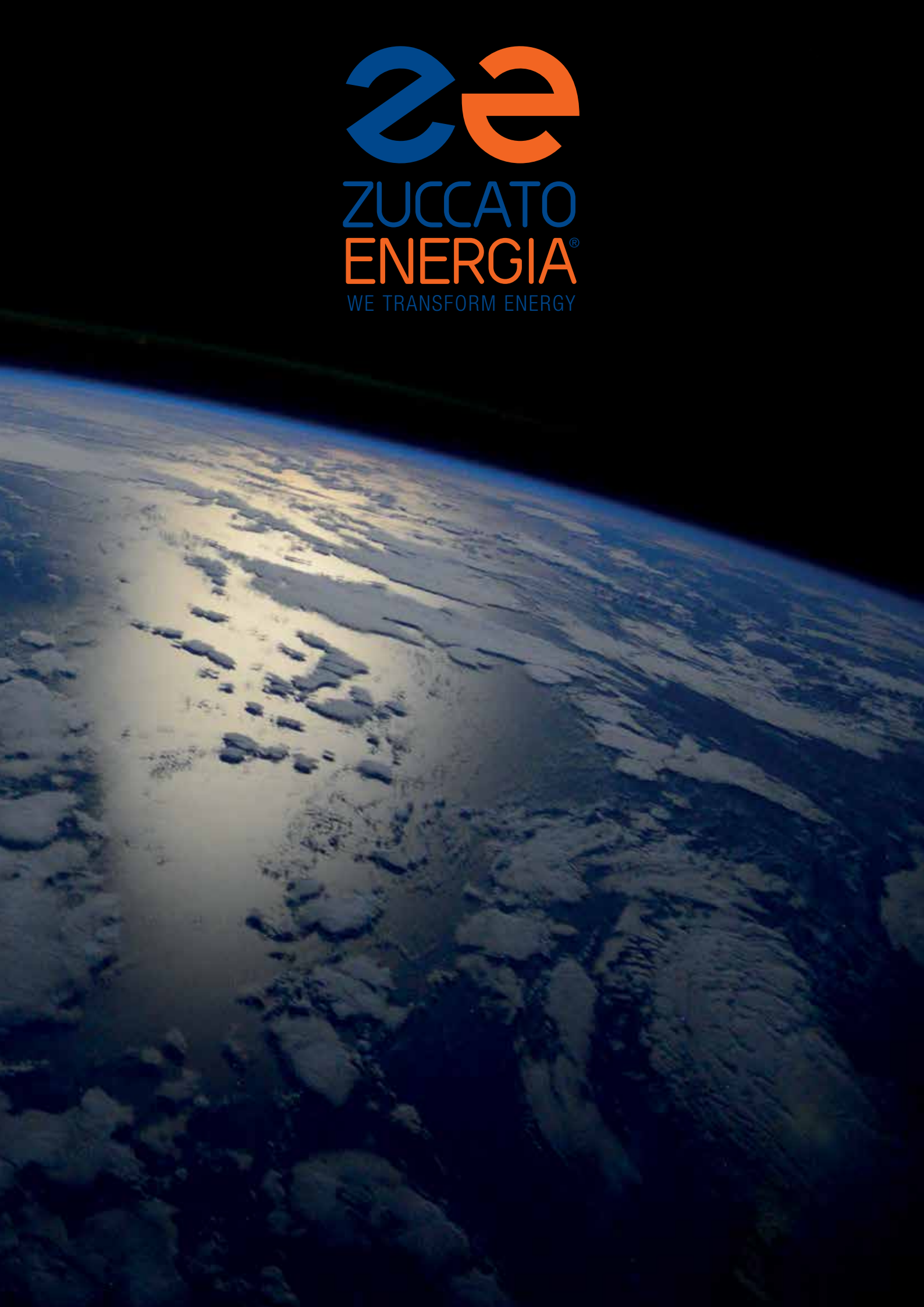
ZUCCATO
ENERGIA®
WE TRANSFORM ENERGY



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COMPANY PRESENTATION

Zuccato Energia Srl is an Italian company, **founded in 2006** and based in **Verona, Italy**, operating in the renewable energy sector and having its core business in the design and production of **organic Rankine cycle** (ORC) **electric power generation systems**. These systems enable **efficient conversion of low-temperature heat into electricity** and have several applications, which will be described further on in this brochure.

Zuccato Energia **is not just a systems integrator**, as it **designs** and **manufactures** its ORC modules, testing their performance in their Verona facility. Always devoted to R&D, it is open to new challenges, creating both **standard** and **custom** ORC systems and prototypes, to efficiently meet the requirements of even the most complex projects.

The firm is proud to have **dozens of installations** in Italy, Africa, USA, Asia and Latin America, some of which have been **operating non-stop since 2011**, as a testimonial of their reliability.

MANUFACTURERS, NOT JUST INTEGRATORS

Zuccato Energia **does not just integrate systems**: it also and above all **designs** and **manufactures** its own ORC modules, so it can offer **standard**, "off the shelf" systems as well as **custom** systems tailored to the user's needs. Some examples of customization:

- **Containerization** of the system for **outdoor use**, or creation of **soundproofed enclosures** for applications in residential areas;
- Modifications to the **geometry of the module frame** ("skid") to better fit it into available spaces;
- Adaptation of the **working point** of a module to meet particular temperature or thermal power needs;
- Manufacture of **full-custom turbines** and modules perfectly tailored to the available thermal power and temperature specifications.

Zuccato Energia **tests each one of its ORC modules** in a purpose-built **test area** on its premises: each module is extensively tested there **in the presence of the client or its representatives** before shipping, using **specific operational parameters** and conditions that **closely mimic** those of the final installation site, to make sure it fully **meets or exceeds** nominal design specifications.

COMPREHENSIVE CONSULTANCY SERVICES

Zuccato Energia is **not just a supplier of ORC modules**: it is also able, thanks to its **accumulated know-how** and the **cooperation** with primary accessory systems manufacturers, to **analyze** how its systems may be applied to the client's reality and proceed from there to designing and supplying **entire turn-key plants**. Its technical department can:

- Carry out **feasibility studies**;
- Correctly **size thermal production / heat recovery systems** (boiler or heat exchangers);
- Create **preliminary designs** of the entire plant, based on the most suitable of its ORC system;
- **Integrate** the new system with existing ones, and **size out the project** both from a **technical** and **financial** standpoint, or – if the client so prefers – **assist** the client's preferred system integrators in doing the same;
- Draw up financial amortization estimates (**business plans**).

In short, Zuccato Energia can be seen as **an all-round partner**, able to work side-by-side with the client to make sure that the latter receives an optimal answer to its needs.

SPECIALIZED IN RANKINE CYCLE SYSTEMS

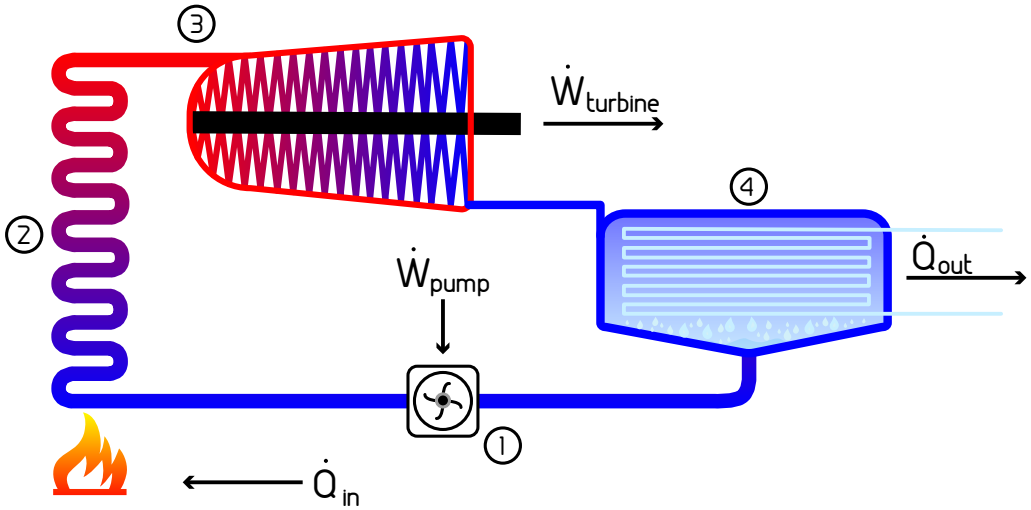
All of Zuccato Energia's systems are based on the **Organic Rankine cycle** (ORC), a **simple, high efficiency** thermodynamic cycle that is ideally suited for the **conversion of low- and medium-temperature** heat sources (**86°C and up**) into electrical energy.

Invented by Scottish physicist William Rankine (1820 -1872), one of the fathers of thermodynamics, it operates in an **emission-free, closed loop**, illustrated in the diagram below.

In the closed ORC loop, a special low-evaporation-point **working fluid** receives thermal energy from the heat source within a primary **heat exchanger** (2) where it **evaporates** becoming a gas which **actuates** with its expansion a **turbo-generator** (3) that produces electricity.

The fluid then passes into a **condenser-exchanger** (4) where it cools down and **condenses** back into liquid phase; a **pump** (1) then sends it back to the primary heat exchanger, where the cycle restarts. **Excess heat** released into the exchanger-condenser (Q_{OUT}) is in turn **a source of thermal energy** which can be directly used for other purposes (such as **fuel preheating or drying**). In systems designed for it, this excess heat can also be used for **environmental heating** purposes (**CHP -** combined heat and power) or to generate both heat and cold using heat absorbers (**trigeneration**).

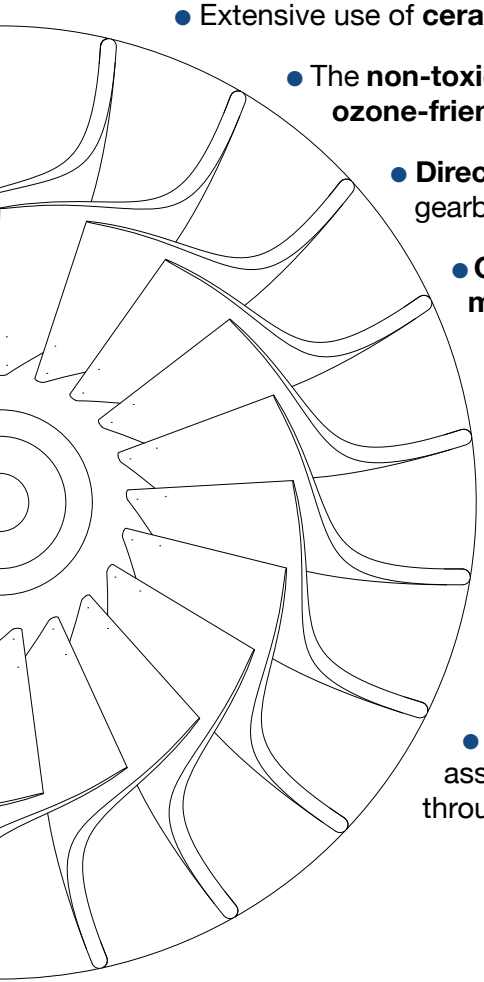
The Rankine cycle has **several advantages** compared to other technologies: it is **compact, simple and reliable**, it can exploit even relatively **low-temperature** thermal sources and – being a **closed and sealed circuit** – it does not produce any atmospherical emission.



EXCLUSIVE TECHNICAL ADVANTAGES

Accurate design together with an extensive **accumulated know-how** give Zuccato Energia's ORC modules exclusive technical advantages which set them a notch above the competitors:

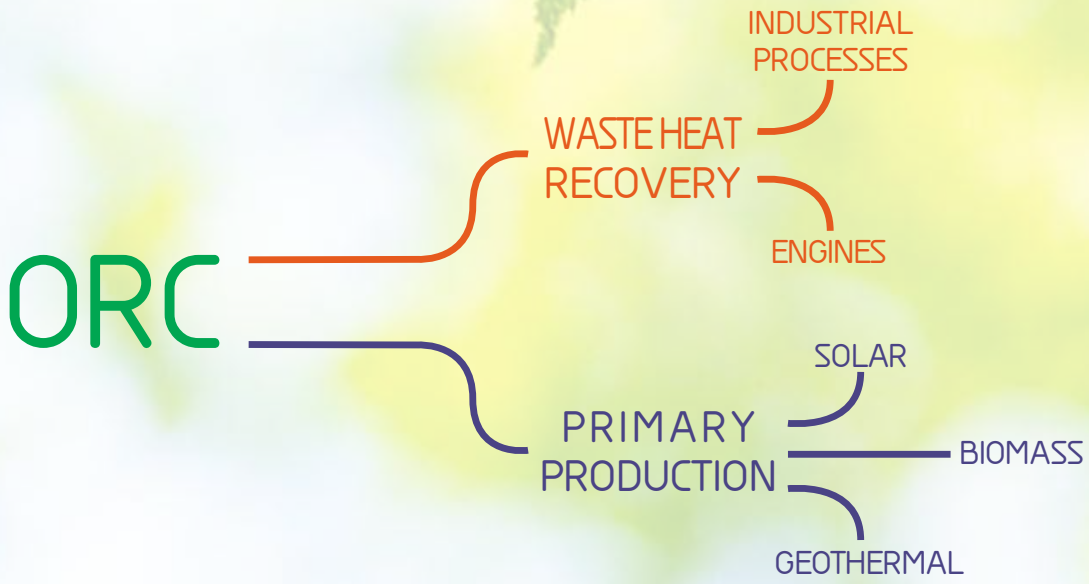
- Implementation of single-stage turbines **specifically designed in-house** for each model of ORC module guarantee **top efficiency** (up to 90%);
- Excellent operational performances **even under partial load** allow **modulation of electrical production** according to the available thermal power;
- Each module is mounted on a **self-supporting, self-contained, flange-to-flange frame** ("skid"), which can be **containerized** for maximum **modularity** and **compactness**;
- Exclusive use of **hot or overheated water** as a thermal vector fluid, gives better **safety**, reduced **costs** and easier **management** with respect to other vector fluids such as diathermal oil or steam;
- Extensive use of **ceramic bearings** grants a longer service life and maximum **reliability**;
- The **non-toxic**, **non-flammable** working fluid is 100% **biodegradable** as well as being **ozone-friendly**;
- **Direct coupling** of the **generator** to the **turbine shaft** eliminates the need for a gearbox and **eliminates** the inherent **efficiency losses**;
- **Custom-designed power converters** (inverters) for each model guarantee **maximum efficiency** in energy conversion;
- The **completely dry** working fluid ensures against **turbine blade erosion**;
- An accurate choice of top-quality components grants a **long service life**;
- **Low operational pressures** give better operational **safety** and require far **less bureaucratic red tape** for operation;
- **Full-scale automatization** removes the need to employ **specialized personnel** for operation;
- No need for **special authorizations** for installation and operation;
- An integrated remote control system grants the client and technical assistance personnel **full remote monitoring and management capabilities** through LAN, WAN and the Web.



FIELDS OF APPLICATION

ORC systems allow **clean energy generation** through the use of what is often considered as **waste**, or by exploiting natural, **inexhaustible energy sources**, such as the heat of the sun or of the earth.

These systems are able to generate valuable electrical energy by **recycling waste heat** generated by industrial processes, or by exploiting thermal energy generated by the combustion of **waste materials** or **processing scraps**, as better illustrated in the following pages.



HARNESSING GEOTHERMAL HEAT

Geothermal energy is a form of **renewable, inexhaustible energy** that derives from the **Earth's own internal heat**, which rises proportionally to the depth one penetrates into the Earth's crust.

By placing a **thermal collection system** into an existing **hot spring** or into an ad-hoc **geothermal pit** drilled in an appropriate point of the Earth surface, it is possible to obtain hot water with enough **flowrate** and **temperature** to operate one or more Zuccato Energia ORC modules.

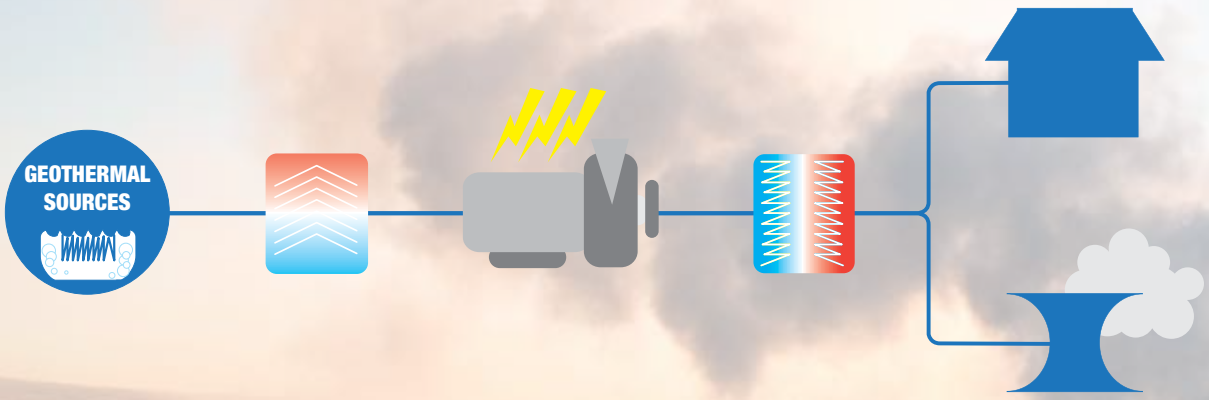
Said modules have **exclusive technical advantages** which make them particularly suitable to **harness energy from "weak", relatively low-temperature sources**, without having to resort to complex and difficult-to-manage systems.

It is thus possible to use Zuccato Energia ORC modules to **exploit geothermal heat sources** or geothermal pits having a **reduced depth** with regard to those required by conventional, steam-based systems.

Among the exploitable sources the following can be counted:

- **Hot springs** having a temperature of 95°C or above;
- **Volcanic heat** sources having temperatures equal or greater than 150°C;
- Purpose-made **geothermal pits**.

Why not exploit a free and inexhaustible energy source ?



COLLECTING SOLAR POWER

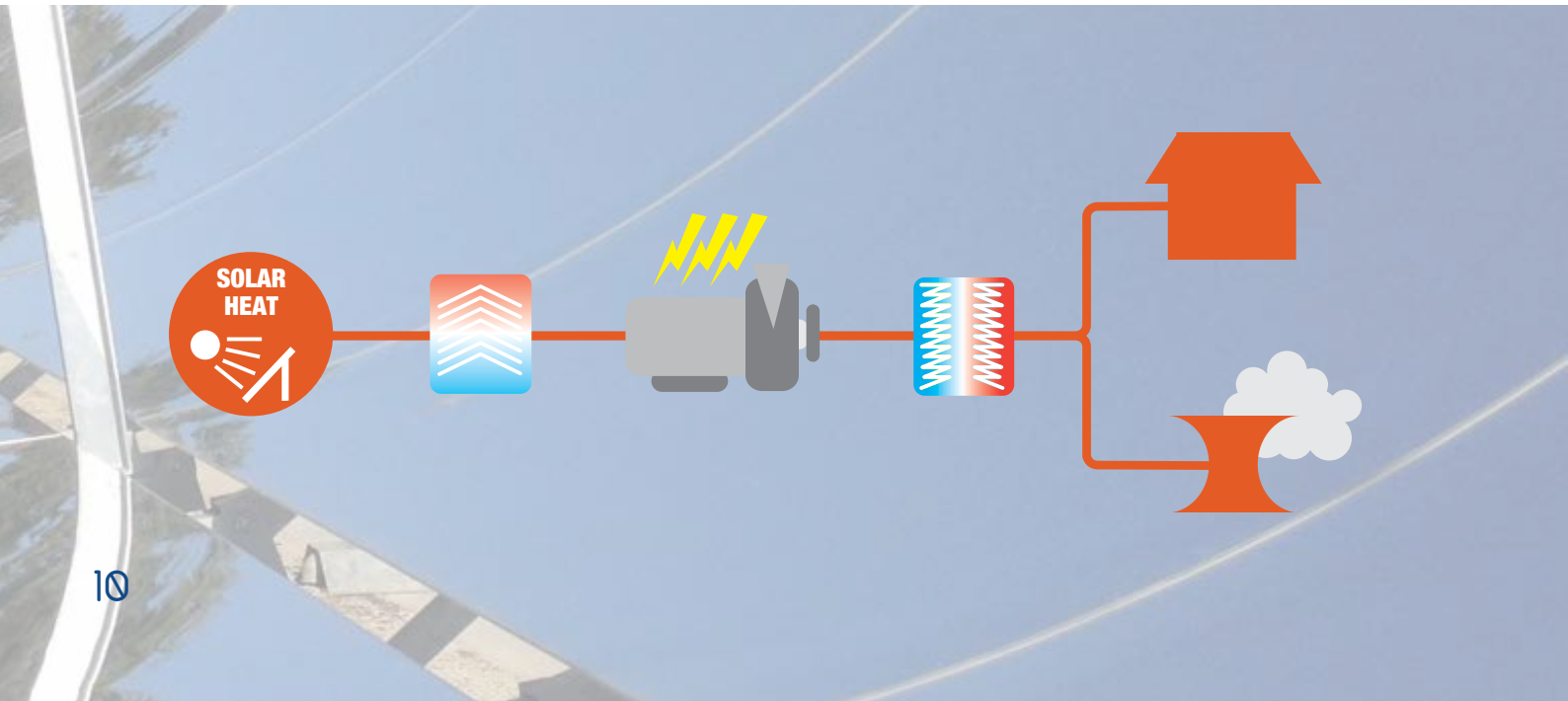
Thanks also to their **excellent performance under partial load** - i.e. when thermal power input is below nominal values - Zuccato Energia ORC modules can easily be used to implement **thermodynamic** or **hybrid solar plants**.

These ORC-based thermodynamic system can exploit the relatively low-temperature heat obtained by **simple concentration-type solar panels** to produce electric power as long as enough solar power is available.

Hybrid systems can then **automatically switch over** the ORC module to using **alternative heat sources** (such as biomass/biogas boilers, geothermal heat systems...) **when solar heat is insufficient**, such as during night time or in case of inclement weather conditions.

Zuccato Energia **has already built and installed pilot systems of this kind** as part of research and in partnership with prestigious Universities both in Italy and abroad.

Why not use the largest, inexhaustible power source ?



MONETIZING BIOMASS

ORC modules by Zuccato Energia have found several applications in combination with a wide range of overheated water generation systems based on **biomass combustion**.

A typical system connects one or more ORC modules to a **fixed- or movable-grate boiler** fueled via an **automated feeding system** by wooden chips derived from **woodworking waste** or from **pruning residues** derived from the management of municipal, regional or state parks.

Wooden biomass is **far from being the only possible fuel**: thanks to the cooperation with a primary boiler manufacturer, Zuccato Energia has been able to solve the long-standing problem of **chicken manure disposal** in poultry farming. Said biomass – a mix of excrements, feathers and litter residues – **can now be monetized** by transforming it into electricity using a **specifically designed** movable grate boiler equipped with special devices for **efficient combustion** and **pollutant reduction**, coupled to an ORC module of suitable power.

The biomass conversion plants built by Zuccato Energia – several of which **have been operating for years** – are **highly reliable** and **compact** enough to be employed **even in a small firm**, monetizing its waste, **simplifying waste disposal**, and paying themselves back **in a few years**.

Waste? No: resources!

HEAT RECOVERY FROM BIOGAS ENGINES

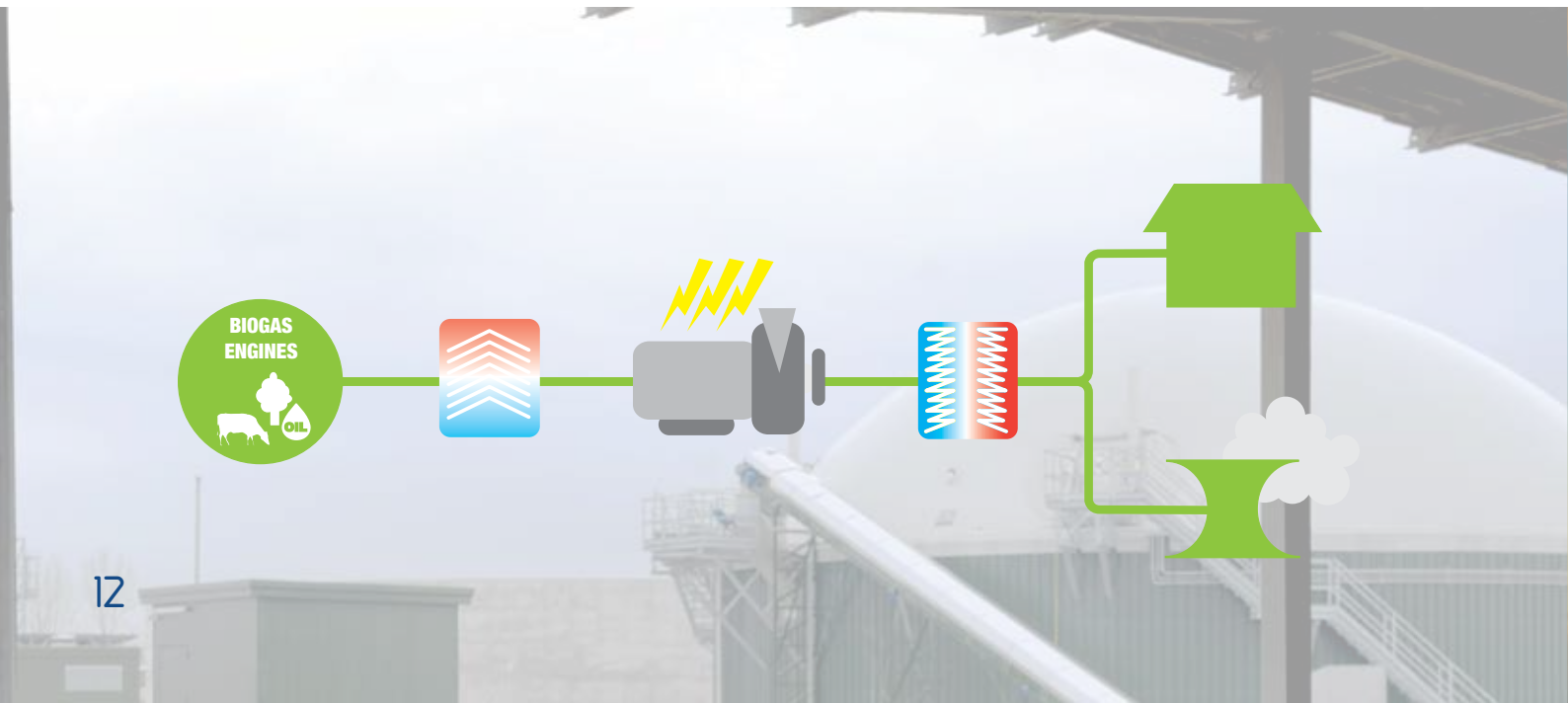
Many cattle breeders choose to use the manure of their livestock to **generate biogas** through the use of **fermenter digesters**; this biogas is then used as fuel for engines connected to electrical generators (commonly called *gensets*).

Few of them know, however, that thanks to the Zuccato Energia ORC systems it is also possible to r**ecover the waste heat** contained in the **exhaust fumes** or carried away by the **cooling jackets** of said gensets - a **valuable thermal resource** that would otherwise be wasted.

The same heat recovery system can of course be applied to **any genset of sufficient power**, regardless of the fuel it uses - biogas, syngas, vegetable oil, methane or biofuel, thus pushing **the overall system efficiency of said systems to the maximum**.

Zuccato Energia has an **extensive experience** in this field, having installed **several systems of this type** both in Italy and Germany.

Why not obtain maximum efficiency ?



HEAT RECOVERY FROM NAVAL ENGINES

Thanks to their **compactness** and **modularity**, ORC-based heat recovery systems by Zuccato Energia are ideal to be **factory-mounted** or applied as a **retrofit** to naval engines.

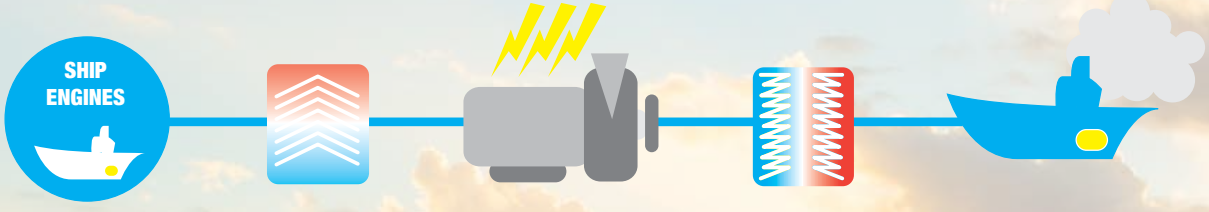
In this capacity, ORC modules can in fact excellently **replace one or more gensets** in the task of producing electric power by using **waste thermal energy** recovered from the ship's engines **instead of fuel**.

Essentially, **two types** of energy recovery are possible:

- **Medium-temperature** (165°C) heat recovery from exhaust gases and cooling jackets of auxiliary engines or primary engines too small to justify a steam-based recovery system;
- **Low-temperature** (≥ 85°C) heat recovery from the cooling jackets of large engines or multi-engine units already equipped with a steam-based energy recovery system;

ORC modules manufactured by Zuccato Energia are **comparable in size with gensets** of equal electric output, but differently from the latter, they **do not pollute** nor use a **single drop of fuel more**.

Why burn more fuel ?



HEAT RECOVERY FROM CERAMIC KILNS

Ceramic manufacture **consumes** and at the same time **disperses** a great quantity of energy.

Depending on the type of kiln, up to **20%** of the thermal energy input into a kiln goes **up the chimney with the fumes**, **25%** is wasted as thermal dispersion **through the kiln walls**, and a massive **55%** is purposely dissipated to **cool down** the finished products at the end of the firing process.

Using a special **patented technology** it is possible to **recover up to 45% of the heat** generated by the burners by placing special **heat exchangers** in the hottest part of the **cooling stages** of the kiln.

This way, a standard 4000-kW_T tiles kiln – which can produce up to 7600 kg/h of tiles – can supply **enough heat to drive a 175-kW_E ORC system** from Zuccato Energia, which can output more than **1GW/year** to the grid, thus allowing a **quick amortization** of the investment.

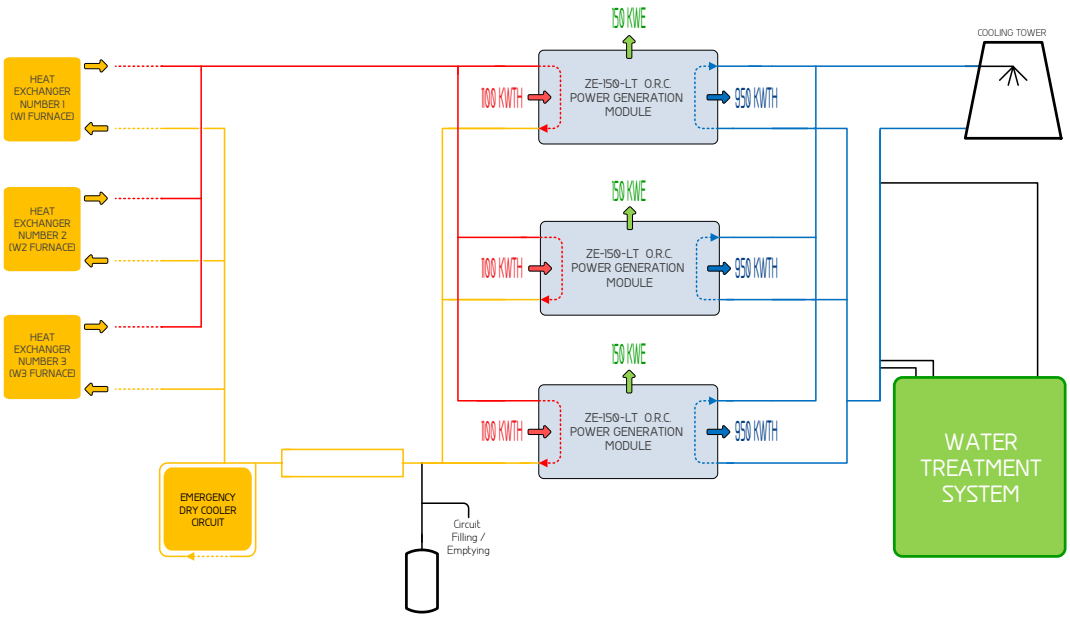
HEAT RECOVERY FROM INDUSTRIAL PROCESSES

As already said in the previous pages, the ORC systems by Zuccato Energia can **recover energy from most industrial processes** involving heat, such as:

- **Ovens, furnaces and kilns** in steel, glass and ceramic industries and cement mills;
- **Boilers and steam generators** in paper mills and naval industry;
- **Ovens, dryers and smokehouses** in the food industries as well as **incinerators** in animal fat rendering.

As an example, by installing **heat exchangers** in the flue gas circuit of a **glass bottle manufacturing plant** equipped with three ovens, enough thermal energy can be recovered to drive the same number of ZE-150-LT ORC modules , which can **output up to 3GW/year** of electricity to the power grid.

Even an **end-of life waste disposal site** can become a power generation plant, by using an ORC module to recover the heat from the **combustion of flared-off waste gas** too weak to operate a normal genset.



THE ULH AND ULH+ SERIES MODULES

Designed using the most advanced technologies, the ORC modules in the ULH and ULH+ series from Zuccato Energia are a **compact** and **efficient** solution to **exploit low-temperature thermal sources**. Available in models ranging from **30 to 300 kW_E output**, they are able to operate efficiently **even under partial load conditions** (i.e. when thermal power input is lower than nominal) and find their ideal fields of application in sectors such as **waste heat recovery** from engines and industrial processes, harnessing **geothermal power** and converting **solar heat** from concentrator-type solar panels into electricity.

GENERAL SPECIFICATIONS	ZE-30-ULH	ZE-40-ULH	ZE-50-ULH	ZE-200-ULH+	ZE-250-ULH+	ZE-300-ULH+
Thermal Energy Input	350 kW_T	450 kW_T	550 kW_T	2 500 kW_T	3 050 kW_T	3 600 kW_T
Electric Power Output	30 kW_E	40 kW_E	50 kW_E	200 kW_E	250 kW_E	300 kW_E
System Efficiency	8.50 %	8.90 %	9.60 %	8.00%	8.20%	8.30%
Skid dimensions (L x W x H, approx.)	3.8m x 1.2m x 2.25m			6.2m x 2.6m x 3.2m		
Weight (incl. working fluid)	~ 3 100 Kg			~ 5 000 Kg		
Vector Fluid						
Hot Water T_{IN} / T_{OUT}	94°C / 86°C			95°C / 80°C		
Nominal Vector Fluid Flowrate	10.20 kg/s	13.40 kg/s	14.93 kg/s	39.68 kg/s	48.41 kg/s	57.14 kg/s
Condensation Stage						
Thermal energy dissipation	310 kW_T	390 kW_T	470 kW_T	2 266 kW_T	2 758 kW_T	3 249 kW_T
Cooling Water T_{IN} / T_{OUT}	26°C / 31°C			26°C / 31°C		
Cooling Water Flowrate (nominal)	14.81 kg/s	18.65 kg/s	22.46 kg/s	108.27 kg/s	131.75 kg/s	155.24 kg/s
Turbine						
Type	Single-stage, radial inflow, fixed nozzles, directly coupled to generator			Single-stage, radial inflow, fixed nozzles, directly coupled to generator		
Working Fluid Temperature	85°C input / ~60°C output			81°C input / ~60°C output		
Stage Pressure	PS4,42 (final testing up to 10 bar)			PS4,42 (final testing up to 10 bar)		
Construction Materials	Machined steel body / Aluminium impeller			Machined steel body / Aluminium impeller		
Working Fluid						
Type	Mixture of eco-friendly, non-inflammable HFCs			Mixture of eco-friendly, non-inflammable HFCs		
Operating Temperatures Range	60°C < T <165 °C			60°C < T <165 °C		
Operating Pressure	≤ 20 bar			≤ 20 bar		
Toxicity/Biodegradabillity/Ozone impact	Non Toxic / 100% Biodegradable / Ozone-Friendly			Non Toxic / 100% Biodegradable / Ozone-Friendly		

THE LT AND CHP SERIES MODULES

Designed using the most advanced technologies, the ORC modules in the LT and CHP series from Zuccato Energia are a **compact** and **efficient** solution for **small-scale primary power generation** and – in the case of the CHP modules – **combined heat and power generation**. Available in models ranging from **75 to 550 kW_E**, and able to operate efficiently **even under partial load conditions** (i.e. lower than nominal thermal power input), these systems find their ideal field of application in association with **biomass-fueled boilers**, as well as in **waste heat recovery** applications from ovens and industrial processes.

GENERAL SPECIFICATIONS	ZE-75-LT	ZE-100-LT	ZE-150-LT	ZE-175-LT	ZE-500-LT	ZE-105-CHP	ZE-175-CHP	
							Full-Power Mode	CHP Mode
Thermal Energy Input	550 kW_T	740 kW_T	1 100 kW_T	1 280 kW_T	3 500 kW_T	1 280 kW_T	1 280 kW_T	
Electric Power Output	75 kW_E	100 kW_E	150 kW_E	175 kW_E	561 kW_E	105 kW_E	175 kW_E	105 kW_E
System Efficiency	13.60 %	13.50 %	13.60 %	13.60 %	16.00 %	8.20 %	13.60 %	8.20 %
Skid dimensions (L x W x H, approx.)	5.5m x 2.5m x 3.2m				10.5 x 4.5 x 4.6m	5.5m x 2.5m x 3.2m		
Weight (incl. working fluid)	~ 6 500 Kg				~ 21 500 Kg	~ 6 000 Kg	~ 6 500 Kg	
Vector Fluid								
Overheated Water T_{IN} / T_{OUT}	160°C / 145°C		160°C / 140°C		≥160°C / 145°C	160°C /140°C		
Nominal Vector Fluid Flowrate	8.49 kg/s	11.91 kg/s	13.14 kg/s	14.88 kg/s	54.03 kg/s	14.88 kg/s		
Condensation Stage								
Thermal Energy Dissipation	471 kW_T	640 kW_T	940 kW_T	1075 kW_T	2 909 kW_T	1 157 kW_T	1 075 kW_T	1 157 kW_T
Cooling Water T_{IN} /T_{OUT}	32°C / 40°C	26°C / 36°C			28°C / 38°C	60°C / 80°C	26°C / 36°C	60°C / 80°C
Cooling Water Flowrate (nominal)	14.07 kg/s	15.60 kg/s	22.46 kg/s	25.69 kg/s	69.41 kg/s	13.82 kg/s	25.69 kg/s	13.82 kg/s
Turbine								
Type	Single stage, radial inflow, fixed nozzles, directly coupled to generator					Single stage, radial inflow, fixed nozzles, directly coupled to generator		
Working Fluid Temperature	145°C $_{IN}$ ~100°C $_{OUT}$					145°C $_{IN}$ ~100°C $_{OUT}$		
Stage Pressure	PS16 (final testing up to 24 bar)					PS16 (final testing up to 24 bar)		
Construction Materials	Machined steel body / Aluminium impeller					Machined steel body / Aluminium impeller		
Working Fluid								
Type	Mixture of eco-friendly, non-inflammable HFCs					Mixture of eco-friendly, non-inflammable HFCs		
Operating Temperature Range	60°C < T <165 °C					60°C < T <165 °C		
Operating Pressure	≤ 20 bar					≤ 20 bar		
Toxicity / Biodegradabillity / Ozone impact	Non Toxic / 100% Biodegradable / Ozone-Friendly					Non Toxic / 100% Biodegradable / Ozone-Friendly		

ZUCCATO ENERGIA

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