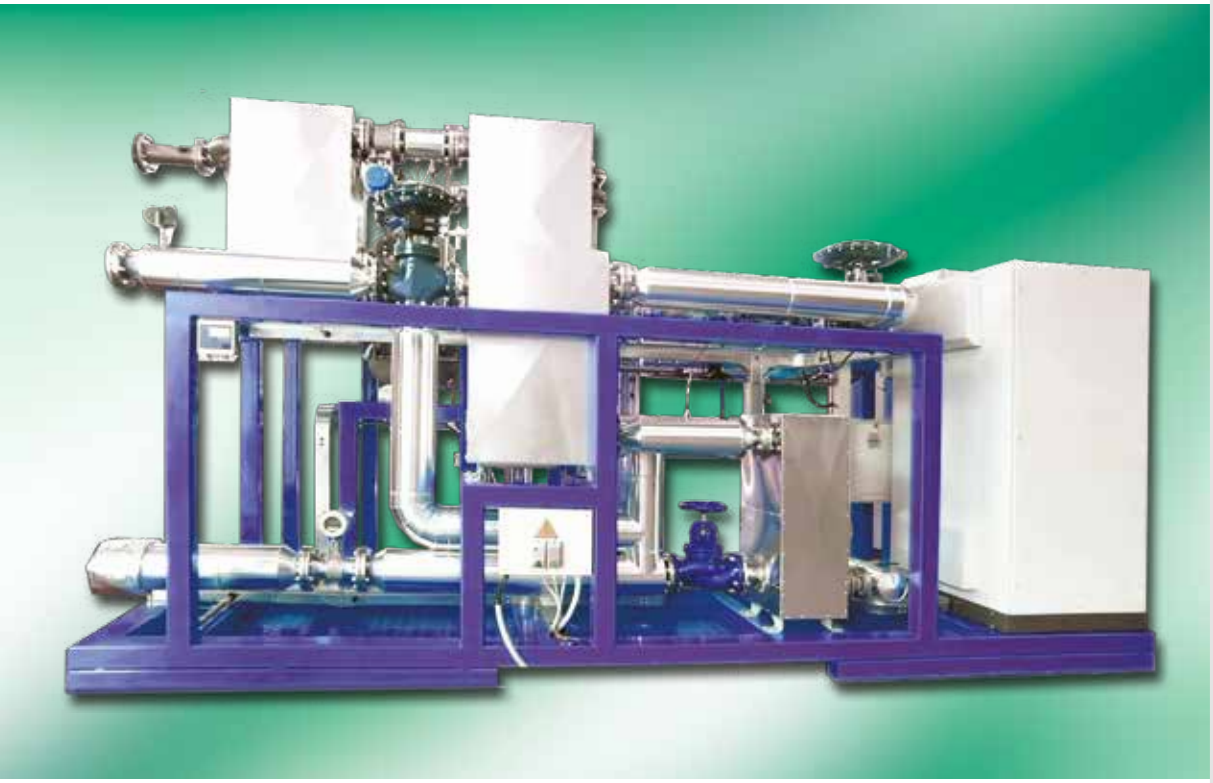
TECHNICAL ATTACHMENT

ZUCCATO ENERGIA

PRODUCT SHEET
105-KWe, Skid-mounted,
Low Temperature Organic Rankine Cycle (LT-ORC)
Combined Heat & Power Energy Production Module

ZE-105-CHP



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PLANT TECHNOLOGY DESCRIPTION

IN SHORT

Low-Temperature Organic Rankine Cycle (LT-ORC) Technology

Emission-free closed loop operation

A low-boiling-point working fluid is evaporated and expanded by heat

Working fluid expansion spins an high-speed turbine

The spinning turbine drives directly a generator

The working fluid is cooled down, condenses back into a liquid and is pumped back into the loop

The structure of the proposed plant is based on the so-called low-temperature organic Rankine cycle (LT-ORC), and may be summed up by the diagram in Figure 1.

A heat source [1] heats, through a hot water loop and a primary heat exchanger, also known as evaporator [2], a special working fluid placed into a closed ORC circuit.

This totally biodegradable and non-toxic organic working fluid, boils in the evaporator at a temperature far lower than that of water, becoming a high-pressure dry gas the expansion of which spins the impeller of a specifically designed and sized turbine [3].

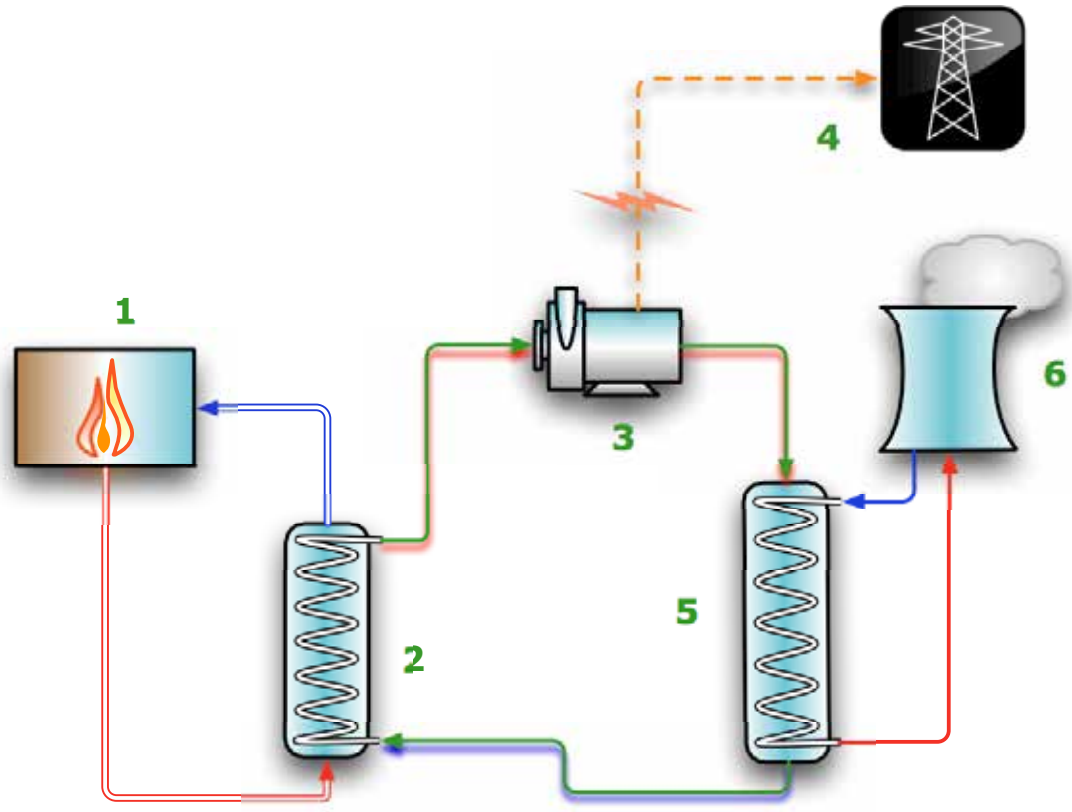
The high-speed rotation (12.000÷18.000 Rpm) of the turbine shaft spins the rotor of a generator which is directly connected to it, thus producing electric power [4] which, after getting its phase and voltage synchronized by an inverter, may be self-consumed or released to the national grid.

Downstream the turbine, the working fluid - still in gas phase - is conveyed to another heat exchanger, called a condenser (5), where excess heat is released and the fluid condenses back into a liquid which is collected in a tank, ready to be pumped back to tyhe primary heat exchanger, thus closing the loop.

Excess heat released in the condenser is a thermal energy source which may be used for other purposes such as preheating or dessiccating biomass fuel (thus increasing its heating value), building heating, hot water production and so on.

In case that is not possible, residual heat may be dissipated by using a compact cooling tower [6]

Figure 1 - Plant diagram



INNOVATIVE TECHNOLOGY

Independently designed and manufactured using the most advanced technologies in finite elements and fluid-dynamics analysis (CFD/CFX), Zuccato Energia's turbogenerators are designed from scratch to operate in a low-temperature organic Rankine cycle which uses a special working fluid that offers better performances and several advances over traditional steam turbines:

- **Low operational temperature** that allows tapping very low-grade heat sources;
- **High condensation temperature** which may allow the use of simple air-cooled condensers;
- Totally dry working fluid, which means no turbine blade erosion, giving the system **high reliability** and **reduced maintenance costs** as well as **fewer controls**;
- **Lower pressures** (20 bar max), for safer operation, less bureaucratic hassles and lower costs;
- **No atmospheric emissions** (closed circuit operation);

What's more, the organic working fluid used is 100% ozone-friendly, non-toxic and biodegradable.

The ZE turbogenerators - **custom designed from scratch** to be installed in small plants (<1MWe)- implement several performance-enhancing engineering solutions such as:

- **Direct turbine-to-alternator coupling**, to eliminate the attrition losses inherent in gearboxes;
- **Use of ceramic bearings** to prolong operational life and allow very high-rpm operation;
- **Custom-designed and sized inverters** for optimal energy conversion performance.

Our innovative technology has already been **widely field-tested with success** in more than a dozen plants throughout Italy and Germany, in vegetable-oil fueled micro power plants, in biomass and biogas fueled plants, in boiler rooms of cinemas and hotels, as well as in district heating systems.

OPERATIONAL VERSATILITY

The ZE-105-CHP is a highly versatile **combined heat and power generation system**, which operates in combined heat & power (CHP) mode producing more than **1 MW_T thermal output** at 80°C for heating or sanitary use as well as **105 kW of electric power**. This makes this system the ideal choice for large residential plants or any other application where the need for thermal power takes a precedence over that for electric power. Moreover, as a purely cogenerative plant, this system has access to the **regional and state incentives** reserved for those systems.

IN SHORT

May be used to tap "low-grade" heat sources

Simpler plants

No turbine blade erosion

Lower pressure, higher safety

No atmospheric emissions

High reliability

State-of-the-art technology

Automated, operatorless systems

Remotely monitorable and controllable

IN SHORT

Widely tested technology

Several installations already in operation

Primary energy production from biomass-fueled boilers

Heat recovery from exhaust gases and cooling jackets

Heat recovery from engines, gasifiers, turbines

FIELD TESTED TECHNOLOGY

Zuccato Energia ORC systems have been in use for years in several installations : the following photos show some of them.

Renon (Bozen) - Heat recovery from cooling jackets and exhausts of vegetable oil-fueled engines

Portogruaro (Venice) -Heat recovery from cooling jackets and exhaust gases of biogas-fueled engines

Rome - Heat recovery from cooling jackets and exhausts of gasifiers and syngas-fueled engines

Morgex (Aosta) - Heat recovery from cooling jackets and exhausts of vegetable oil-fueled engines

Mestre (Venice) - Heat recovery from biomass boiler and hot air turbines

S.Pietro in Gu (Padua) - Heat recovery from cooling jackets and exhausts of biogas-fueled engines

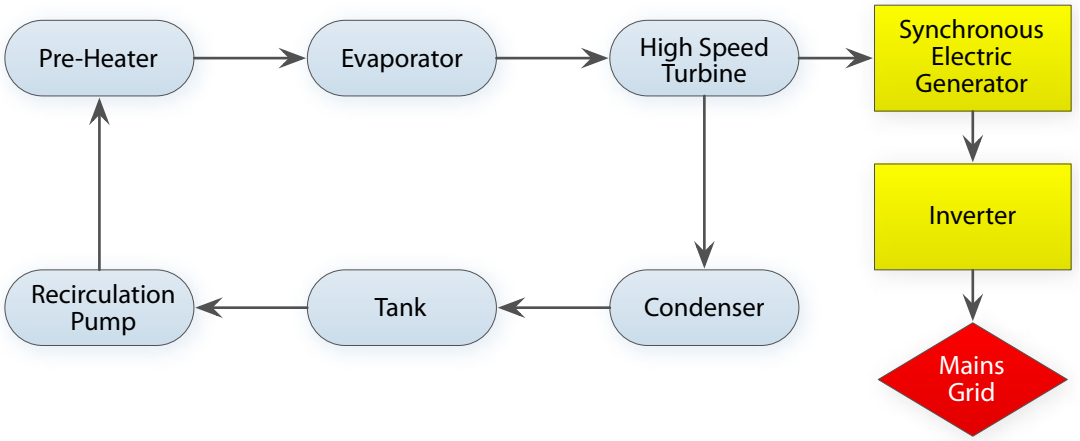
Meran (Bozen) - Heat recovery from cooling jackets and exhausts of gasifiers and syngas-fueled engines

Borgoforte (Mantua) - Heat recovery from cooling jackets and exhausts of biogas-fueled engines

For a more up-to-date and exhaustive list of our references, please consult the “References” section of our website, **www.zuccatoenergia.it.**

ORC CIRCUIT COMPONENTS

Besides the aforementioned working fluid, the power generation module is made of various elements, shown in the following diagram.



- **Pre-Heater**: preheats working fluid using the overheated water of the diathermic loop which feeds the ORC power generation module;
- **Evaporator**: uses the heat of the overheated water in the diathermic loop feeding the ORC power generation module to vaporize the working fluid (i.e. change its state from liquid to gas, increasing its pressure);
- **Turbine:** propelled by working fluid exponsion, it has an ultralight impeller that reaches very high rotational speed (12-18.000 rpm) drawing along the generator rotor assembly;
- **Synchronous Electric Generator** : spinning at high speed thanks to its direct connection with the turbine, it produces electric power.
- **Inverter** : makes all specifications (phase, frequency and voltage) of the electric current output by the generator suitable for interfacing with the national power grid;
- **Condenser** : reduces the temperature of the working fluid gas downstream of the turbine, to make it go back to its originary liquid state;
- **Storage tank** to keep the condensed working fluid in liquid form;
- **Recirculation pump** to pump the fluid back in the ORC loop;

PROCESS DATA

These are the estimated process data for the plant:

PREHEATER + EVAPORATOR	VALUE	U.M.
Total thermal power input	1280	[kWth]
Overheated water input temperature	= > 160	[°C]
Overheated water output temperature	140	[°C]
Max overheated water inflow	14,85	[kg/s]
Electric power output from turbine *(Standard / CHP operation)*	175 / 105	[kWe]

CONDENSER	VALORE	U.M.
Thermal power dissipation	1157	[kWth]
Water output temperature	80	[°C]
Water input temperature	60	[°C]
Condenser circuit flow	13.82	[kg/s]

WORKING FLUID

IN SHORT

Exclusive working fluid

Low boiling point, high condensation point

Closed circuit = no contamination

No turbine blade erosion

Safe for man and environment

The working fluid is the special component that allowed Zuccato Energia to create this type of plants.

The high-tech solutions Zuccato Energia has been able to develop and propose are as a matter of fact due to its existence.

The working fluid employed by Zuccato Energia has the following excellent characteristics:

- Wide working range which allows to exploit previously unexploitable heat sources;
- High condensing temperature which allows the use of standard cooling towers;
- No turbine blade erosion, as the working fluid in gas form is totally dry;
- Low operational pressures (20 bar) mean better safety, less bureaucratic problems, lower costs;
- Totally ozone-friendly, organic, non toxic, 100% biodegradable and non-flammable in liquid form. As such, it is totally environmentally compatible and any accidental leaks are neither harmful or dangerous;
- It rarely requires refills as it works in a closed loop;
- What's more, there's no steam nor water consumption so the plant is far more economical to operate as well as simpler and more compact than steam-based systems.

The fluid inside the plant undergoes several phase changes and treatments; the process specifications are resumed in the following table:

WORKING FLUID	
Operational range	60-165°C
Condensation temperature	~33°C
Working pressure	max. 20 bar
Vector fluid	Water
Input temperature	145 °C
Input pressure	16,08 bar
Thermal power required	1280 kW_T (145/40°C) w/regenerator
Condenser output pressure	1,17 bar
Organic vapor mass flow	~ 6 kg/s (145/40°C)

TURBOGENERATOR SPECIFICATIONS

The following tables show the main technical specification of the ZE-175-CHP power generation module turbine and its attached generator and inverter

TURBINE	
Type	Single-stage radial inflow turbine w/fixed nozzles, directly coupled to the generator shaft
Input Temperature	145°C
Output temperature	~ 100°C
Stage pressure	PS 16 (tested to 24 bar)
Turbine body	Welded steel
Impeller	Aluminium alloy
Speed control	Feedback loop on the generator current output
Seals and gaskets	Labyrinth seal on impeller back Axial labyrinth seal on generator interface (opt.). Outside seal: Gaskets, O-rings

GENERATOR	
Type	Synchronous, permanent magnet
Power Output	180 kWe
Rotational Speed	15.000 Rpm (12...18 kRpm)
Rectifier	Built-in
Synchronizer	Includes
Output voltage	503- 577 VAC @ 500Hz
Cooling	Water jacket
Cooling requirements	15 kW_T
Cooling fluid	Water /glycol
Cooling fluid input temperature	< 40°C
Cooling fluid volumetric flow	30 l/min
Additional cooling (optional)	working fluid injection
Pressure seal	2,5 bar (gas seal)

INVERTER	
Type	IGBT- mains synchronized
Output power	175 kWe
Output voltage	400 V + 5% Tol.
Output frequency	50 Hz +0,5% Tol.
Cooling	Air cooling
Max operational environmental temperature	40°C
Braking chopper	Built-in, 200 kJ

IN SHORT

Custom designed low-temperature, high-speed radial turbine

Built-in alternator, mounted directly on the turbine shaft

Custom-designed, integrated inverter

SYSTEM COMPONENTS

HEAT EXCHANGERS

IN SHORT

Compact & efficient Brazed plate heat exchangers

Ample reservoir of working fluid

High-efficiency recircilation pump

The heat exchangers used in this power generation module are of the brazed plate type - the most compact and efficient solution for several applications. They are made by brazing several quality corrugated steel plates together, taking care first to turn the fishbone-shaped corrugations on each plate 180° from the adjacent plate. Keeping in mind that the fluid-passing sections are very small, the heat exchange-to-encumbrance ratio of these exchangers is great. Among the characteristics for this type of exchanger, these are the most important ones:

- **Small size :** they occupy up to 10% of the space other exchanger types require, making transport easier and the plant smaller.
- **Low temperature differentials**: it is possible to work with minimal temperature differences between the cooling fluid and the fluid to be cooled, thus increasing overall system efficiency;
- **Reduced weight:** their compact construction and small internal volume make this echanger type weight a fraction of that of traditional exchangers;
- **Low load losses:** in most cases, the load loss in a brazed plate exchanger is even lower than that of a coaxial exchanger.
- **Resistance to dirt and corrosion:** high fluid turbulence and total use of the available surface means a drastic reduction in deposits due to material contained in the fluids. What's more, they may be perfectly cleaned using normal detergent fluids. Corrosion problems are avoided by using specifically resistant materials in their construction.

HEAT EXCHANGERS	
Type	Brazed plate
Nominal working pressure	30 bar
Test pressure	39 bar
Bursting pressure	225 bar
Construction materials	AISI316 S/Steel & 99,9% copper
Max working temperature	195°C

CONDENSATION TANK

It is a container to keep an adequate reserve of liquid working fluid for the plant, equipped with sensors to constantly monitor fluid levels.

CONDENSATION TANK	
Construction material	Rustproofed carbon steel
Capacity	180 l
Connectors	PN25
Level sensor	Built-in

WORKING FLUID PUMP

It is used to pump the condensed, liquid working fluid back into the ORC loop. The hydraulic part is kept in place between the upper cap and the pump body by tie rods.

WORKING FLUID PUMP	
Motor	Closed short-circuited cage type with external ventilation
Energy Efficiency	Efficiency class 1
Degree of protection	IP55
Insulation	Class F (T_{MAX}=155°C);
Certification standard	EN 60034-1;

CONTROL PANEL

The control panel hosts all control, supervision, automation and communication electronics for the power generation module. It contains :

- Process management electronics;
- Temperature control electronics;
- Pressure control electronics;
- Alarm management systems;
- Mains connection management systems;
- Inverter circuitry for produced energy power factor correction;
- Mains interface panel with low-voltage protection circuitry.

The control panel also include telecontrol and telediagnostic systems that allow constant monitoring of the plant perfornmances as well as real-time remote control for intervention in case of malfunctions.

Said connections take place trough a built-in 3G / GPRS / EDGE cellular modemn router and allow access through any Internet-savvy device (PC or tablet).

COOLING TOWER (optional)

Whenever the client has no use for the residual heat that has to be dissipated during working fluid condensation and has no cooling tower available, we have chosen a type of cooling tower with superior construction specifications, able to ensure a constant condensing temperature all year round - a fundamental requirement for a continued optimal cycle efficiency. The heat exchange battery in this tower has been designed to obtain a large heat exchange surface and to make maintenance and cleaning easy. Proper use of fiberglass and polymer components helps keeping its weight down and allows its installation almost anywhere.

COOLING TOWER	
Type	Axial fan
Dimensions	2,6 x 2,3 x h 3,9 m
Dissipation performance	1000 kWT
Working weight	3 t
Wet bulb	25°C
Required water refill supply (PMAX=4bar)	26,4 l/min
Maximom noise level @ 1 m/ 15 m	80 / 67 dBA (without silencer)
Frame material	Hot-galvanized steel
Water tank material	Hot-galvanized steel
Fasteners material	AISI 304 stainless steel
Water distribution conduits	PN10 PVC piping
Nozzle	PVC, clog-proof construction
Splash deflectors	Reinforced nylon extrusion

Optional silencing system for residential area applications

Twin-tower unit without silencers

IN SHORT

Fully automated control system

No human presence required

Touch-screen synoptic control panel

Remote control via mobile internet interface

Inverter and mains interface panels on board

Optional lightweight and efficient cooling tower

IN SHORT

Standard version skid for indoor installation

Skid dimensions: 495 x 215 cm h 280

Required area: 800 x 515 cm h 410

Skid weight: about 5 t

Weatherproofed, paneled version for outdoor installation available (495 x 252 x 320 cm, weight ~ 6 t)

Custom skid designs available upon request

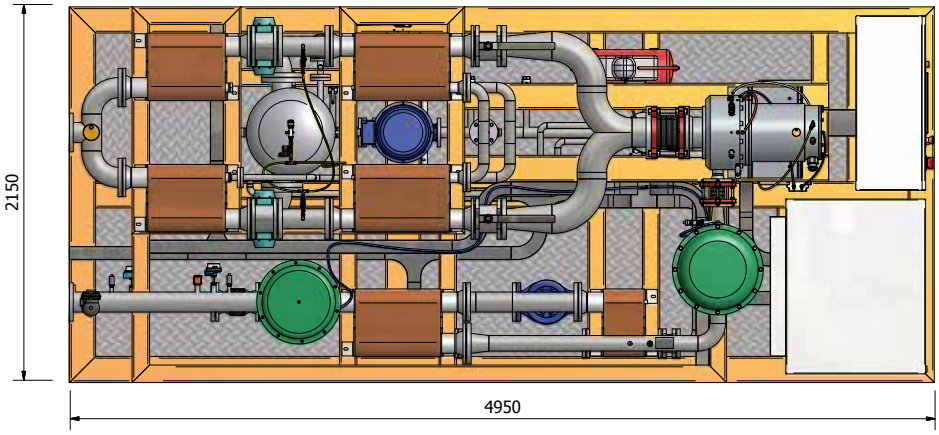
ZE-105-CHP SYSTEM DIMENSIONS

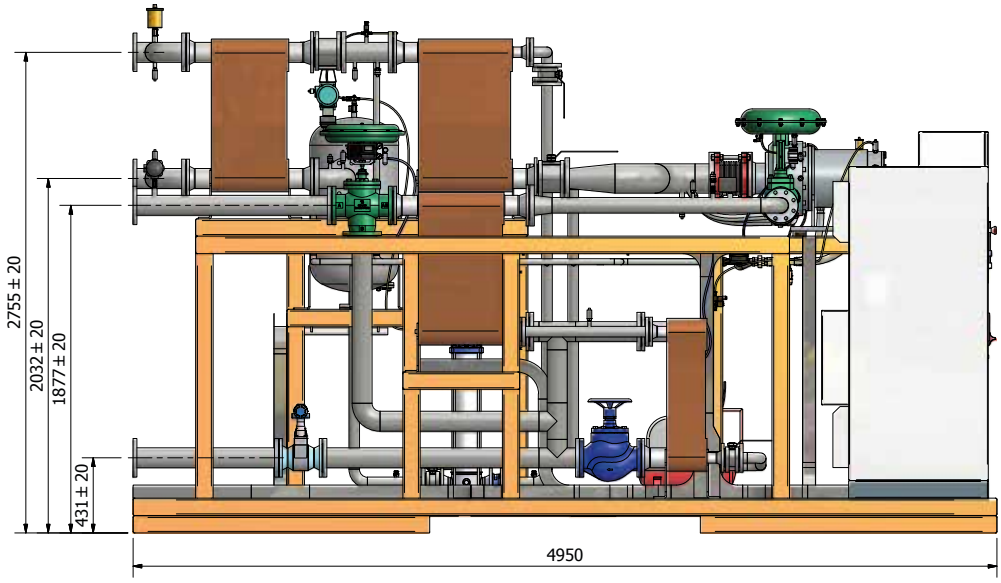
SKID

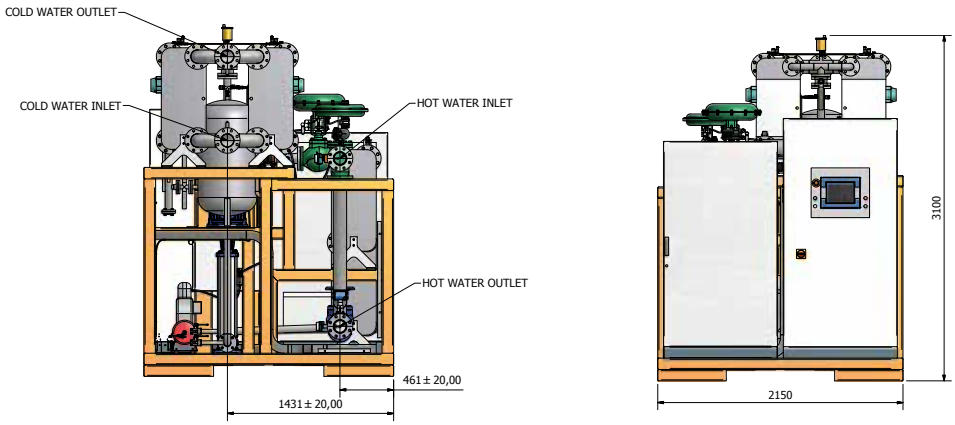
The power generation module is supplied mounted on a self-supporting compact frame ("skid") which houses all the principal components, except for the optional cooling tower, which is a separate system (see next page).

The following drawings show the standard version of the power generation module, which has a weight of about 5 tons an is designed for indoor installation.

A closed, weatherproof version of the skid for outdoor installation is also available.





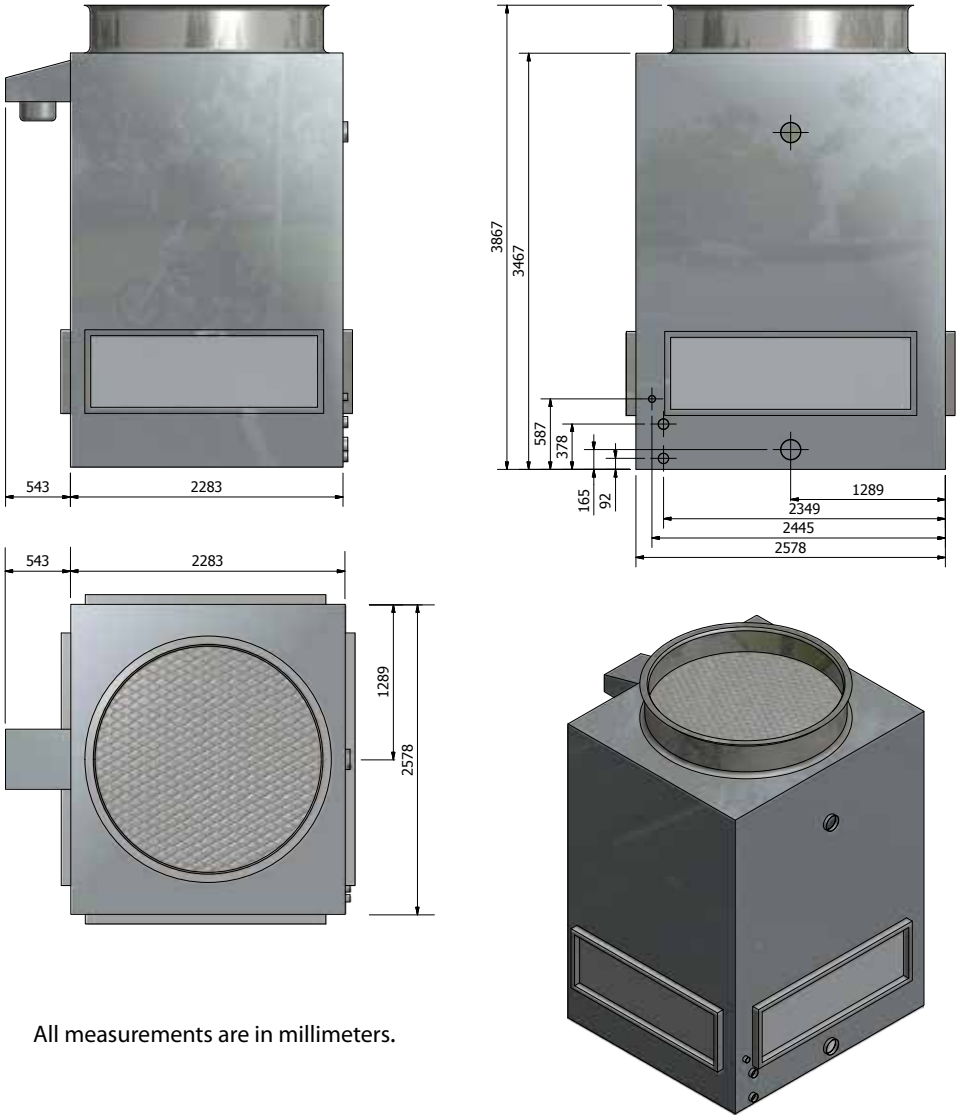


Please keep in mind that the skid requires at least 1.5 meters of free space on all sides for easy maintenance access.

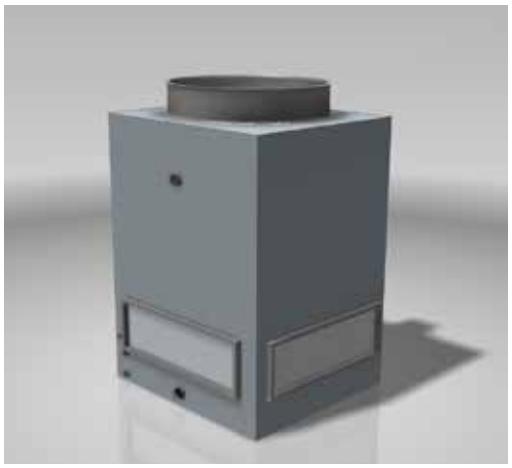
Zuccato Energia, being the system developer and manufacturer may also build the skid in non-standard dimensions different from the above, to tailor the system on the client's needs.

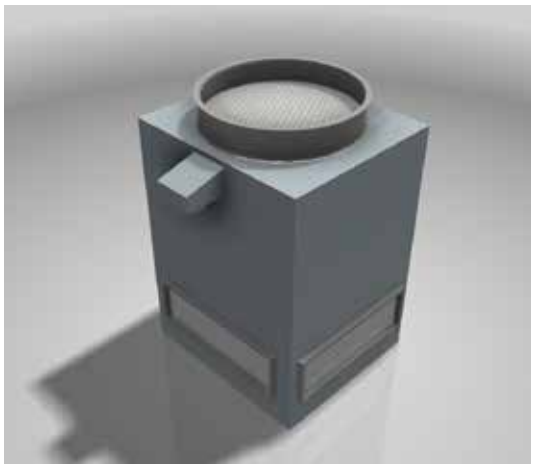
COOLING TOWER

The cooling tower is an optional unit that has the purpose to dissipate residual heat from working fluid condensation whenever it is not used for other purposes (ambient heating, fuell dessiccation...). It occupies a 2,6 x 2,8 m area by 3,9 m high, as in the following drawings.



All measurements are in millimeters.





In this case,too, a further meter of space on every side is required for maintenance access and to allow proper air circulation.

This required space doubles between this and any other already present cooling tower, to avoid interference between the two.

IN SHORT

Galvanized steel construction

Dimensions: 260 x 282 cm h 387

Required area: 460 x 482 cm h 486

Minimum distance from other cooling towers: 2 meters

Working weight: ~ 3,0 t

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