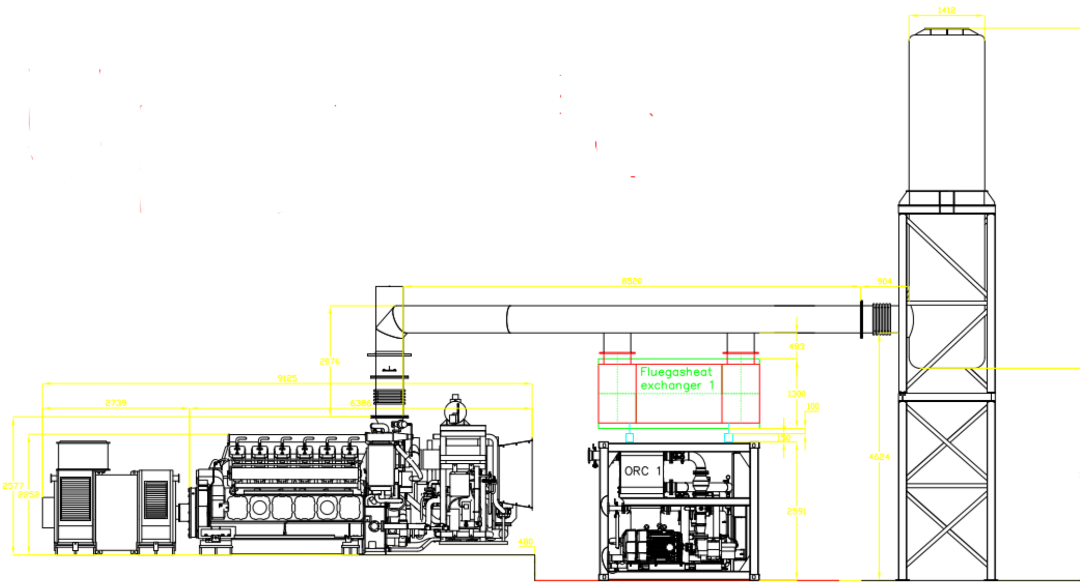



*Fig. 1 – Original solution design*

## 2.3 Procedure in designing the technical solution

The above mentioned meant to solve three basic issues of the ORC installation:

1. Keeping the minimum counter-pressure of the newly installed technology up to 10 mbar;
2. Keeping the layout of the existing technology;
3. Solving the lack of space for the new ORC technology.

### 2.3.1 Flue-gas exchanger

An important task was to find such a technical solution for the flue-gas exchanger that limited the pressure loss to 10 mbar. With regard to pressure losses, the best technical solution is to locate the flue-gas exchanger straight into the flue-gas path, see Fig. 2.

This location requires turning the skid on which the engine technology (compressor, cooler, chimney) is situated by 180° and moving the chimney and damper structure by 533 mm.

The designed flue-gas exchanger has the following parameters:

| | | |
|---|---|---|
| Flue-gas temperature at exchanger input | °C | 427 |
| Flue-gas overpressure at exchanger input | Pa | 2 490 |
| Flue-gas flow rate | m3/h | 32 460 |
| Excess air coefficient λ | | 1.65 |
| Water temperature at output | °C | 122 |
| Exchanger output | kW | 1 200 |
| Flue-gas temperature at output | °C | 195.4 |
| Final length including connection | m | 5.5 |
| Approximate diameter without insulation | m | 1.41 |
| Total pressure loss | Pa | 240 |

The exchanger is designed to be made of stainless steel 17 349.

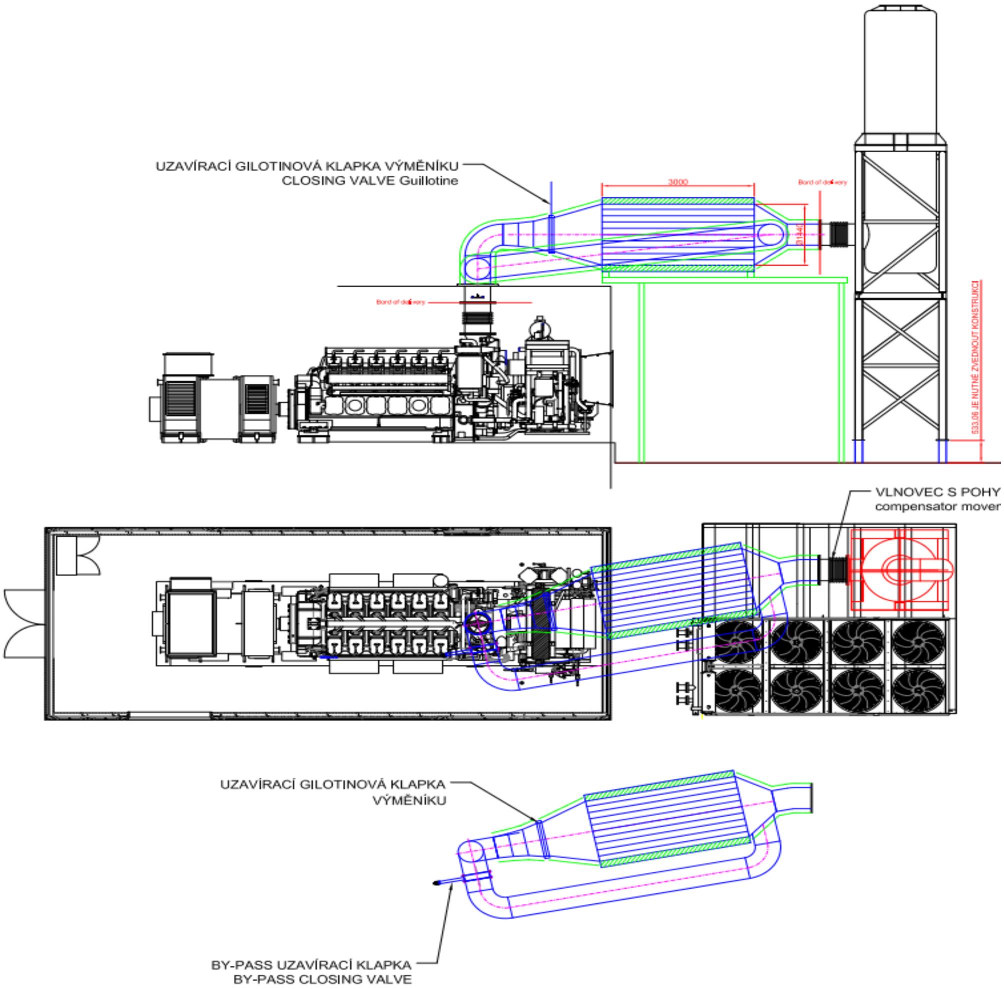



*Fig. 2 – Location of the flue-gas exchanger into flue-gas paths*

### 2.3.2 ORC system

With regard to the heat exchanger output (1 200 kW) it is ideal to use ORC Electratherm model Power+ 6500. Under the conditions stated in Fig. 3, this ORC can supply 61 kWe net (after deduction of all internal consumption). It is further necessary to deduct the pump consumption on the hot-water circuit from the calculated output, in this case 4 kWe.

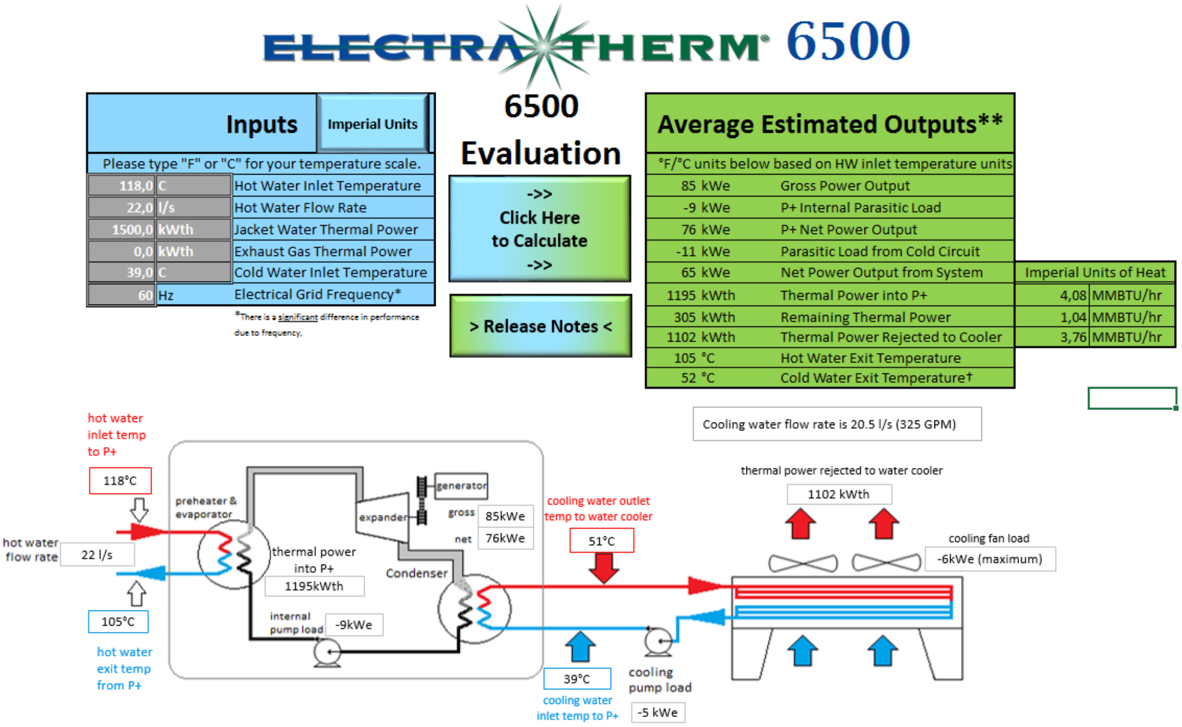



*Fig. 3 – Energy balance of the designed ORC Power+ type 6500*

The most efficient solution is based on connecting the ORC only to the flue-gas exchanger. Originally, it was planned to use the energy from the cooling water of the engine, but due to a sufficient amount of energy in flue gases, this was abandoned.

### 2.3.3 Cooler and cooling circuit

The cooler is very important for the equipment to operate correctly. When designing the cooler, it is necessary to consider, apart from the required cooling output, also the internal power consumption of the cooler and the price. For this purpose it is most suitable to use a cooler from Alfalaval, type VDDQE1008.1DY120 SK C4.

**Major parameters:**

| | |
|---|---|
| Design output | 1 132.76 kW |
| Input/output fluid temperature | 51.0°C / 39.0°C |
| Fluid pressure loss | 21.7 kPa |
| Rated input power | 7 680 W |

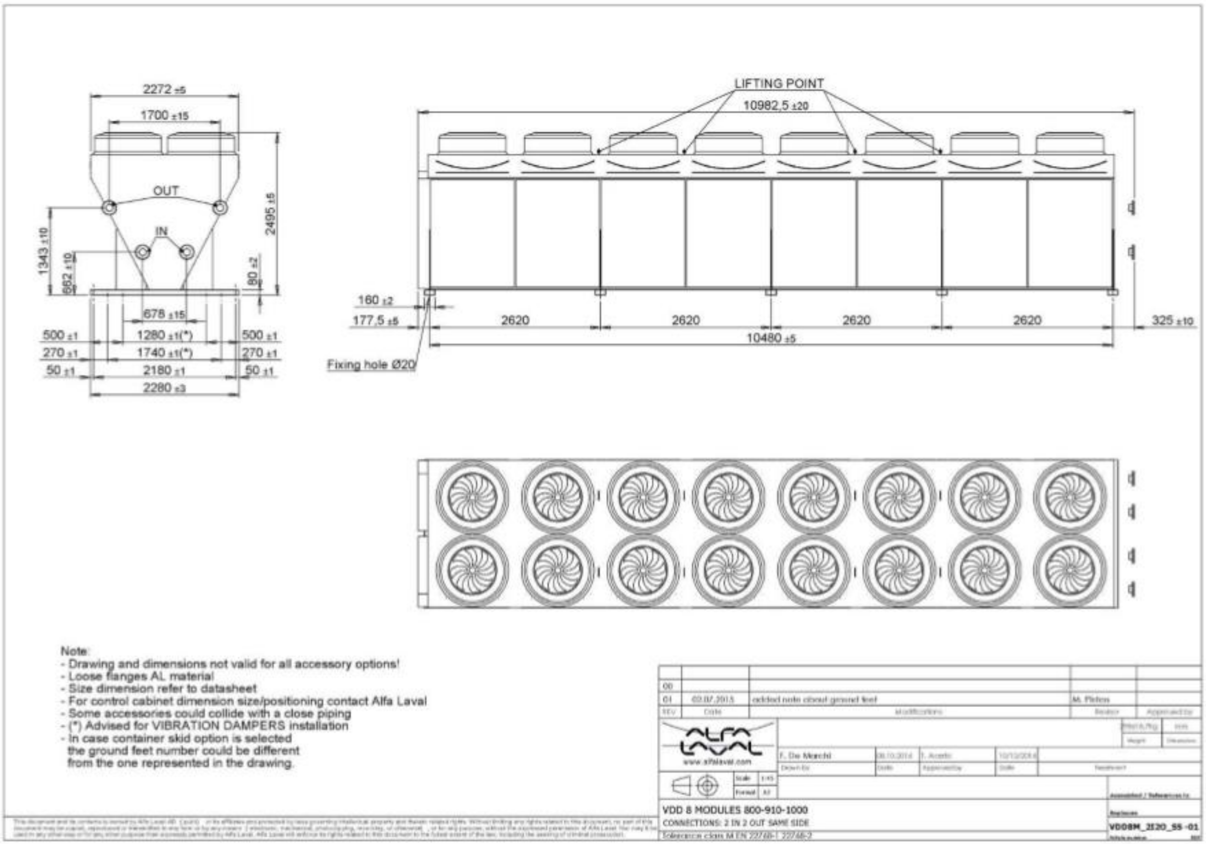
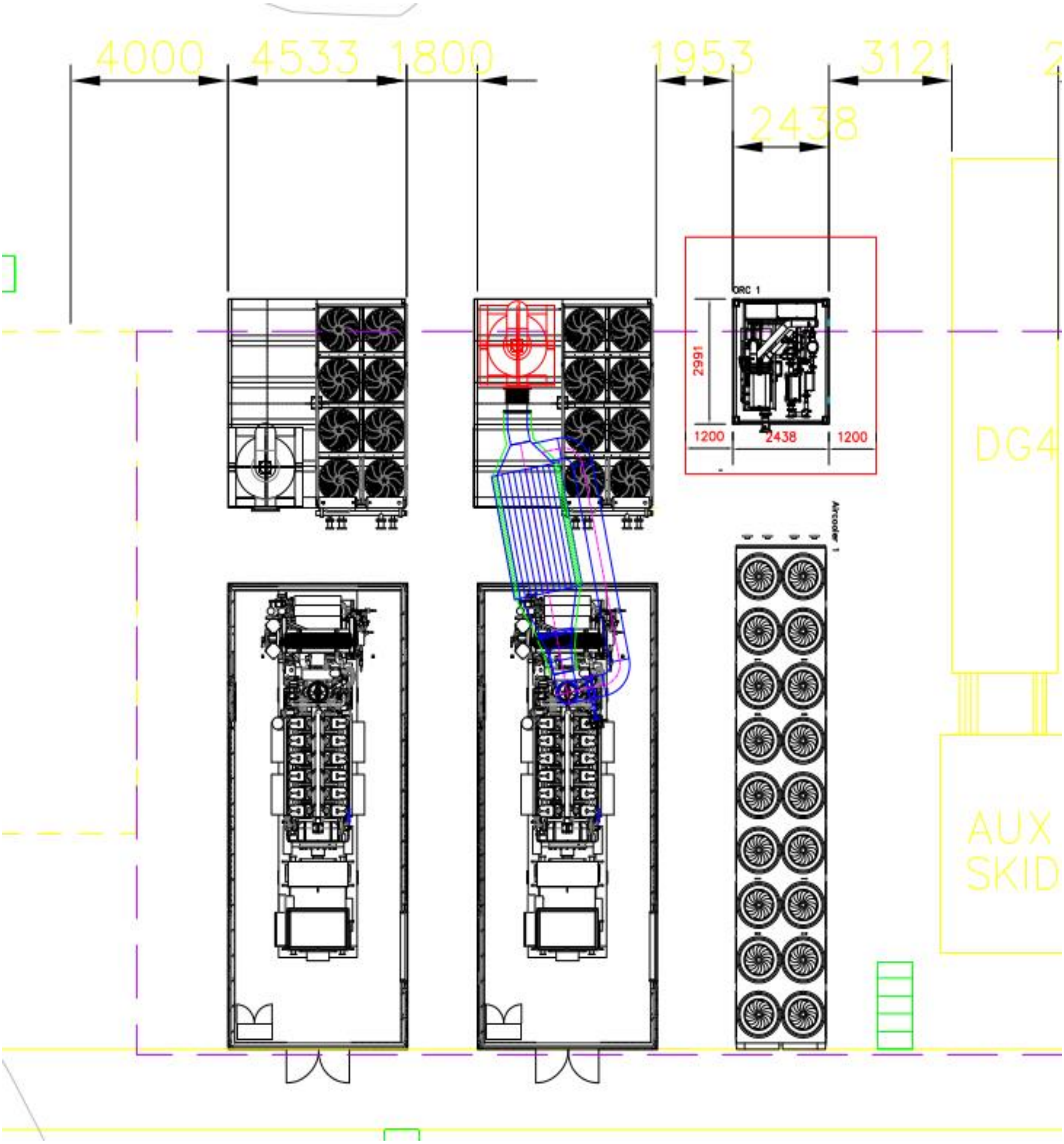



*Fig. 4 – Technical drawing of the cooler under consideration*

## 2.4 Designed technology layout (one flue-gas exchanger with one ORC)

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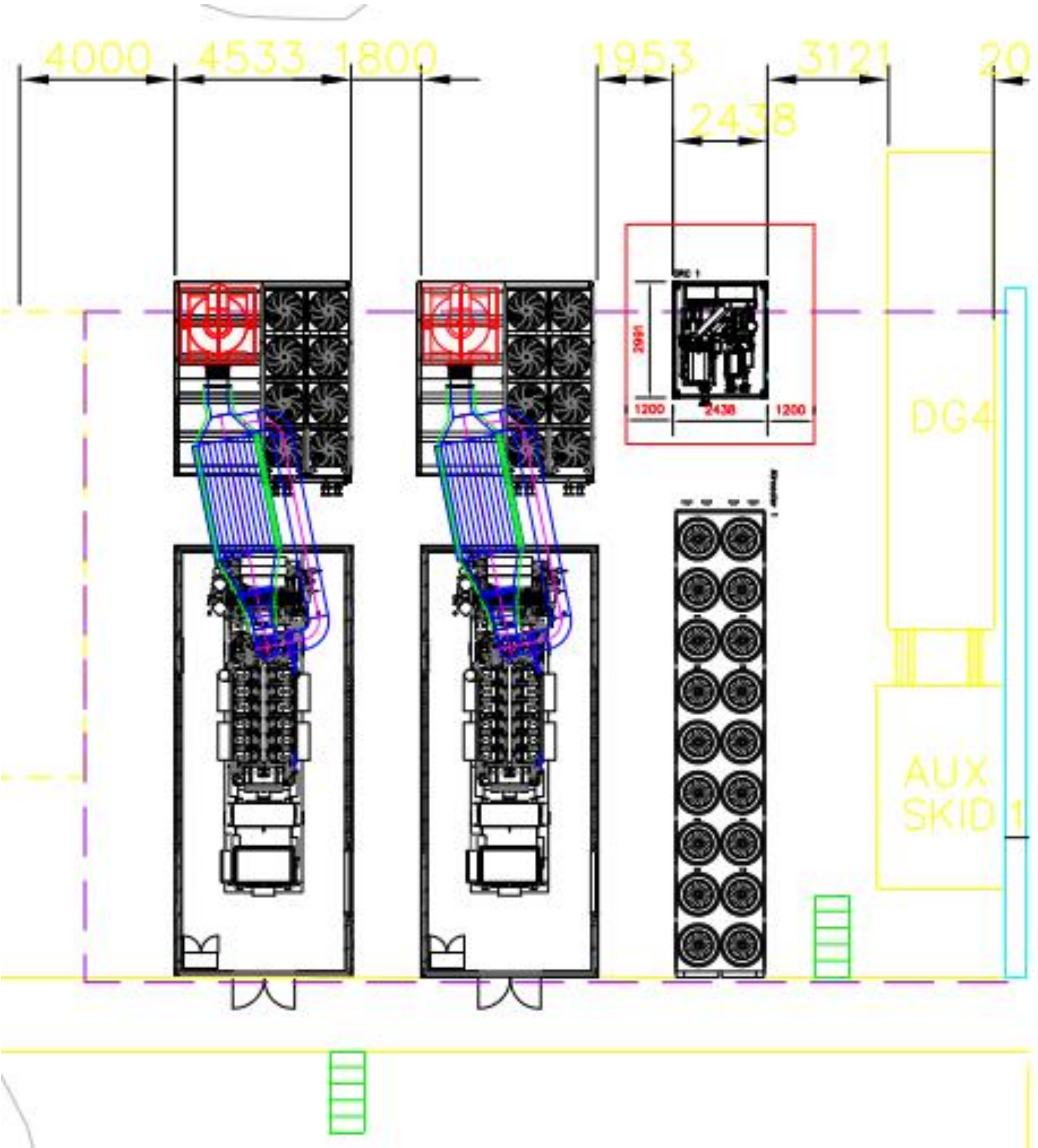
## 2.5 Designed technology layout (two flue-gas exchangers with one ORC)



# 3 SCOPE OF DELIVERY UNDER CONSIDERATION

### 3.1.1 Price calculation includes

- Drawing of the system layout
- Implementing design documentation:
  - Connecting pipe to heat source
  - Electrical documentation
  - ORC coordination drawing
  - Technical report
- ORC system, model 6500
- Flue-gas/water exchanger
- Supporting structure under flue-gas exchanger
- ORC control switchboard
- Connection to water circuit of flue-gas exchanger
- ORC cooling circuit system acc. to the required ORC parameters
- Pipeline between heat source (flue-gas exchanger) and ORC
- Cooling water pump
- ORC set-up
- System activation
- Transport from manufacturing plants (Reno, Havlíčkův Brod, Prague) to Adelaide

### 3.1.2 Price calculation does not include

- Administrative acts to obtain a permit to increase output, a building permit, a permit for connection to the network, etc.
- Construction work (concrete foundation), grounding
- Lightning conductor
- Obtaining approval of the technical documentation by the relevant authorities
- Transport from Adelaide to the site of installation
- Crane and handling equipment at the site of installation
- Customs duties and taxes
- Connection of the output to the distribution network (the delivery limit is the ORC switchboard)
- Billing electric meter

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# 4 PRICE CALCULATION

## 4.1 Price calculation for one flue-gas exchanger connected into one ORC

**The total delivery price acc. to calculation in Chap. 4.1 is: <u>$xxxxxx</u>**

| | | |
|---|---|---|
| **P+ 6500** | 1 | |
| Transport cost + insurance from Reno to Adelaide | 1 | |
| Customs (not includet in price) | 0 | |
| Heat Exchanger - 900 kW (HE, constrution, fluegas ways, valve, insulation) | 1 | |
| Transport cost + insurance from Havlíčkův Brod to Adelaide | 1 | |
| Customs (not includet in price) | 0 | |
| Cooler - 1100 kW | 1 | |
| Transport cost + insurance from Prague to Adelaide | 1 | |
| Customs (not includet in price) | 0 | |
| Refrigerant R245fa | 1 | |
| Hot water | 1 | |
| Cooling circuit - maximum 20m | 1 | |
| Electro (CC, SW, cable) | 1 | |
| Design | 1 | |
| Work on site (4 people - three weeks) | 1 | |
| PRM | 1 | |
| Reserve (insurance, paper work, management with transport) | 1 | |
| | | |
| **total cost price** | | |

## 4.2 Price calculation for two flue-gas exchangers connected into one ORC

Unlike the version with one exchanger, this quotation includes, in addition, an exchanger, connecting hot-water pipe and software for automatic operation in this mode.

**The total delivery price acc. to calculation in Chap. 4.2 is: <u>$xxxxxx</u>**

| | | |
|---|---|---|
| P+ 6500 | 1 | [redacted] |
| Transport cost + insurance from Reno to Adelaide | 1 | [redacted] |
| Customs (not includet in price) | 0 | [redacted] |
| Heat Exchanger - 900 kW (HE, constrution, fluegas ways, valve, insulation) | 2 | [redacted] |
| Transport cost + insurance from Havlíčkův Brod to Adelaide | 2 | [redacted] |
| Customs (not includet in price) | 0 | [redacted] |
| Cooler - 1100 kW | 1 | [redacted] |
| Transport cost + insurance from Prague to Adelaide | 1 | [redacted] |
| Customs (not includet in price) | 0 | [redacted] |
| Refrigerant R245fa | 1 | [redacted] |
| Hot water | 2 | [redacted] |
| Cooling circuit - maximum 20m | 1 | [redacted] |
| Electro (CC, SW, cable) | 1 | [redacted] |
| Design | 1 | [redacted] |
| Work on site (4 people - three weeks) | 1 | [redacted] |
| PRM | 1 | [redacted] |
| Reserve (insurance, paper work, management with transport) | 1 | [redacted] |
| | | |
| **total cost price** | | [redacted] |

Terms of Payment

We advise that the above price calculations have been based on the total scope of work and the following terms of payment;

- Deposit of 40% of contract value payable on signing of contract
- 50% of contract value prior to shipment
- 10% on completion of commissioning of ORC

## 5 SERVICE

The entire ORC technology is characterized by low service and operating costs. The following paragraphs describe the requirements for regular inspections and servicing of individual components:

**Flue-gas exchanger**: no special service required.

**Cooler and flue-gas flaps:** cleaning and lubrication twice a year. This work can be performed by the system operator and it requires approximately ten man-hours a year.

**ORC**: The course and requirements for preventive service, maintenance and inspections are determined in the table of preventive inspections prescribed by the equipment manufacturer – see the tables of service inspections in this chapter. The average time spent on servicing ORC is 22 man-hours a year.

Travel expenses, which make up a not negligible amount in this project, must be added to the service operations alone. The calculation of service costs including travel expenses have shown that if servicing is needed twice a year, the service cost without spare parts climbs to $13 100 a year. (This price includes the time spent on journey, an air ticket, accommodation for one service technician.) A great advantage is that if a second ORC is acquired, this cost only increases by $1 920 and effectiveness of the system operation increases significantly.

**Summary:**

- In total, the entire technology requires service work of 32 man-hours a year.
- At the price of $60 per hour, the final average annual cost of the service technician work is $1 920 year.
- The average annual cost of spare parts for ORC is $8 291.

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## P+ S6000 End User Maintenance Item Descriptions:

| Service Item Description | ElectraTherm Part # | Miscellaneous Maintenance Item Requirements/Notes | Estimated Part Costs from ElectraTherm (USD) | *Estimated Maintenance Material Cost (USD) | Total Estimated Maintenance costs (USD) | Estimated Labor Hours Required for Service (hours) | Required Service Maintenance Interval (hours) |
|---|---|---|---|---|---|---|---|
| Inspect all plumbing, flanges, and valves for leaks/ Check oil catch bottle | | *if visual sign of leak present, use liquid leak detector | | $ 10.00 | $ 10.00 | 1 | 4400 |
| Inspect coupling / expander and generator bearings | | **Adjust alignment if necessary / check for smooth generator shaft rotation | | | $ - | 1 | 4400 |
| Grease generator bearings | | | | $ 25.00 | $ 25.00 | 1 | 4400 |
| Clean cooling vents of generator | | *requires cleaning materials | | $ 5.00 | $ 5.00 | 1 | 4400 |
| Inspect hardware for wear/damage | | Manually actuate air valves, and inspect rotating equipment | | | $ - | 0.5 | 4400 |
| Inspect for electrical wear/damage | | visual inspection of electrical connections or use infrared camera | | | $ - | 0.5 | 4400 |
| Clean cabinet heat exchanger | | visual inspection and cleaning of cabinet heat exchanger | | | $ - | 0.5 | 4400 |
| Check for NCGs in working fluid | | | | | $ - | 0.5 | 4400 |
| Check operation of compressed air system | | *May require leak detector | | | $ - | 0.5 | 4400 |
| Check HX water-side pressure drop | | measure and record pressure drop | | | $ - | 0.5 | 8800 |
| Verify operability of safety equipment | | visual inspection of buttons, lights, and labels | | | $ - | 0.5 | 8800 |
| Clean enclosure / clean LLR | | *requires cleaning materials | | $ 5.00 | $ 5.00 | 2 | 8800 |
| Replace PLC and HMI batteries | 11214 x2 | Machine must be powered on when replaced | | $ 15.43 | $ 15.43 | 0.5 | 17600 |
| Expander rebuild | | ***Expander is replaced at site with refurbished unit from ElectraTherm. | $ 22,266.00 | | $ 22,266.00 | 16 | 22000 |
| Replace VFD internal cooling fan | | available from from VFD manufacturer, not stocked by ElectraTherm | | $ 300.00 | $ 300.00 | 1 | 26400 |
| Replace High Side PRVs & Low Side PRVs**** | 11397 x2 / 11405 x2 | replace per local code requirement (4 total PRVs) | | $ 1,671.43 | $ 1,671.43 | 2 | 44000 |
| Replace Generator Bearings | | Generator may be have to be removed from ORC | | $ 1,000.00 | $ 1,000.00 | 8 | 92400 |

**Current maintenance intervals are conservative, and may be extended based on field experience.**

**Estimated hours are based on time to perform service at site, and do not include any mobilization or transportation time to and from the site.**

***Maintenance items that are not supplied by ElectraTherm. Cleaning supplies, leak detector solution--these items should be available locally.**

****Requires special tools not provided by Electratherm to align coupling.**

*****The cost for the rebuilt expander listed here is an amount NET of the following transactions: Owner will issue payment for the amount of a new expander (greater than the amount listed here) and receive a refund when the owner has returned the expander being removed from service, and that used expander is in condition to be rebuilt and or refurbished.**

******PRVs should be replaced immediately if they discharge or show signs of water ingress. PRVs should be replaced at the interval required by local code or every 5 years, whichever is less.**

**Detailed instructions and part number details are provided in Operation and Maintenance Manual, available from ElectraTherm Service Department.**



ST-000001 Payback Estimator, Dual currency REV 12

## P+ Series 6000: 3 Year End User Routine Maintenance Schedule

CUMULATIVE RUN TIME HOURS

| | 1 YEAR(8760 HOURS PER YEAR) | | | | | | 2 YEARS(8760 HOURS PER YEAR) | | | | | | 3 YEARS(8760 HOURS PER YEAR) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 4400HR SERVICE ITEMS | | | 8800HR SERVICE ITEMS | | | 13200HR SERVICE ITEMS | | | 17600HR SERVICE ITEMS | | | 22000HR SERVICE ITEMS | | | 26400HR SERVICE ITEMS | | |
| REQUIRED SERVICE ITEMS | ITEM | HRS | COST | ITEM | HRS | COST | ITEM | HRS | COST | ITEM | HRS | COST | ITEM | HRS | COST | ITEM | HRS | COST |
| Inspect all plumbing, flanges, and valves for leaks/ Check oil catch bottle | ♦ | 1 | $ 10 | ♦ | 1 | $ 10 | ♦ | 1 | $ 10 | ♦ | 1 | $ 10 | ♦ | 1 | $ 10 | ♦ | 1 | $ 10 |
| Inspect coupling / expander and generator bearings | ♦ | 1 | $ - | ♦ | 1 | $ - | ♦ | 1 | $ - | ♦ | 1 | $ - | ♦ | 1 | $ - | ♦ | 1 | $ - |
| Grease generator bearings | ♦ | 1 | $ 25 | ♦ | 1 | $ 25 | ♦ | 1 | $ 25 | ♦ | 1 | $ 25 | ♦ | 1 | $ 25 | ♦ | 1 | $ 25 |
| Clean cooling vents of generator | ♦ | 1 | $ 5 | ♦ | 1 | $ 5 | ♦ | 1 | $ 5 | ♦ | 1 | $ 5 | ♦ | 1 | $ 5 | ♦ | 1 | $ 5 |
| Inspect hardware for wear/damage | ♦ | 0.5 | $ - | ♦ | 0.5 | $ - | ♦ | 0.5 | $ - | ♦ | 0.5 | $ - | ♦ | 0.5 | $ - | ♦ | 0.5 | $ - |
| Inspect for electrical wear/damage | ♦ | 0.5 | $ - | ♦ | 0.5 | $ - | ♦ | 0.5 | $ - | ♦ | 0.5 | $ - | ♦ | 0.5 | $ - | ♦ | 0.5 | $ - |
| Clean cabinet heat exchanger | ♦ | 0.5 | $ - | ♦ | 0.5 | $ - | ♦ | 0.5 | $ - | ♦ | 0.5 | $ - | ♦ | 0.5 | $ - | ♦ | 0.5 | $ - |
| Check for NCGs in working fluid | ♦ | 0.5 | $ - | ♦ | 0.5 | $ - | ♦ | 0.5 | $ - | ♦ | 0.5 | $ - | ♦ | 0.5 | $ - | ♦ | 0.5 | $ - |
| Check operation of compressed air system | ♦ | 0.5 | $ - | ♦ | 0.5 | $ - | ♦ | 0.5 | $ - | ♦ | 0.5 | $ - | ♦ | 0.5 | $ - | ♦ | 0.5 | $ - |
| Check HX water-side pressure drop | | | | ♦ | 0.5 | $ - | | | | ♦ | 0.5 | $ - | | | | ♦ | 0.5 | $ - |
| Verify operability of safety equipment | | | | ♦ | 0.5 | $ - | | | | ♦ | 0.5 | $ - | | | | ♦ | 0.5 | $ - |
| Clean enclosure / clean LLR | | | | ♦ | 2 | $ 5 | | | | ♦ | 2 | $ 5 | | | | ♦ | 2 | $ 5 |
| Replace PLC and HMI batteries | | | | | | | | | | ♦ | 0.5 | $ 15 | | | | | | |
| Expander rebuild | | | | | | | | | | | | | ♦ | 16 | $ 22,266 | | | |
| Replace VFD internal cooling fan | | | | | | | | | | | | | | | | ♦ | 1 | $ 300 |
| Service Interval Parts Total (USD) | | | $ 40 | | | $ 45 | | | $ 40 | | | $ 60 | | | $ 22,306 | | | $ 345 |
| Service Interval Labor Hours Total | | 6.5 | | | 9.5 | | | 6.5 | | | 10 | | | 22.5 | | | 10.5 | |

**Current maintenance intervals are conservative, and may be extended based on field experience.**

**Estimated hours are based on time to perform service at site, and do not include any mobilization or transportation time to and from the site.**

**Costs shown are in USD.**

| | |
|---|---|
| 3 Year Part Total (USD): | $22,836.43 |
| 3 Year Labor Hours Total: | 65.5 |



ST-000001 Payback Estimator, Dual currency REV 12

P+ S6000: 20 Year End User Maintenance Schedule

CUMULATIVE RUN TIME HOURS ON POWER+ GENERATOR

| REQUIRED SERVICE WORK | 4400 | 8800 | 13200 | 17600 | 22000 | 26400 | 30800 | 35200 | 39600 | 44000 | 48400 | 52800 | 57200 | 61600 | 66000 | 70400 | 74800 | 79200 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 year | | 2 years | | 3 years | | 4 years | | 5 years | | 6 years | | 7 years | | 8 years | | 9 years | |
| Inspect all plumbing, flanges, and valves for leaks/ Check oil catch bottle | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ |
| Inspect coupling / expander and generator bearings | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ |
| Grease generator bearings | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ |
| Clean cooling vents of generator | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ |
| Inspect hardware for wear/damage | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ |
| Inspect for electrical wear/damage | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ |
| Clean cabinet heat exchanger | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ |
| Check for NCGs in working fluid | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ |
| Check operation of compressed air system | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ |
| Check HX water-side pressure drop | | ♦ | | ♦ | | ♦ | | ♦ | | ♦ | | ♦ | | ♦ | | ♦ | | ♦ |
| Verify operability of safety equipment | | ♦ | | ♦ | | ♦ | | ♦ | | ♦ | | ♦ | | ♦ | | ♦ | | ♦ |
| Clean enclosure / clean LLR | | ♦ | | ♦ | | ♦ | | ♦ | | ♦ | | ♦ | | ♦ | | ♦ | | ♦ |
| Replace PLC and HMI batteries | | | | ♦ | | | | ♦ | | | | ♦ | | | | ♦ | | |
| Expander rebuild | | | | | ♦ | | | | | ♦ | | | | | ♦ | | | |
| Replace VFD internal cooling fan | | | | | | ♦ | | | | | | ♦ | | | | | | ♦ |
| Replace High Side PRVs & Low Side PRVs* | | | | | | | | | ♦ | | | | | | | | | |
| Replace Generator Bearings** | | | | | | | | | | | | | | | | | | |

continued on chart below

CUMULATIVE RUN TIME HOURS ON POWER+ GENERATOR

| REQUIRED SERVICE WORK | 83600 | 88000 | 92400 | 96800 | 101200 | 105600 | 110000 | 114400 | 118800 | 123200 | 127600 | 132000 | 136400 | 140800 | 145200 | 149600 | 154000 | 158400 | 162800 | 167200 | 171600 | 176000 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 10 years | | 11 years | | 12 years | | 13 years | | 14 years | | 15 years | | 16 years | | 17 years | | 18 years | | 19 years | | 20 years | |
| Inspect all plumbing, flanges, and valves for leaks/ Check oil catch bottle | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ |
| Inspect coupling / expander and generator bearings | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ |
| Grease generator bearings | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ |
| Clean cooling vents of generator | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ |
| Inspect hardware for wear/damage | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ |
| Inspect for electrical wear/damage | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ |
| Clean cabinet heat exchanger | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ |
| Check for NCGs in working fluid | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ |
| Check operation of compressed air system | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ | ♦ |
| Check HX water-side pressure drop | | ♦ | | ♦ | | ♦ | | ♦ | | ♦ | | ♦ | | ♦ | | ♦ | | ♦ | | ♦ | | ♦ |
| Verify operability of safety equipment | | ♦ | | ♦ | | ♦ | | ♦ | | ♦ | | ♦ | | ♦ | | ♦ | | ♦ | | ♦ | | ♦ |
| Clean enclosure / clean LLR | | ♦ | | ♦ | | ♦ | | ♦ | | ♦ | | ♦ | | ♦ | | ♦ | | ♦ | | ♦ | | ♦ |
| Replace PLC and HMI batteries | | ♦ | | | | ♦ | | | | ♦ | | | | ♦ | | | | ♦ | | | | ♦ |
| Expander rebuild | | ♦ | | | | | ♦ | | | | | ♦ | | | | | ♦ | | | | | ♦ |
| Replace VFD internal cooling fan | | | | | | ♦ | | | | | | ♦ | | | | | | ♦ | | | | ♦ |
| Replace High Side PRVs & Low Side PRVs* | ♦ | | | | | | | | | | ♦ | | | | | | | | | | ♦ | |
| Replace Generator Bearings** | | | ♦ | | | | | | | | | | | | | | | | | | | |

**Current maintenance intervals are conservative, and may be extended based on field experience.**

* PRVs should be replaced immediately if they discharge or show signs of water ingress. PRVs should be replaced at the interval required by local code or every 5 years, whichever is lower.
** Generator bearings are rated for 100,000 hours of operation.



ST-000001 Payback Estimator, Dual currency REV 12

B: POWER | ELECTRATHERM

## 6 ECONOMIC MODEL

One ORC with One Heat Exchanger Installed. Maintenance costs including travelling costs - $US 21,391 – Average Yearly Operating Hrs 8,200

| ELECTRATHERM | $ | Single Currency<br>CONFIDENTIAL<br>Payback Estimator | Expand Null Values | Collapse Null Values |
|---|---|---|---|---|
| Series 6000 Power+ Generator | | Power+ Generator and HEX | | |
| **Estimated Total Capital Expenditure (CapEx)** | | **Estimated Total CapEx for this Project** | | |
| Total value of power per kWh | | Average value of kWh produced | | |
| Percentage of uptime hours (100% max/8760hrs) | | 94% uptime is equal to 8200 hrs. | | |
| Estimated net power output in kWe | | P+ net output in kWe | | |
| **Average Total Net Power Output in kWe** | | **Average Total Net Annual Power Output in kWe** | | |
| Annual value of power produced by P+ | | 1st year annual revenue from P+ Generator [$17924 Gross per month] | | |
| Annual maintenance and travel expenses | | Operation, maintenance, travel expenses based on projected lifetime | | |
| **Simple Payback in Years** | | **Years (this does account for 0% increase $/kWh for electricity** | | |
| Projected lifetime | | Years | | |
| Estimated % annual increase in $/kWh | | Estimated percentage per year in increased power costs | | |
| **Projected Lifetime Net Revenue** | | **Based on 0.00% increase in power costs per year** | | |
| Total cost per kWh over lifetime | | Total cost over lifetime including O&M costs of $0.043 per kWh | | |
| IRR for projected lifetime | | Internal Rate of Return for 20.0 years | | |
| **Net Present Value of Investment over 20 Years** | | **Based on inflation rate of 0.00%** | | |



ST-000001 Payback Estimator, Dual currency REV 12

B: POWER

ELECTRATHERM

One ORC with One Heat Exchanger Installed. Maintenance costs including travelling costs - $US 21,391 – Average Yearly Operating Hrs 5,300

| ELECTRATHERM | $ | Single Currency |
|---|---|---|
| | | CONFIDENTIAL |
| | | Payback Estimator |
| Series 6000 Power+ Generator | | Power+ Generator and HEX |
| **Estimated Total Capital Expenditure (CapEx)** | | **Estimated Total CapEx for this Project** |
| Total value of power per kWh | | Average value of kWh produced |
| Percentage of uptime hours (100% max/8760hrs) | | 61% uptime is equal to 5300 hrs. |
| Estimated net power output in kWe | | P+ net output in kWe |
| **Average Total Net Power Output in kWe** | | **Average Total Net Annual Power Output in kWe** |
| Annual value of power produced by P+ | | 1st year annual revenue from P+ Generator [$11584 Gross per month] |
| Annual maintenance and travel expenses | | Operation, maintenance, travel expenses based on projected lifetime |
| **Simple Payback in Years** | | **Years (this does account for 0% increase $/kWh for electricity** |
| Projected lifetime | | Years |
| Estimated % annual increase in $/kWh | | Estimated percentage per year in increased power costs |
| **Projected Lifetime Net Revenue** | | **Based on 0.00% increase in power costs per year** |
| Total cost per kWh over lifetime | | Total cost over lifetime including O&M costs of $0.044 per kWh |
| IRR for projected lifetime | | Internal Rate of Return for 20.0 years |
| **Net Present Value of Investment over 20 Years** | | **Based on inflation rate of 0.00%** |

Expand Null Values

Collapse Null Values



ST-000001 Payback Estimator, Dual currency REV 12

One ORC with Two Heat Exchangers Installed.   Maintenance costs including travelling costs - $US 21,391 – Average Yearly Operating Hrs 8,400

Single Currency

Expand Null Values

Collapse Null Values

CONFIDENTIAL

ayback Estimator

| | | |
|---|---|---|
| Series 6000 Power+ Generator | | ower+ Generator and two HEX |
| **Estimated Total Capital Expenditure (CapEx)** | | **stimated Total CapEx for this Project** |
| Total value of power per kWh | | verage value of kWh produced |
| Percentage of uptime hours (100% max/8760hrs) | | 6% uptime is equal to 8400 hrs. |
| Estimated net power output in kWe | | + net output in kWe |
| **Average Total Net Power Output in kWe** | | **verage Total Net Annual Power Output in kWe** |
| Annual value of power produced by P+ | | st year annual revenue from P+ Generator [$18361 Gross per month] |
| Annual maintenance and travel expenses | | peration, maintenance, travel expenses based on projected lifetime |
| **Simple Payback in Years** | | **ears (this does account for 0% increase $/kWh for electricity** |
| Projected lifetime | | ears |
| Estimated % annual increase in $/kWh | | stimated percentage per year in increased power costs |
| **Projected Lifetime Net Revenue** | | **ased on 0.00% increase in power costs per year** |
| Total cost per kWh over lifetime | | otal cost over lifetime including O&M costs of $0.042 per kWh |
| IRR for projected lifetime | | nternal Rate of Return for 20.0 years |
| **Net Present Value of Investment over 20 Years** | | **ased on inflation rate of 0.00%** |



ST-000001 Payback Estimator, Dual currency REV 12

## 7 CONCLUSION

The presented study shows that the project is technically feasible and has good economic parameters. An identified project risk is, a lack of time for the production and delivery of components to the site of installation. The production time for a flue-gas exchanger and cooler is at least 8 weeks from ordering. Transport to Adelaide is 8-10 weeks and the start of engines is planned for March 2017.

This risk connected with a late delivery can be mitigated by the provision of transport straight to the site of installation (Weno, Chuuck). If this cannot be ensured, then the alternative solution is to install a bypass before starting the engines and to prepare the installation for mounting the ORC at a later date. The exchanger and ORC can then be delivered later. If the bypass is installed, it will not be necessary to shut down the engines at the time of installation of the flue-gas exchanger and ORC.

We believe that this solution seems to be the most favourable with regard to possible additional costs connected with the provision of special transport of the technology to the site of installation.

Other possible risks such as technical risks etc. were not found during the study; it is a standard connection of the engine to the ORC system, which has been implemented and verified in many other installations all over the world.