



***Installation manual for ENOGIA 20 kW Low
Temperature Direct Condensation ORC unit
ENO-20LT/DC***

Document	User Manual ENO-20LT	Version	A
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1 Disclaimers

a. General disclaimer

The following document is a manual written in order to give the information and instructions needed for the integration of ENOGIA's Organic Rankine Cycle (ORC) following ORC module:

- ENO-20LT/DC v2017

This document is not to be used for calculating the performance or the output of the ORC unit because operating values and ORC unit output can be affected by many variables, including hot water temperature at ORC inlet, cooling water temperature, flow rates, etc.

For a complete project evaluation please ask ENOGIA staff.

b. About Safety of Operation

The following document is an installation manual which depicts the proper installation of ENOGIA's ENO20-LT/DC product. In case of a non-compliant use of the ORC by the End User, ENOGIA shall not be considered as responsible of any harm or damage caused.

Please respect the integration instructions described in this document. In case of any doubts, please contact ENOGIA.

c. Contact information

You can contact ENOGIA commercial and technical teams at the following:

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Tel: +33 4 84 25 60 17

2 General guidelines on ENOGIA's ORC products

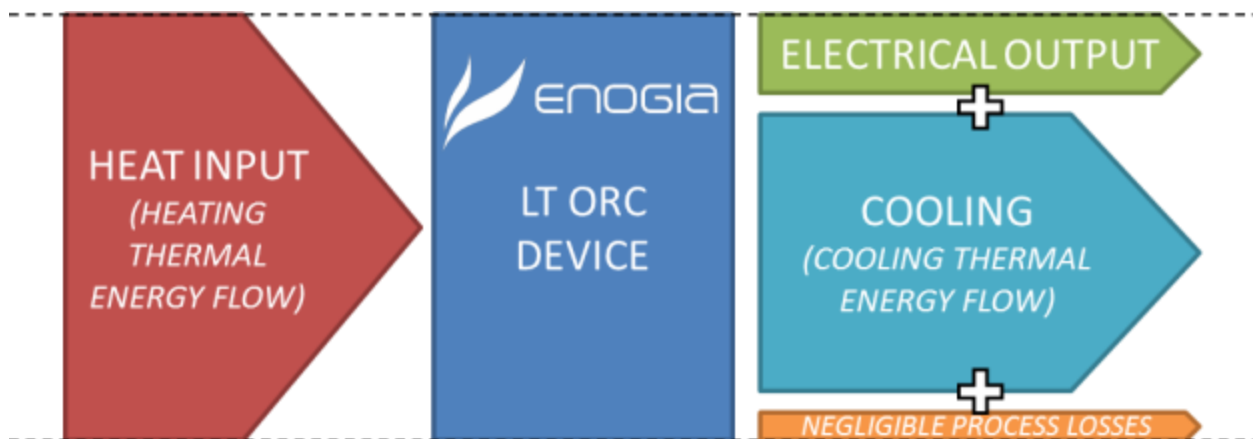
2.1 About ORC technology

Although the principle of Organic Rankine Cycle (ORC) was stated by Mr Rankine in the 19th century, small operational ORC products are cutting edge technology able to convert low temperature streams of energy into useful energy, namely electricity.

The Organic Rankine Cycle is an alternative to the traditional Rankine Cycle, which uses steam as a working fluid: the ORC can use any organic fluid, but to attain successful low temperature performances, refrigerant fluids can be used.

a. Balance of energy flows

The ORC is a power thermodynamic cycle. It is used to convert heat into electricity. The following schematic explains the balance of the energy flows with the ORC.



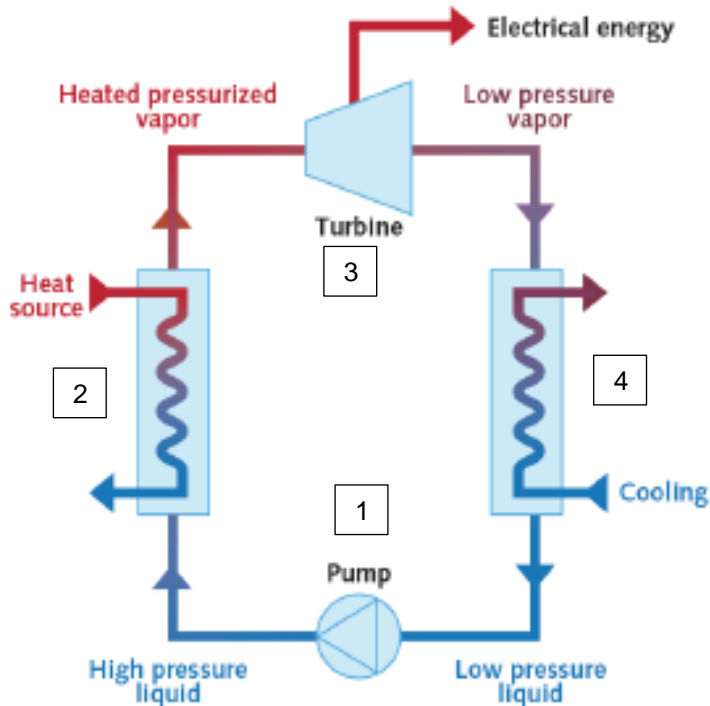
However, all the heat cannot be converted into electricity. The system has a system efficiency, which can be calculated by using the electrical output power, divided by the thermal inlet power.

The heat which was not turned into electrical power needs to be removed from the system in order to balance the energy flows. To this end, an ORC always needs a cooling source, which is provided by cold ambient air for the ENO-20LT/DC module.

Performance of the ORC unit is highly dependent of the quality (temperature) of the cooling source, so ORC output can vary when cooling source parameters vary (ie. Variation of ambient temperature).

b. General working principle of ORC

The internal layout of a typical ORC unit is as follows:



As the commonly used steam Rankine cycle, the Organic Rankine Cycle uses the discharge of high pressure fluid through a turbine expander in order to produce mechanical and electrical output (3).

To this end, the working fluid is heated in the “boiler” exchanger (2), in order to produce high pressure gas. For the turbine to perform efficiently, a low outlet pressure is needed.

The “condenser” exchanger (4) uses ambient air to condense the fluid at low pressure, allowing a high pressure ratio for correct turbine operation.

The pump (or also called feed-pump, (1)) is then used to feed the liquid fluid coming from the condenser to the boiler.

2.2 About ENOGIA's ORC

Hereafter are depicted the technical choices done by ENOGIA in order to optimize the performance and the reliability of the ENO20-LT/DC product.

a. Evaporator

The thermal exchange between the heat source and the working fluid is done through one heat exchanger called the evaporator.

To guarantee the performance and the reliability of this exchanger, the evaporator is supplied by SWEP, one of the leading company regarding exchangers manufacturing.

The evaporator's main purpose is to catch the thermal power from the heat source while warming up and boiling the working fluid contained in it.

The evaporator is a plate exchanger specially designed to fit with the flow rate and temperature condition involved in each project.



b. Condenser

Regarding the condenser, its role is to evacuate the residual heat of the ORC and condense the working fluid. Indeed, after being expanded in the turbine, the working fluid still contains thermal power that must be evacuated in order to fit with the Organic Rankine Cycle. It also needs to be liquid again to be pumped back into the evaporator.

For the ENO20-LT/DC module, the cold source is the ambient air.

Thus, the condenser transfers the heat from the working fluid to the ambient air at a lower temperature than the heating loop.

As for the evaporator, the condenser is supplied by one of the leading company regarding micro channels condensers manufacturing: Thermokey.

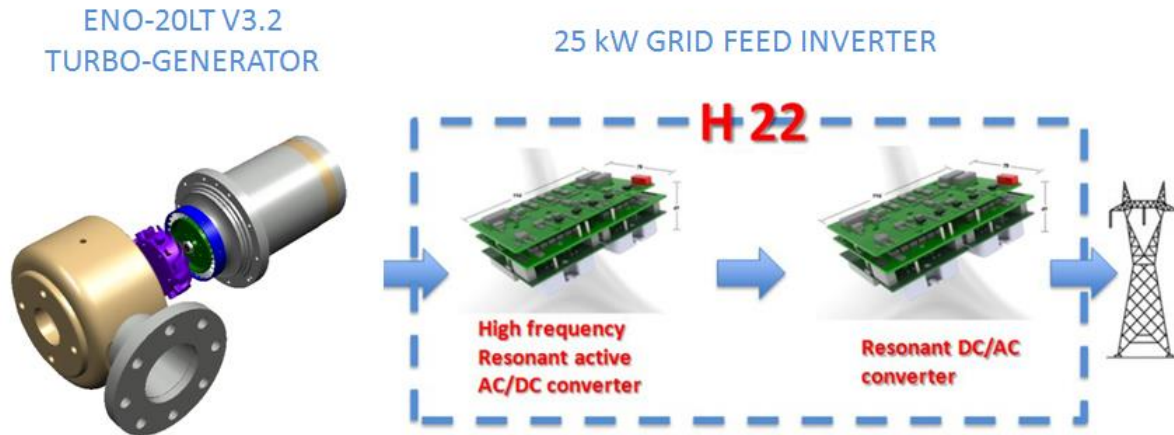


How the ORC is cooled plays a very important role in the conversion cycle performance meaning that the condenser's design needs to be optimized to guarantee the efficiency of the system.

c. ENOGIA turbo expander and H22 inverter

Each ENO-20LT/DC ORC system manufactured by ENOGIA is associated to an ENOGIA turbo-expander and H22 inverter.

The ENO-20LT/DC has the following inverter and turbine configuration:



The strengths of this combination of elements are:

- Extremely compact** turbo expander shaft
- 100 % oil free** running involving less maintenance on the calorific fluid and on the system itself
- Hermetic** and homogeneous turbine + generator block without any mechanical seal 10 to 100 times less working fluid reload than the competitors using mechanical seal.
- Modular** architecture of the blades allowing ENOGIA to adapt and optimize the turbo-expander to each thermal power and temperature of heat sources
- Contactless** rotating parts of the turbo expander guarantees no wear of the blades of the turbine
- Highly efficient** H22 inverter offering turbine to grid current conversion ratio over 97 %

d. Main feed-pump

To generate power thanks to the expansion gas through the turbine, the Organic Rankine Cycle requires the compression of the working fluid upstream.

In the perspective of a long lasting ORC system, ENOGIA selected the best technology on the market for its pumps such as the Grundfos brand.

More precisely ENOGIA adopted the magnetic coupling multistage range of product offering the perfect combination between performance, reliability, compactness and power consumption.



e. R245fa working fluid

The calorific fluid used in ENOGIA's ENO20-LT/DC ORC module is the R245fa manufactured by Honeywell which product name is Genetron® 245fa (1,1,1,3,3-Pentafluoropropane).

This fluid is chosen for its very interesting performance for the low temperature ORC applications.

Thus, coupled with the ENOGIA turbo expander technology, this make possible the waste heat recovery and conversion even with "low "temperature such as water at 80°C.

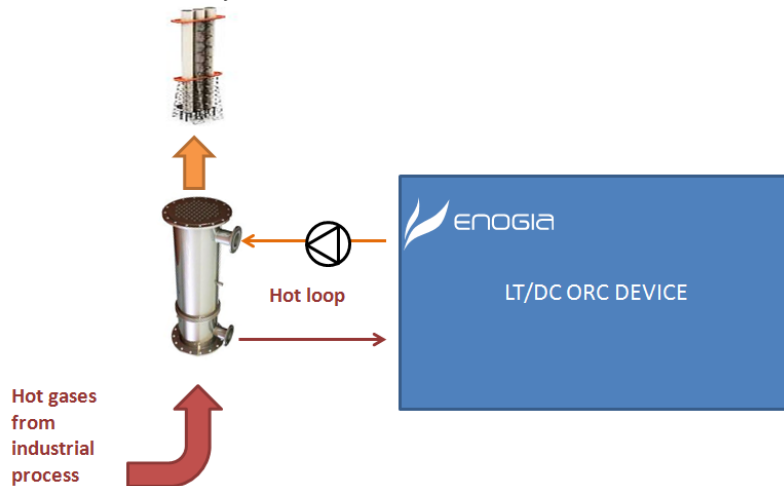
Beside the performance aspect, the R245fa possesses safety properties that guarantee the security of the people and the environment around the ORC:

- Non flammable**
- No color**
- Very weak smell**
- Non toxic**
- Neutral pH**
- Reduced GWP compared to other calorific fluid**

2.3 ORC applications

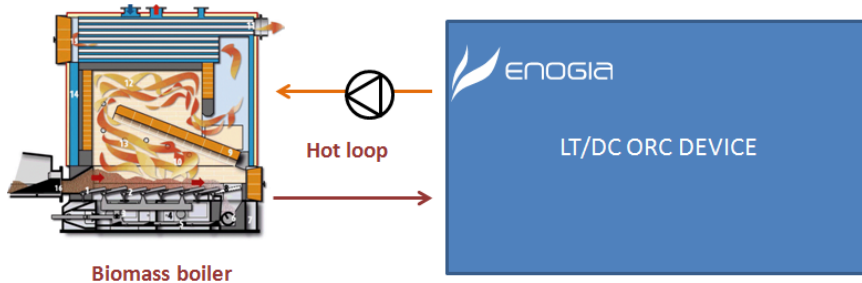
a. Waste heat on exhaust stack

ENOGIA's LT/DC ORC can be used on an intermediate waste heat recovery loop using liquid fluid such as water to recover the heat from hot gases. The hot liquid/water can be fed into the ORC to turn the recovered thermal power into electricity.



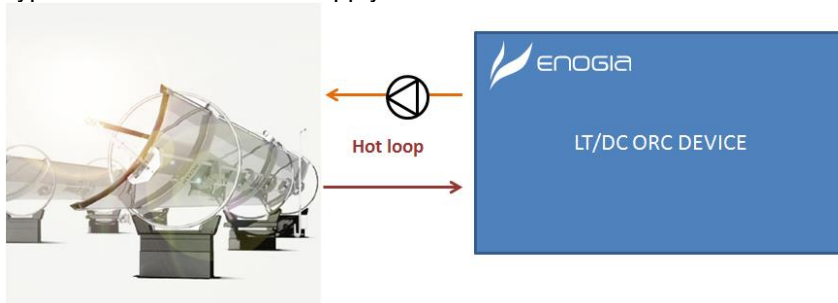
b. Biomass boiler

ENOGIA's LT/DC ORC can be used with the hot water from a biomass boiler as a prime power device. The biomass boiler could be warm water or superheated water type. Obviously efficiency will be higher with a superheated water boiler.



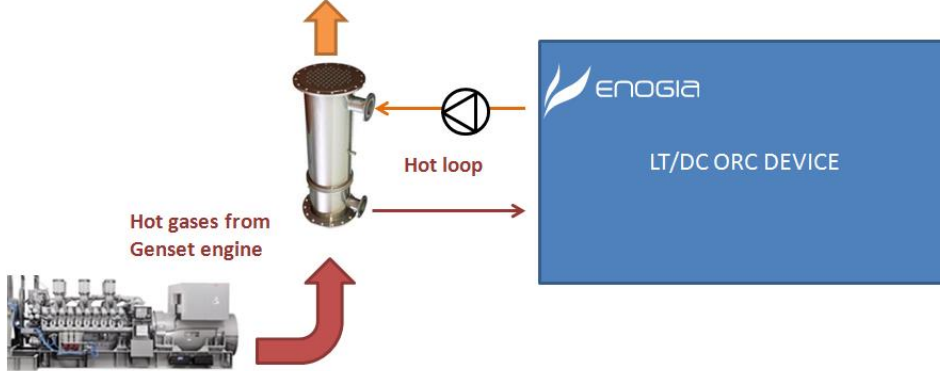
c. Solar

ENOGIA's LT/DC ORC can be used with solar collectors, from planar to parabolic troughs, including tube and Fresnel types. The collectors will supply hot water or hot thermal transfer oil to the ORC.



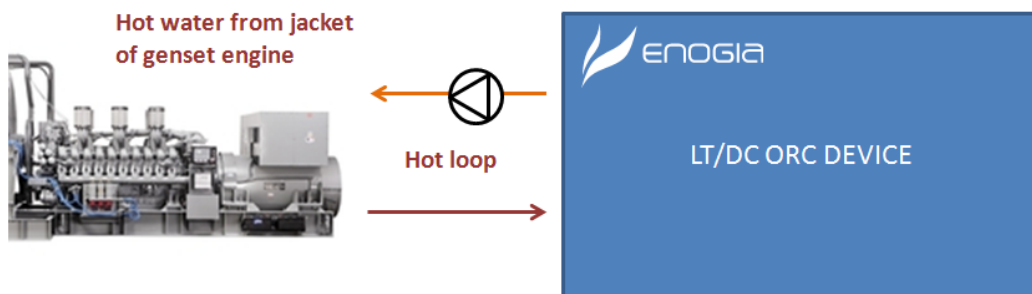
d. Internal combustion engine exhaust

ENOGIA's LT/DC ORC can be used on an intermediate loop filled with water or thermal transfer fluid, in order to recover and convert into electricity the waste heat from the exhaust gases of a genset engine, similarly to an industrial process stack (a).



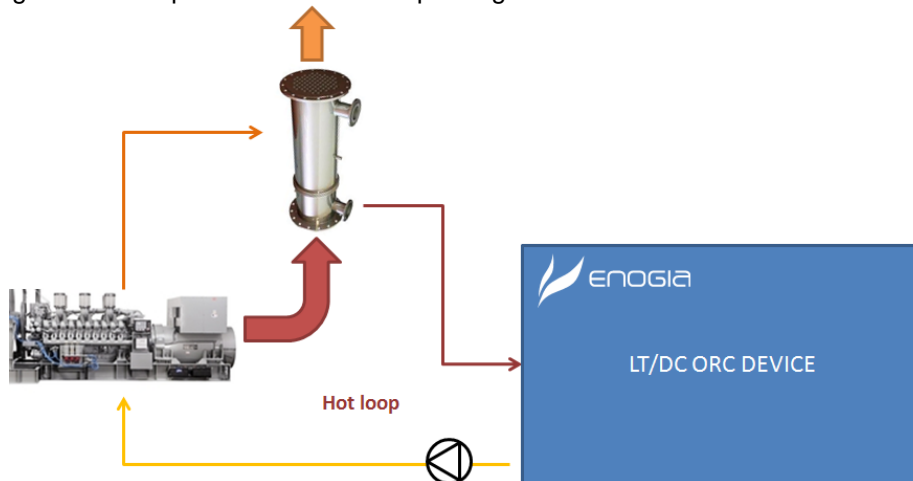
e. Internal combustion engine jacket water

ENOGIA's LT/DC ORC is the only range of ORC products which can make an efficient use of the 90°C hot water from the jacket of an internal combustion genset engine. Indeed, with many genset manufacturers, the water shall be sent back to the engine at 70°C, and the LT/DC range of product can attain full power using a 90/70°C hot loop.



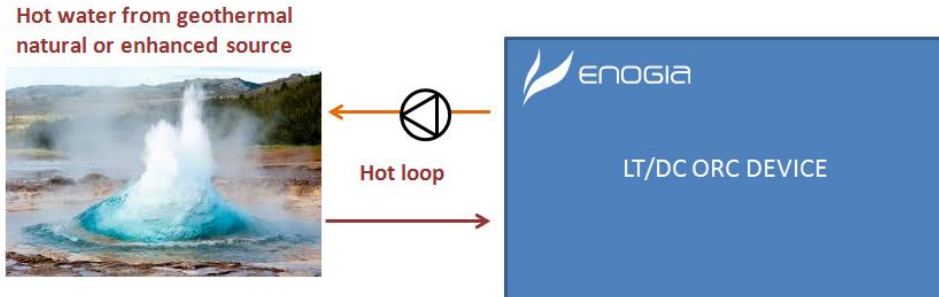
f. Internal combustion engine combined recovery

In some cases, the genset engine is sold as a "CHP unit" meaning it has a loop using the hot gases and the jacket water in order to provide hot water to a user. In those cases, the LT/DC ORC can use the "CHP loop" in order to produce electricity. Again, ENOGIA's LT/DC ORC is the only ORC which can be used at full power using the low temperature 90/70°C loop of a genset CHP.



g. Geothermal

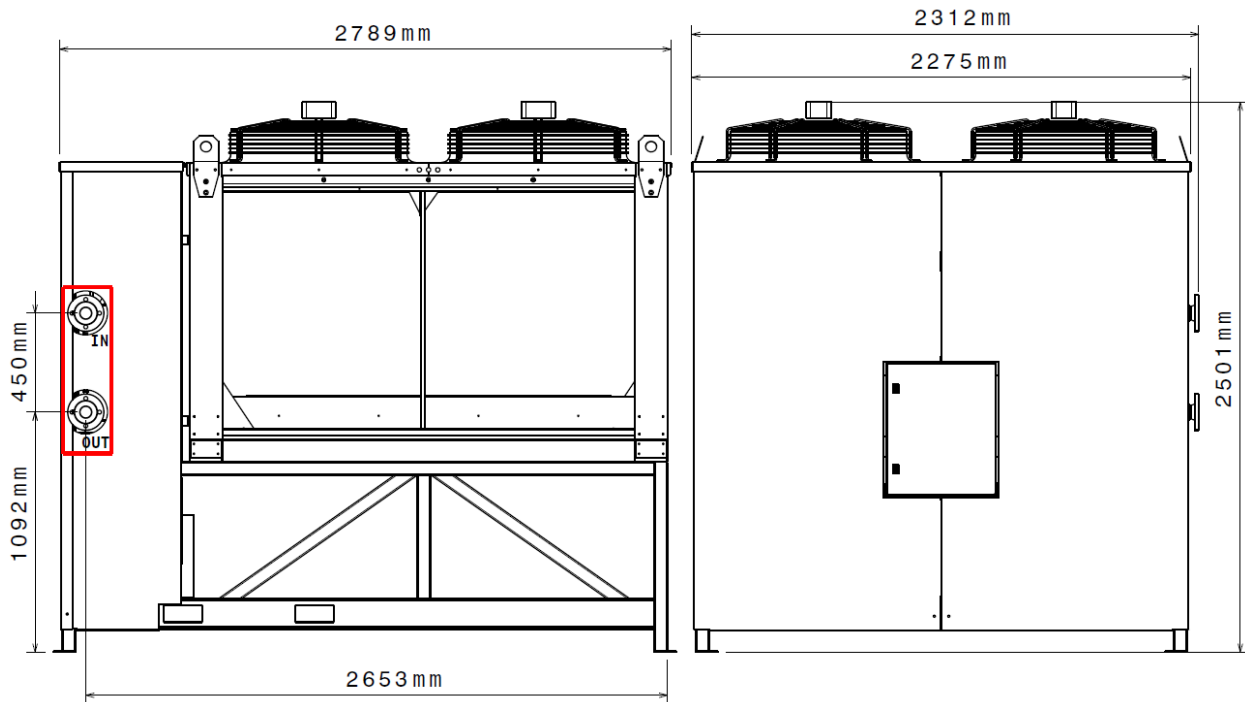
ENOGIA's LT/DC ORC can use natural, artesian or enhanced geothermal sources. One should be careful to water specifications when considering a geothermal ORC project. Please contact ENOGIA's sales representative for a project evaluation.



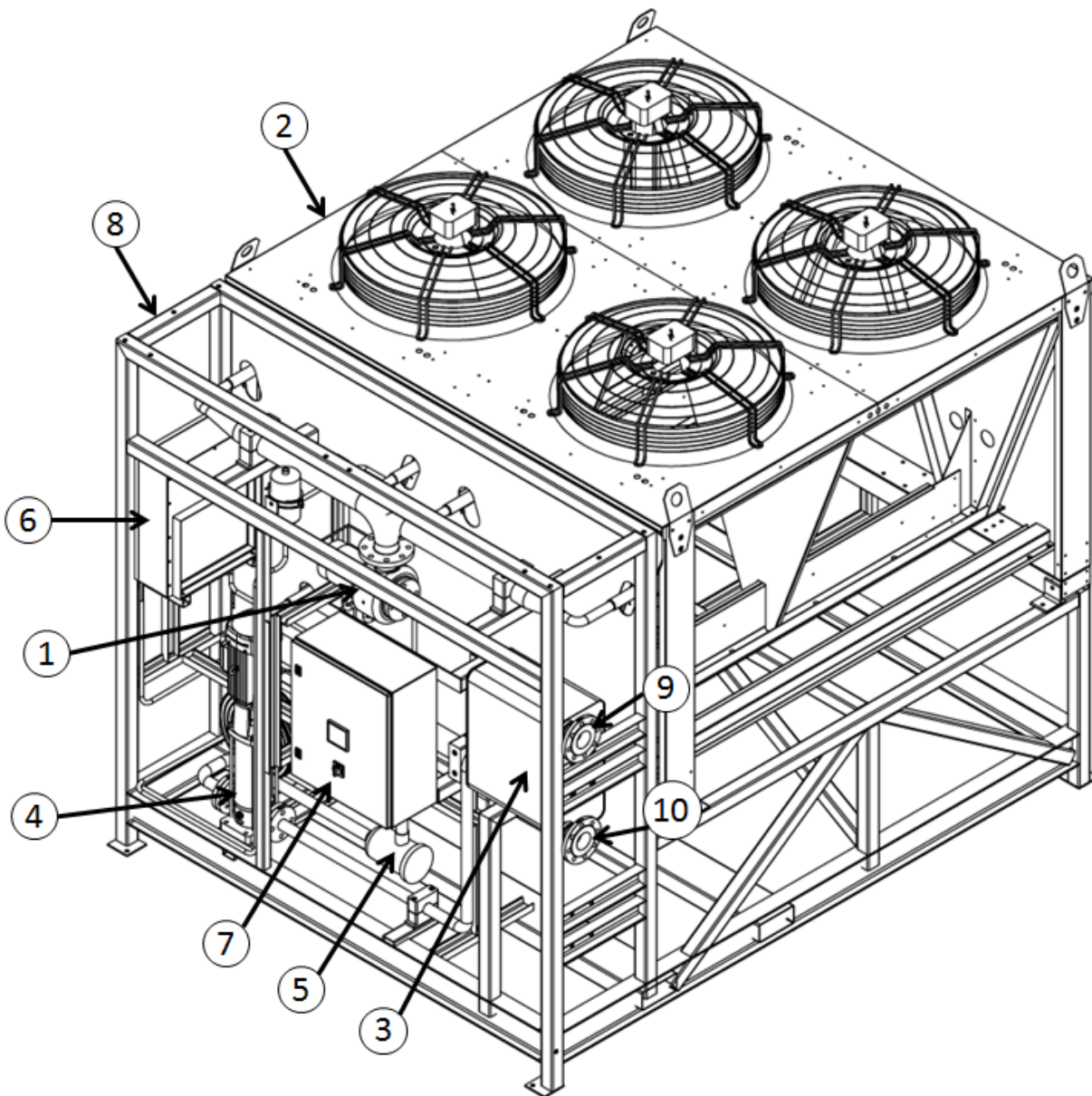
3 Specifications of the ORC

3.1.1 General specifications

Weight : 1500 kg
Length : 2789 mm
Width : 2312 mm
Height : 2501 mm
Sound Level: 50 dB at 10 meters



3.1.2 Description of the ENO20-LT/DC ORC unit



Number	Part
1	Turbine & generator
2	Condenser
3	Boiler
4	Main Pump
5	Filter
6	Grid feed inverter
7	PLC cabinet
8	Chassis
9	Hot loop inlet flange
10	Hot loop outlet flange

4 Installation of the ORC

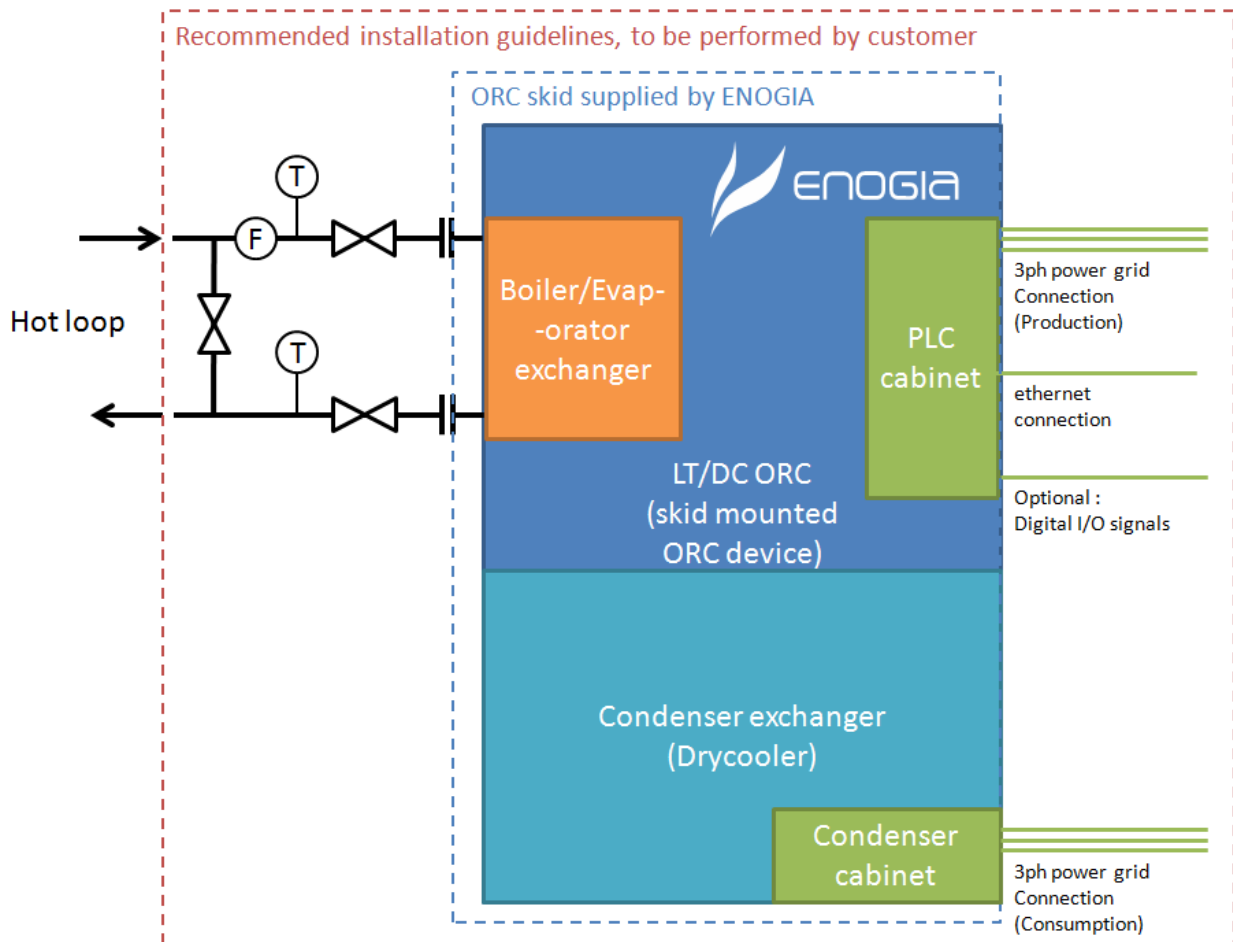
4.1 General considerations about the installation of ENOGIA's ORC

a. General considerations about ORC installation

Installing the ENO20- LT/DC unit means primarily:

- 1- Positioning the ORC skid at the desired location for its operation
- 2- Connecting the hot water to the hot water flanges of the ORC
- 3- Connecting the grid-feed electrical connection
- 4- Connecting the grid-injection electrical connection
- 5- Connecting the Ethernet data line to the ORC integrated PLC
- 6- If needed – connecting the Digital I/O signals

The following schematic shows the connections to be performed by the customer in order to ensure correct operation of the ORC unit. If one connection is not made correctly, the ORC will not operate.



NOTA : the flow meters (F), the temperature sensors (T) and the bypass lines are recommended in order to monitor ORC performance and to ensure customer process running in case ORC is stopped, however they are not mandatory for ORC operation. The Digital I/O signals can be connected as an option.

b. Water specifications

The LT/DC range of ENOGIA's ORC is meant to be used as a heat to electricity converter, effectively taking thermal power out of a hot water flow.

The hot water is in direct contact with the SWEP Brazed Plate Heat Exchanger, and as such should not damage the exchanger. In order to guarantee the correct operation and long lifetime of the product, it should be used only with clean water, with the following specifications:

- Water neutral to slightly alkaline PH (7-8.5).
- Possibility to use a mix of water and glycol, up to 100% glycol. Enogia does not recommend to use more than 70% glycol in the mix, as the freezing temperature will increase above this limit.
- Water free of abrasive material that will abrade and wear down the heat exchanger plates.
- Water with little to no dissolved solids, as scaling on the heat exchanger plates reduces heat transfer capability, and reduces flow rate / increases pressure drop through the heat exchangers.
- The heat exchangers are made of stainless steel (304L as standard, 316L as optional) with copper brazing; chemicals that cause corrosion of stainless steel or copper should not be present in the hot water source.
- As an option, the LT/DC ORC can be manufactured with other heat exchanger which could cope with other quality of water (for example sea cooling or geothermal application). Please ask ENOGIA's sales representatives for technical or commercial information.

c. Environmental and ground conditions

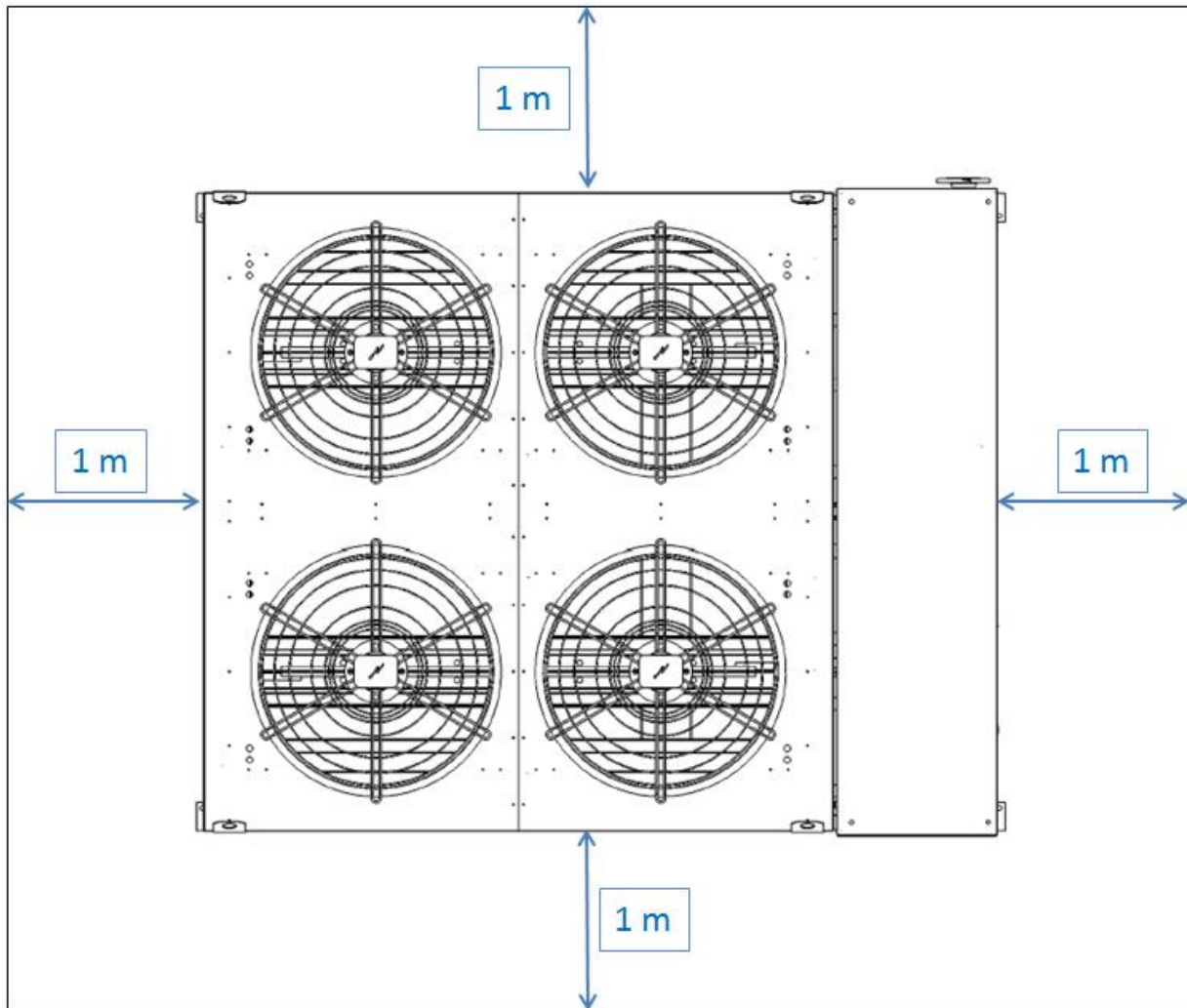
This range of product is meant to be installed on a concrete or any other "hard" leveled floor. The floor should be no more of 1° of slope in any direction.

This range of product is made for outdoor operation.

Maximum operational ambient temperature:	45°C
Maximum storage ambient temperature:	50°C
Minimum operational cold temperature:	-20°C
Minimum storage cold temperature:	-20°C

d. Maintenance clearance

There should be enough clearance left for installation and maintenance around the ORC. One meter on each side minimum is enough.

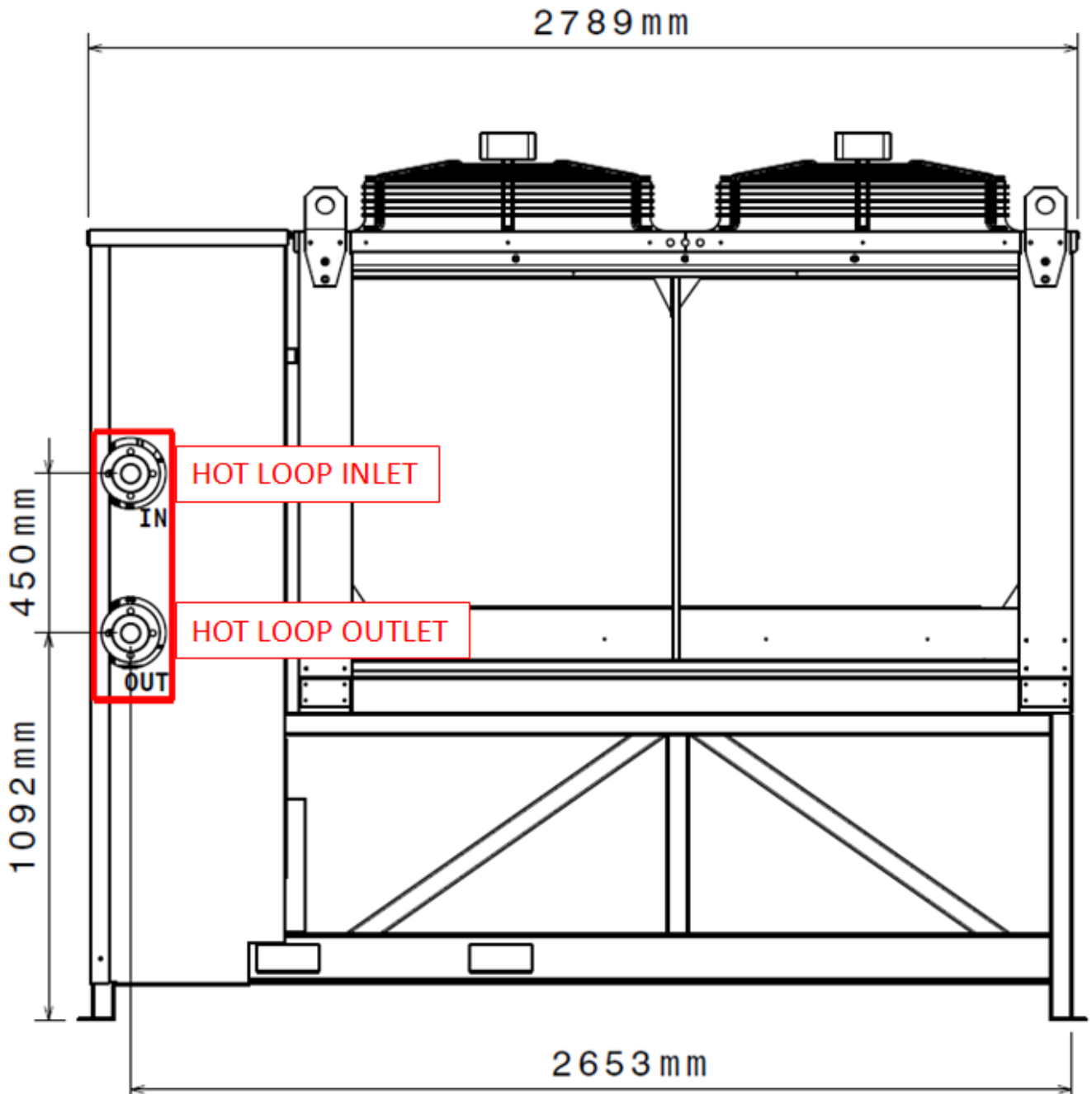


4.2 Hydraulic connections and specifications



IMPORTANT: The hot loop temperature shall not overpass 130°C. If, despite the precaution of the end user the hot loop temperature goes higher than this limit, the guaranty on the product would not be effective anymore. More over the thermal power delivered to the ORC must be lower or equal to one mentioned in the contract. If the heat flux is higher than expected, the Equipment will not be able to recover all the heat available.

Hydraulic connections must be done with ISO DN 65 PN 16 flanges (2 in total). It is recommended to use graphite seals for the hot loop.

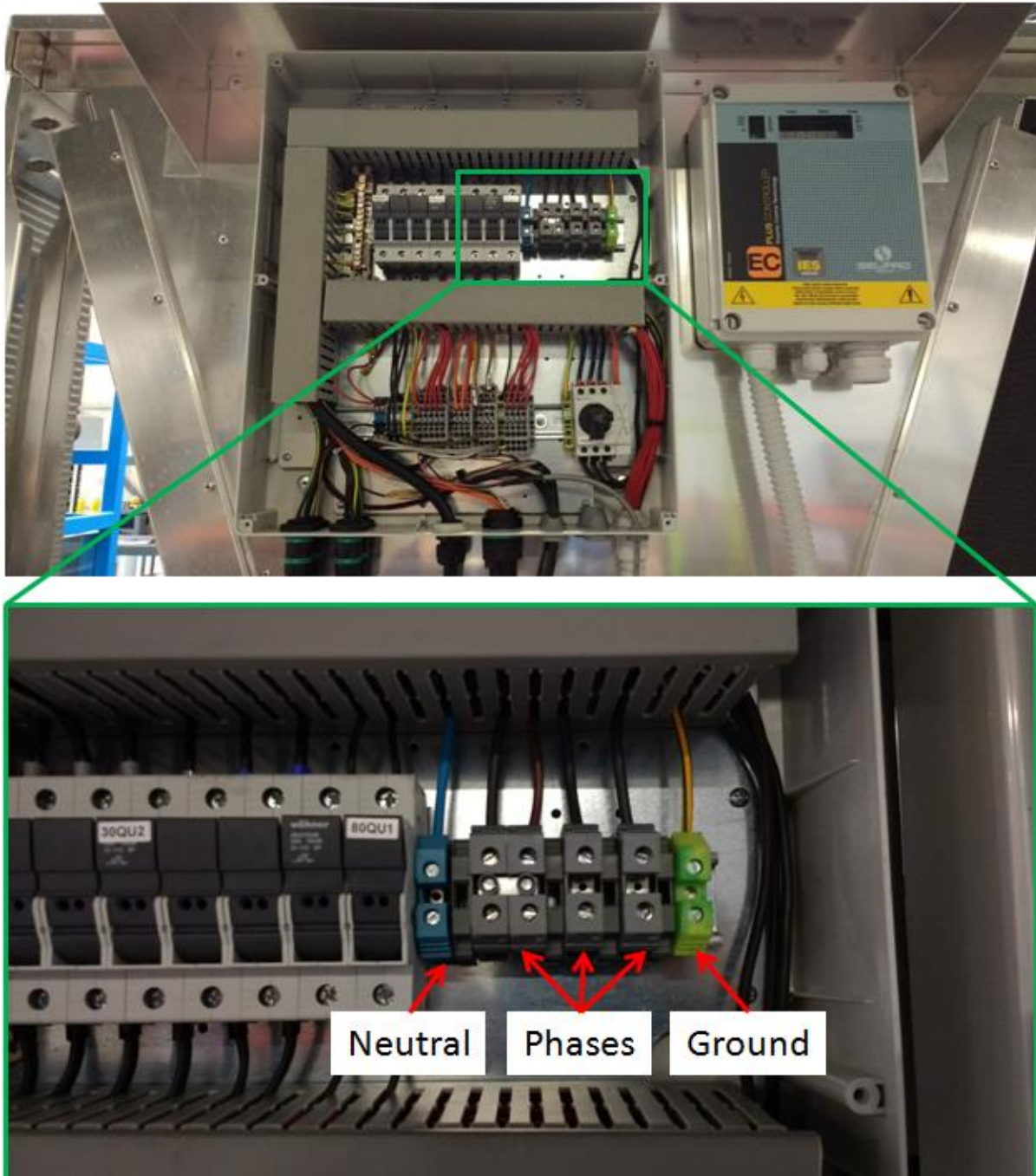


4.3 Electrical junction and data transfer

4.3.1 Electrical junction for power consumption

The electrical connection for consumption must be made in the electrical cabinet of the Condenser of the ORC.

The Connection terminal blocks are positioned as follow:



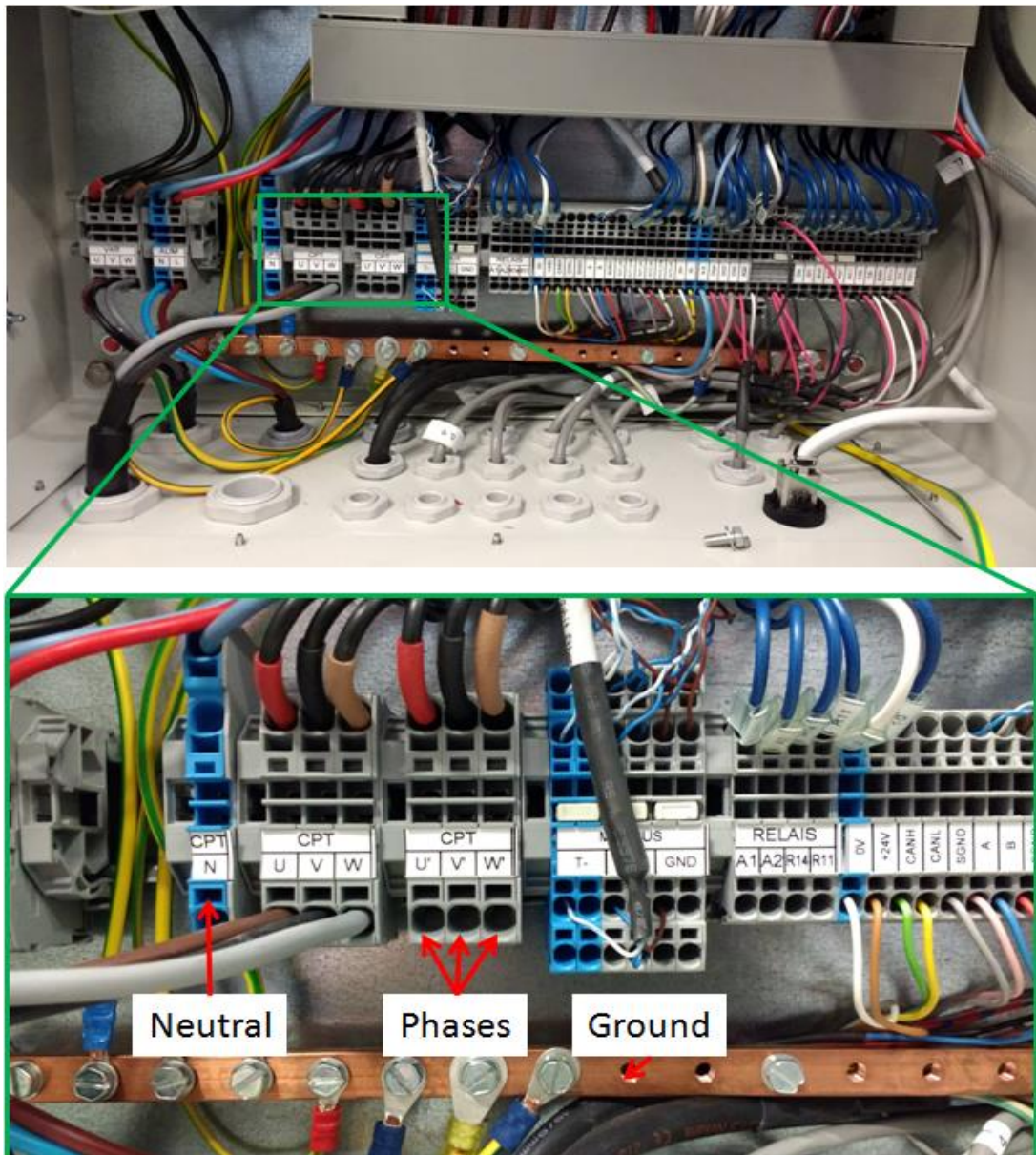
The three-phase connection for the consumption of the ORC is made by an electrical wire **G5** (3 phases, ground and neutral). The section must be **6 mm²**. The distance between the ORC and the connection point must be adapted to this section, regarding the maximum 5 kW consumption.

4.3.2 Electrical junction for power production injection

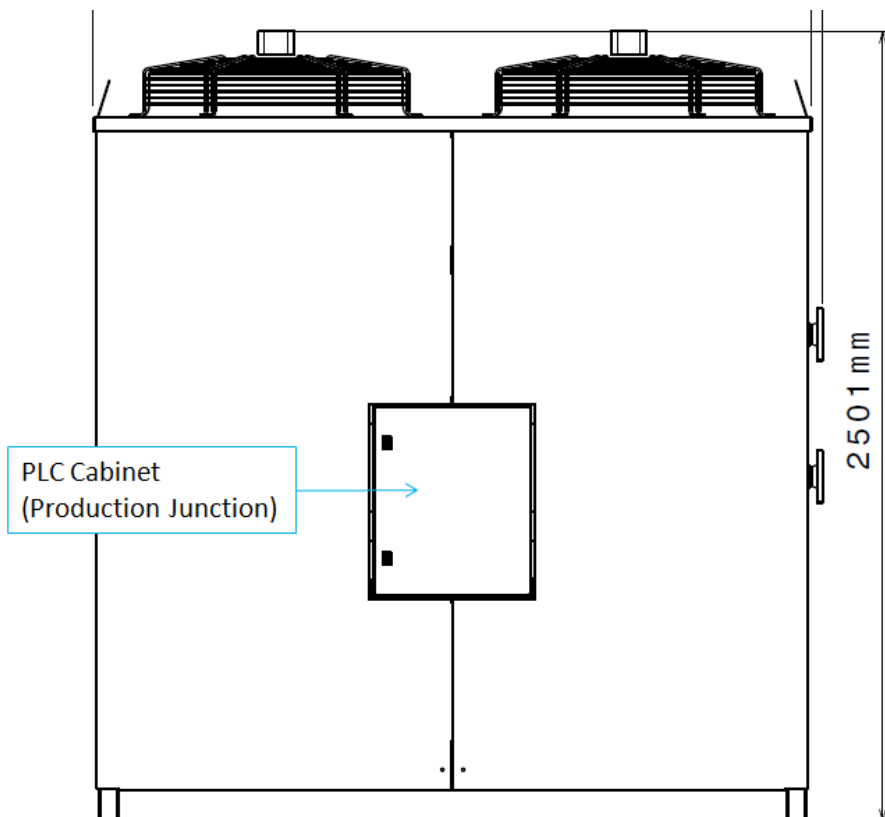
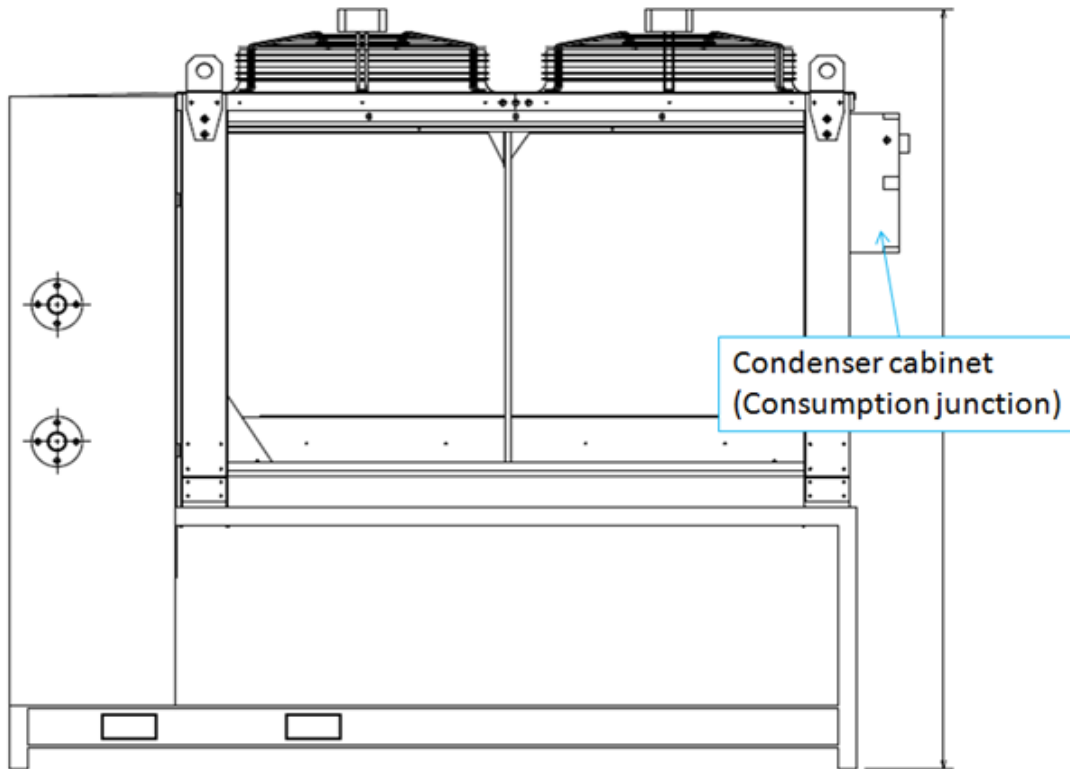
The electrical junction for power production injection is made in the PLC cabinet of the ORC.

The three-phase connection for reinjection of the ORC's production is made by an electrical wire **G5** (3 phases, ground and neutral). The section must be **6 mm²**. The distance between the ORC and the connection point must be adapted to this section, regarding the maximum 20 kW gross production.

The three-phase connection is made on the electricity meter terminals named U', V', and W'. The neutral must be connected on the terminal next to the electricity meter, and the Ground wire should be connected to the Ground copper bar at the bottom of the electrical cabinet as follow:



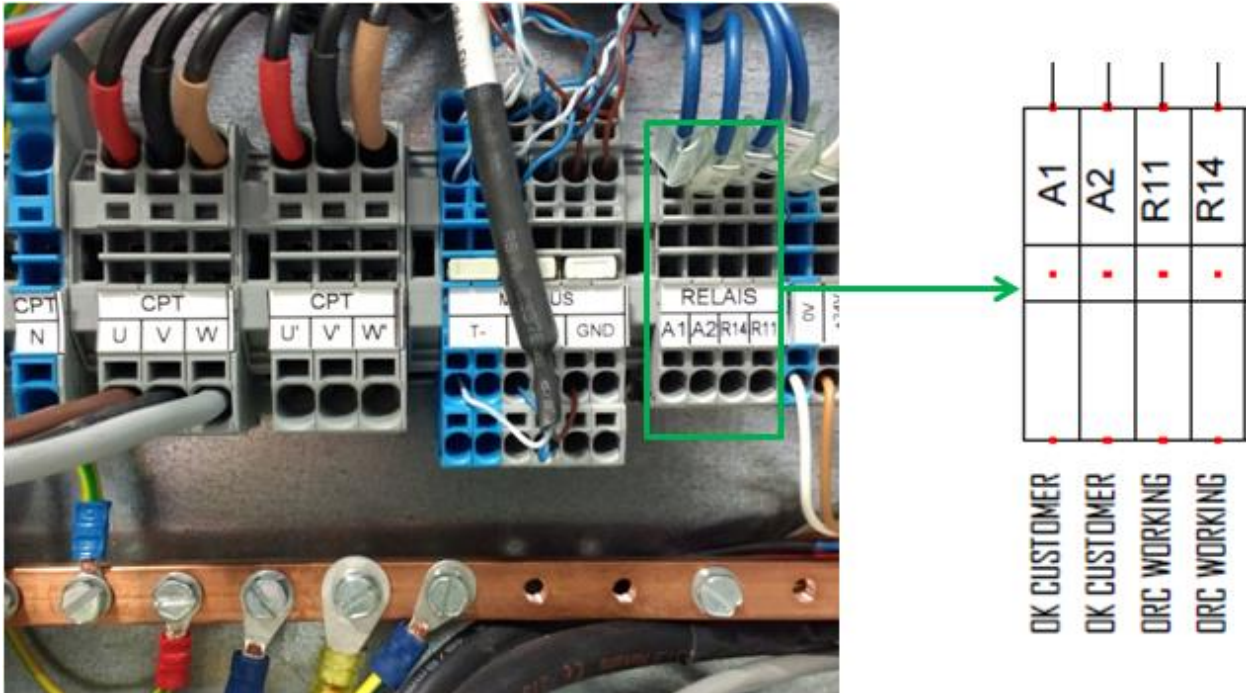
4.3.3 Physical position of the cabinets



4.3.4 Communication between ORC and customer systems

4.3.4.1 Digital I/Os

The following Digital Input / Output are available from the ORC PLC and can be connected to the customer main PLC in order to remote start and stop the ORC, and to obtain the information on the ORC status.



a. Digital input of ORC PLC :

Digital input 1 :

Signal name : ORC can start (OK_CLIENT)
The client allows the ORC to startup

Electrical connections :

A1: +24V
A2: 0V

b. Digital outputs of ORC PLC

Digital output 1 :

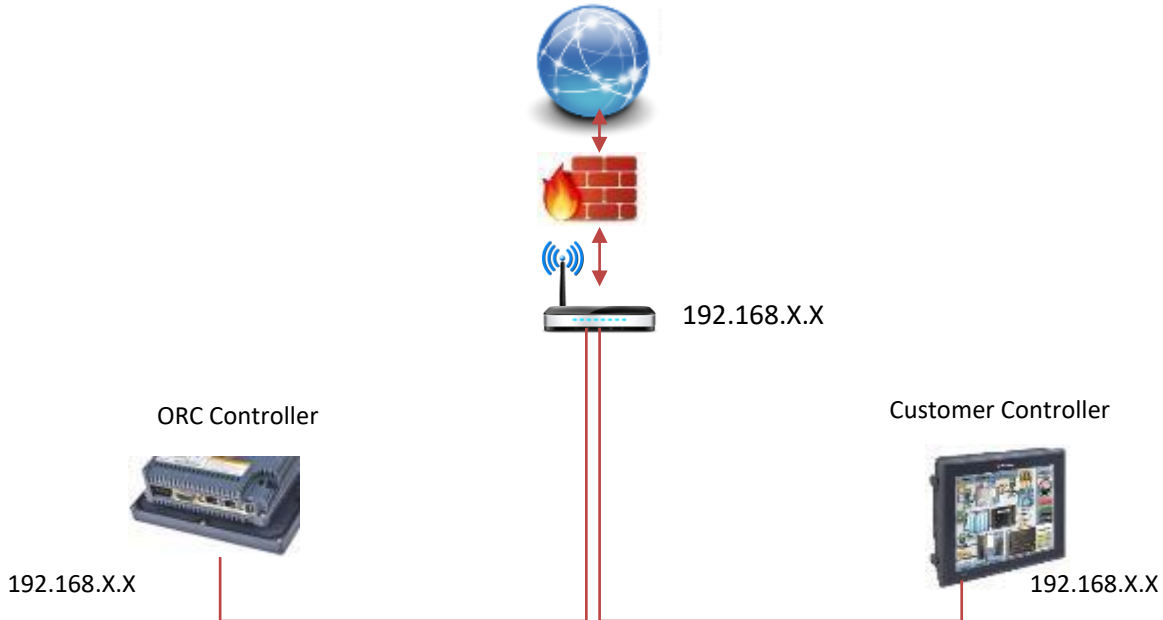
Signal name : ORC working
The ORC is effectively ready to start and perform heat to electricity conversion.

Electrical connections :

COM : 24V
NO : Digital Input from the end user's PLC

4.3.4.2 Ethernet network connection

The TC/IP Ethernet connection is mandatory for the supervision and the remote control of the ORC. Port 1 of the PLC is dedicated to this function, by means of a RJ45 connector.



The ORC Unit is equipped with Schneider HMI SCU 6B5 PLC.

This PLC allows as well to supervise and to do remote monitoring of the system through Internet. ENOGIA already installed Units with such supervision and remote control and give the access to the Client to control panels as follow (10, 20 or 40 kW LT Units):

4.3.4.3 MODBUS ORC

The DATA transfer from the ORC is done by MODBUS protocol TCP/IP with the end user' PLC.

