ZUCCATO ENERGIA

Our Carnet of Selected References

Updated as of May, 2021

Arranged in reverse chronological order (newest installations first)

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United Kingdom 01

Manager: *Private Firm* • ***Location:*** *United Kingdom*
Plant: *1 x ZE-105-CHP power generation module*
Application: *Power generation in combination with a boiler burning biomass (pruning residues)*

The owner of this plant is one of the largest **agricultural producers** of potatoes and onions in England, which has 4 warehouses to store its freshly harvested products until the distribution trucks arrive.

The idea behind it, is to have an **always functioning power plant that deals with disposing of the waste biomass** (mainly residual mowing and pruning) produced by the landowners and the industries in the surroundings and, at the same time, producing electrical and thermal energy for the storage of the products and the thermal utilities used by the staff on site.

The client, therefore, decided to equip itself with a system capable of enhancing the biomass with which it powers a boiler of over 1.2 MW. The generated heat is used to power a **105 kWe ZE-105-CHP module**.

Our system has a thermal output at 60/80 ° C which is reused to supply hot water to the heating systems on the site but, above all to keep the warehouses for potatoes and onions heated, which are constantly monitored in temperature and humidity to remain at the ideal conditions for the correct conservation of the product.

The deposits are heated by heat exchangers which use the water leaving the ORC to heat some air which is introduced into the deposits through fans. The system, like all Zuccato Energia systems, is mounted on a self-supporting frame (skid) which includes heat exchangers, turbogenerator and control panel. The skid is housed indoors in an ad hoc built room together with the boiler and it operates fully automatically, without the need for an operator as **it can be managed entirely remotely.**

Before the installation of the ORC, the customer was obliged to use diesel oil to heat the deposits and rooms for employees with consequent purchase costs and the high rate of pollution resulting from combustion. Now instead, the fuel used to power the boiler (pruning cuttings) is an **environmentally friendly** and **renewable** resource.

Loading hopper.

The ZE-105-CHP ORC module in place.

Boiler preheating system and superheated water at the ORC.

The ZE-105-CHP ORC seen from the control panel side.

United Kingdom 01 : Entire plant.

United Kingdom 01 : The ZE-105-CHP ORC module in place.

Tunisie 01

Manager: State University • **Location:** Tunis (Tunisie)
Plant: 1 x ZE-60-DSG LT-ORC power generation module
Application: Didactic hybrid plant *(thermic solar power+biogas boiler)*

This plant - the first Zuccato Energia plant in Africa - is located in the region of Tunis, the capital of Tunisia.

It is an **experimental hybrid plant**, built in collaboration with several european academic and industrial entities within the frame of the RE.EL.COOP project, financed by the European Union.

This plant shows some parallels with our **Sicily 2** installation in Sicily, Italy. In both plants the goal in not as much energy production as the demostration of various engineering principles, and in both plants concentration-type thermal solar panels work side-by-side with a gas boiler as an alternate power source.

The Tunis plant, however, shows several differences with the Sicily one, the main being - for the first time in a Zuccato Energia plant - t**he use of 160°C saturated steam as vector fluid in direct heat exchange with the working fluid** without the use of an intermediate steam/water heat exchanger. The new working point required a full turbine blade redesign, and several modifications were made to the "hot side" of the ORC module, adding various devices to better handle and exploit this new vector fluid.

From the thermal source viewpoint, the plant relies on a small solar field made of Soltigua parabolic concentrators, **using a boiler fueled by the biogas** produced in a fermentation plant fed by the food residues of the local universitary dining hall as an alternate heat source. Residual heat from the condensation stage of the ORC is dissipated by a battery of dry coolers.

While the plant as a whole is the concerted effort of a dozen firms, the heart of the whole plant – The ZE-60-DSG Organic Rankine Cycle power module – has been entirely designed and developed in-house by us. It is a compact, skid-mounted system, which is now hosted – together with the boiler – in a small building adjacent to the main campus building.

The compact size of the ORC module has simplified shipping while its capacity to interface through secure protocols with the web for control, monitoring and diagnostics (a common characteristic of all our ORC modules) has allowed our company's technicians to supply real-time assistance to their colleagues commissioning the plant in Tunis.

A general overview of the plant.

The solar field seen from another angle.

The white building protecting the skid (L).

The ZE-60-DSG skid seen from the door.

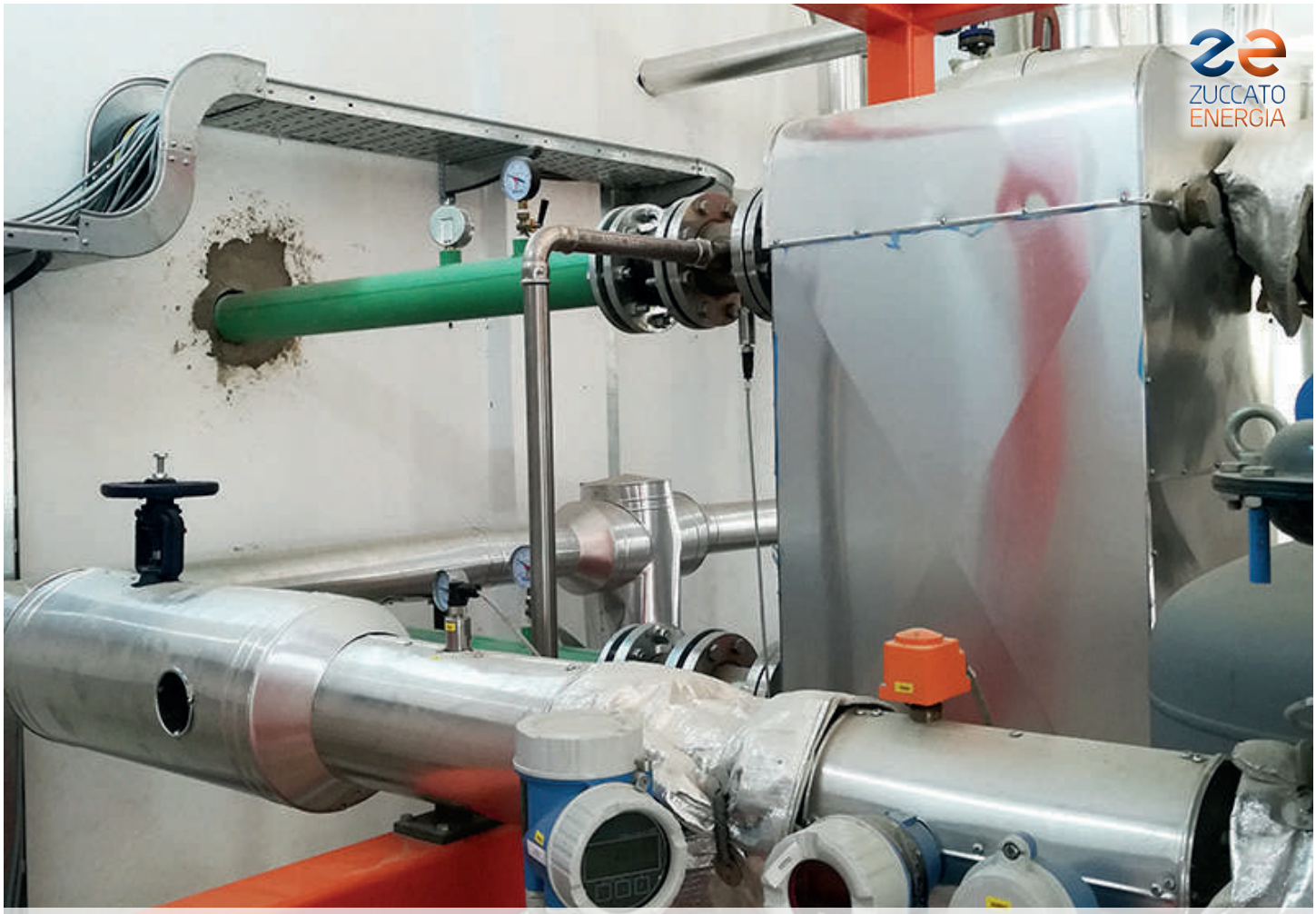
The biogas boiler (R) and the ORC module skid (L).

The ZE-60-DSG ORC Module during commissioning.

A detail of the plant's custom turbine.

The dry coolers with the main campus building in the background.

The dry coolers from the opposite side.



Tunis 01 : The heat exchangers. This is the first plant by ZE using live saturated steam as a vector fluid.

Tunis 01 : The solar field at sunset from the awning adjacent to the ORC system building.

Korea 01

Manager: *Private Korean Firm* • **Location:** *South Korea*
Plant: *1 x customized ZE-40-ULH LT-ORC module*
Application: *Heat recovery from engines* *(Heavy fuel diesel gensets)*

This plant – **our first installation in the Far East** – is located in the main hamlet of a small island located in the Yellow Sea off the southeastern shore of South Korea. This small island, occupying less than 20 km2, is home to about 3000 persons who rely for their electricity on a local power station based on eight large diesel gensets.

A Korean private firm has received from the plant owner (KEPCO) the task to increase plant efficiency. To do so it asked us to manufacture a 30-kWE nominal output Low-Temperature Organic Rankine Cycle Module with a peak output power of 40 kWE and maximum efficiency of 9% designed to operate by recovering the heat from the 1-MW diesel engine operating one of the gensets according to their specifications.

The plant – a self-contained module in open-frame, non-containerized configuration – has been located under a little awning off the main entrance to the generator room, and has been interfaced with generator #8 through a heat exchanger placed in the exhaust chimney.

The compact size of the plant has simplified shipping, while its remote interface with the Internet for control, monitoring and diagnostics has made it possible for our technicians to give real-time assistance to their colleagues performing plant start-up nearly 9000 km away.

Satellite view. The plant is in the SW corner of the large white buiding in the center.

The entrance to the power plant.

The generators building. The skid is on the right, below a small awning.

The ZE-40-ULH module during installation.

The large diesel genset from which waste heat is recovered.

A general view of our skid installation and the cooling tower.

The hot-side piping conveying heat to the ORC. The heat exchanger is on the platform at the top.

A front view of the turbine.

A back view of the turbine.

Korea 01 : The cooling tower and the awning hosting the ZE-40-ULH organic Rankine cycle power generation module.

Korea 01 : A detail of the ORC skid - the steel cylinder in the middle is the turbogenerator

Umbria 01

Manager: *Private Italian Firm* • ***Location:*** *Umbria, Italy*
Plant: *2 x ZE-100-LT Module*
Application: *Power generation in combination with a boiler burning biomass (pruning residues)*

The client who commissioned us this plant is a **large holiday farm** located in the Umbria countryside near the border with Tuscany, that includes several restructured historical buildings, as well as a **60-hectares park** including woods and fields. They decided to monetize **the waste biomass their park produces** (i.e.pruning residues) by using its combustion to generate electricity taking advantage of the existing **state incentives**.

Pruning residues are collected and used to fuel a **movable-grate Herz-Binder** boiler that feeds the 1.6MW of heat it generates **to two ZE-100-LT ORC modules**. Said ORC modules are hosted, together with the boiler, inside a **purpose-built building**, each on its own skid with its turbogenerator, exchangers and control panel, but **operating in parallel with each other.** The power produced by the ORC modules (200 kW) is output to the national grid via a nearby grid connection cabin.

The ORC plant was built with the **project financing** formula by an energy services company (E.S.CO) which financed the whole plant in exchange for its ownership and earnings for the first years of the plant's life, during which the client **will supply the biomass at a set cost.** On expiry of the payback period, plant ownership will be given back to the client, which will have then **acquired the plant practically for free.** As all biomass, pruning residues are an **environmentally friendly, renewable and incentivated energy source** that's CO_2-neutral as the CO_2 released when burning biomass is the same captured during biomass growth.

The power station entrance gate.

The power station building. Large door opens on bolier room, small one on ORC room.

The ORC modules through the open ORC room door.

The front of the power station building with the biomass storage area in foreground.

The rear of the power station with (L to R) biomass storage, fuel hopper and control room door.

The fuel loading hopper, with feeding rakes on the bottom.

A peek inside the operating boiler.

One of the two ZE-100-LT modules in its seat.

The boiler (R) and the ash filter (L).

Flue gas treatment system and chimney.
On the right, the dry cooler.

A detail of the dry cooler control panels.

The nearby electrical cabin.

Umbria 01 : A detail of the heat exchangers

Umbria 01: The flue gas exhaust chimney

Umbria 01: A detail of one of the two ZE-100-LT ORC modules in their own room

Lombardy 03

Manager: *Private Italian Firm* • ***Location:*** *Lombardy, Italy*
Plant: *1 x ZE-150-LT ORC module*
Application: *Primary energy production with a boiler fueled by biomass*
(end-of-life shipping pallets)

The client who commissioned this plant is a firm from a small town in the province of Brescia, in northern Italy, dealing in wooden shipping pallets and fully authorized for **transport, stockage and disposal of wooden waste.** The waste biomass it acquires in its line of work (mainly wooden pallets no longer usable for shipping) is burned into a 1-MWe movable-grate boiler by Herz which feeds heat to a ZE-150-LT ORC module.

The versatility of the ZE ORC modules in handling partial loads has come to fruition in this plant, where the generator has been **derated to 135 kWe** from the nominal 150 to meet the client needs. An **economizer** placed on the flue line also **recovers part of the heat to dry and preheat the wooden biomass**.

The system, as every ORC module we supply, is mounted on a self-supporting frame ("skid") that includes exchangers,turbogenerator, and control panel. The skid, in indoor configuration, is housed in a purpose-built building that also hosts the boiler and the biomass hopper, while excess heat is dissipated by an external evaporative cooling tower. The system is **entirely remote operated** and does not require the presence of an operator.

It is also interesting to note the **financing formula** that has been used to build the plant. With our collaboration, the client has been put in contact with an E.S.Co. that **financed the whole plant** in exchange for its ownership and earnings for the first years of the plant's life, during which the client will supply the biomass at zero cost. On expiry of the payback period, plant ownership **will be given back to the client, which will have then acquired the plant practically for free**.

Wooden biomass is an environmentally compatible and renewable fuel, with zero CO_2 impact, as the CO_2 released when burning is the same CO_2 the plants captured during their growth.

A general view of the building housing the plant.

The biomass hopper, with a rake-style feeding system.

The boiler seen from the right side.

The ZE-150-LT ORC module in place, seen from the control panel side.

The turbogenerator (silver cylinder) inside the skid frame.

The skid seen from the hydraulic connections side.

The shredder which reduces the unusable pallets into wooden chips.

The water treatment system feeding the evaporative cooling tower.

L to R: the bag filter for flue gases, the chimney and the cooling tower.

Lombardia 03: *The ZE-150-LT organic Rankine cycle power generation module, seen from the control panel side*

Lombardia 03: *A detail of the ORC skid - the steel cylinder in the middle is the turbogenerator*

Veneto 04

Manager: *Private Italian Firm* • ***Location:*** *Veneto, Italy*
Plant: *2 x ZE-100-LT ORC modules*
Application: *Primary energy production in connection with a boiler fueled* *(wood prunings)*

The owner of this plant is a large agricultural and touristic structure located in a small town in the venetian countryside near Padua, which has installed a system to take advantage of the **waste biomass (mainly pruning residues) created in the course of its activities**.

Said biomass is reduced into chips and fed to a **1.6-MW movable grate boiler**, built by Ahena Boilers. Most of the heat generated by its combustion is then fed, through two overheated water loops, to the couple of ZE-100-LT ORC modules at the heart of this plant, while a lesser part is used for heating and sanitary water production.

The two ORC modules used in this installation and mounted on self-supporting frames (skids) containing turbogenerators, heat exchangers an control systems, are in indoor configuration and hosted inside a specific building. **The ORC modules operate in parallel and output a total of 200 kWe to the grid**, thus giving a significant contribution to the structure's overall energy balance and sustainability. Cooling for the condensation stage of the ORCs is carried out by an evaporative cooling tower placed outside the building.

The fuel used (pruning residues) is an environmentally-compatible, renewable resource made more competitive by state and regional incentives. It has zero CO_2 impact, as its combustion just releases the same CO_2 that was sequestered by the plants during their growth.

A general view of the agritourism.

The boiler building hosting the ORCs and the boiler.

The evaporative cooling tower.

The biomass loading hopper.

The boiler in its room behind the ORC modules.

The control panels for the ORCs.

The mains grid interface panels.

A detail of the boiler and its ash filter.

The flue gas treatment system and the boiler room.

Veneto 04: *The two skid-mounted ZE-100-LT Organic Rankine Cycle modules in their room*

Veneto 04 : *A detail of the ORC skids - the silver cylinder (middle) is one of the turbogenerators*

Calabria 01

Manager: *Private Italian Firm* • ***Location:*** *Calabria, Italy*
Plant: *1 x ZE-175-LT ORC module in indoor configuration*
Application: *Primary energy production in connection with a boiler fueled (prunings pruning)*

The client who commissioned us this plant is an **authorized solid waste manager**, which started in 1993 as a sewer cleaning firm and then moved into the the **waste transportation and processing sector**, where now it operates for several institutional clients.

The firm decided to acquire a **waste-to-energy plant to dispose on-site of the wood biomass it acquires in its line of work** – mainly tree branches and pruning residues from state forests. Doing so, the firm eliminates the costs (both economic and environmental) of transporting that biomass.

Instead of being transported to the dump, the biomass is now processed on their own premises, where it is ground and burned into a specific movable-grate **boiler producing up to 1300 kWT.** That heat is then conveyed by an overheated water loop to the ZE-175-LT Organic Rankine Cycle module. The ORC module is hosted indoors and, as all systems we supply, is installed into a self-contained frame ("skid") that also includes the control panel and the energy grid interface panel. The components that require more ventilation (e.g. the cooling tower for the condensation stage) are installed outdoors.

Untreated, **virgin wood is an environmentally friendly, renewable power source made more competitive for energy production by state incentives**. It also has a minimal CO_2 footprint, as the gas released by burning the biomass is the same that was once captured by the plants from which it derives. An added environmental benefit is the reduction in pollution and fossil fuel usage consequential to on-site processing.

A bird's-eye view of the client's premises.

The biomass storage area.

The ORC module skid seen through the shack doors.

A detail of the ORC module control panel.

The ORC Module; in background, the braking resistors cabinet.

The boiler seen fron the flue gas processing side.

The vector fluid expansion vessel.

The cooling tower.

The tower base hosts the cooling water treatment system.

Calabria 01 : The ZE-175-LT ORC module in its place, seen from the control panel side

Calabria 01 : The boiler seen from the biomass loading side

Germany 02

Manager: *Private Germany Firm* • ***Location:*** *Germany*
Plant: *1x ZE-40-ULH LT-ORC energy module in indoor configuration*
Application: *Waste heat recovery from a MAN genset fueled by biogas*

This plant is located in a German village in Lower Saxony not far from Bremen. Its function is to **optimize the efficiency** of a micro-thermoelectric powerplant based on a biogas-fueled MAN genset by recovering its waste heat, thus making the whole plant eligible for the incentives set forth by the Federal german government for those who set up a microgeneration plant based on renewable energy sources.

The system installed here is **a standard ZE-40-ULH ORC module**, with a nominal output of 40 kWE, which operates by recovering waste heat from the cooling jackets and flue gases of the genset, thus giving a significant contribution to the overall system efficiency

The ORC system used in this installation is hosted inside a small hangar located in the country just outside the village. The plant is **fully operator-independent and entirely monitored and managed via the Internet**. The compactness of the ZE system has made it possible to host the skid – containing the turbogenerator, heat exchangers, and control panels in a corner of the hangar, just behind the containerized genset. Cooling for the condensation stage is ensured by **two small dry-coolers** located just outside the hangar door.

The fuel used by the genset (biogas) is an environment-friendly, renewable source made competitive for energy production by state and regional incentives. In has near zero CO_2 footprint as the CO_2 released when burning it is the same that was captured in the past by the biological sources from which it derives.

An overview of the village.

The hangar that hosts the plant.

The entrance door and the dry coolers for the condensation stage.

The ZE-40-ULH ORC module seen from the control panel side.

Germany 02: The ORC Module seen from the hydraulic connections side

Germany 02: The container hosting the biogas-fueled MAN genset

Sicily 02

Manager: *Private Italian Firm* • ***Location:*** *Sicily, Italy*
Plant: *1x ZE-50-ULH LT-ORC energy module in outdoor installation*
Application: *Didactic hybrid plant* *(gas boiler + thermic solar power)*

The client who commissioned this plant is a recently-estabilished **private university** which has decided to acquire for their Engineering faculty what they defined as an ***"experimental prototypal subsystem with modular and diffuse thermodynamic solar system"*** operating within the frame of one of their research projects.

This plant – **which purpose is not so much energy production as the demonstration of various engineering principles** – uses a **hybrid heat source** composed of a **methane-fueled boiler** assisted by batteries of **concentration-type thermal solar panels,** and has been installed in a small plot not far from the campus.

We won the tender for the realization of the whole energy system, including all hot-side systems (heat production and vectoring), cold side systems (evaporative cooling systems) and ORC module. The latter is a Z**E-50-ULH low-temp organic Rankine cycle (LT-ORC)** power generation module, skid-mounted and hosted in a containerized, weather-resistant outdoor enclosure.

90% of all thermal energy for the plant is supplied by the **high-efficiency, low-emissions methane boiler** supplied by ICI Caldaie on Zuccato Energia's specifications, while **up to the remaining 10% of thermal energy** required for peak performance is supplied by **PTMx parabolic solar collectors** built by Soltigua, which is also one of our partners for our Tunisia 01 hybrid (biomass+solar) plant in Tunisia.

A satellite view of the faculty, with our plant in the lower right corner.

The solar concentrators; behind them, the cooling tower.

A detail of the solar panels, supplied by Soltigua.

An overview of the solar concentrators area.

Behind the cooling tower, the ORC module, in its weatherproof containerized enclosure.

The rear of the tower; in background, the boiler, protected by grid fences, and located under a lean-to.

The ICI boiler which supplies most of the thermal energy for the plant.

The pumps which manage the hybrid heating system.

The plant commissioning plaque.

Sicily 02 : The solar concentrators area

Sicily 02 : Foreground to background: the cooling tower, the containerized ZE-50-ULH ORC module, the boiler housing

Sicily 01

Manager: *Private Italian Firm* • ***Location:*** *Sicily, Italy*
Plant: *ZE-175-LT ORC power generation module in indoor installation*
Application: *Power generation from biomass* *(wood scraps from production of wooden horticultural trays and crates)*

This plant has been commissioned by an Italian manufacturer of **agricultural packaging** (particularly pallets and small wooden crates for fruit and vegetables) which has decided to monetize its production scraps by burning them in a specific boiler after shredding them into wooden chips to simplify moving them and enhance combustion. The heat generated by wood chip combustion is then conveyed through an overheated water loop to a ZE-175-LT Organic Rankine Cycle power generation module, located in a small purpose-built building

This micro power plant uses a **movable grate boiler** rated at 1300 kWT thermal output and equipped with particulate filters. The ORC power generation module, as all of our systems, is supplied mounted inside a stand-alone metal frame ("skid") which also includes control electronics and grid sync electronics. The braking chopper resistor banks are mounted instead **in a separate cabinet**, located near a ventilation grid. The condensation stage dissipates excess heat through an EvapCo cooling tower placed on the roof of a nearby building.

As said before, the fuel used in this plant is **virgin, untreated wood,** a renewable, clean-burning, environment-friendly fuel made even more convenient by local and state incentives. Wood is also CO_2-neutral, as the CO_2 released in the atmosphere during combustion is the same which was captured by the plant while growing.

An aerial overview of the site.

The ZE-175-LT skid being tested before shipping in Zuccato Energia's test area.

The skid being loaded on the truck for shipping to Sicily.

A general view of Ortoimballaggi's wide loading area.

Part of the warehouse. The client is a leader firm in the production of agricultural packaging.

Part of the production line. Only quality, untreated virgin wood is used.

The wooden scraps destined to become fuel for the boiler.

The chipping machine reduces the scraps in fast-burning small wooden chips.

Wood chips being taken for loading in the boiler's fuel hopper.

The building which hosts the ORC module. Behind, a glimpse of cooling tower and chimney.

A detail of the ORC building. The skid may be glimpsed through the open door.

The ZE-175-LT Organic Rankine Cycle energy module, seen from the right side.

The ZE-175-LT ORC module in its skid, seen from the left side.

The 1300-kWT movable grate boiler, fueled by wooden chips.

R to L: boiler, dust trap and and flue gas treatment system.

The dust trap. Wood burns cleanly, requiring only minimal flue gas treatment.

The wood chips loading screw which brings fuel to the boiler.

The cooling tower which dissipates the excess heat of the ORC condensation stage.

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Sicily 01: *The ZE-175 LT ORC Module in place, seen from the right side*

Lombardy 02

Manager: *Private Italian Firm* • ***Location:*** *Lombardy, Italy*
Plant: *1 x ZE-100-LT ORC energy production module*
Application: *Power generation from biomass* *(wood and bark scraps from sawmill operation)*

The client who commissioned this plant is a firm from a small town in the province of Brescia, in northern Italy, dealing in wooden shipping pallets and fully authorized for **transport, stockage and disposal of wooden waste**. The waste biomass it acquires in its line of work (mainly wooden pallets no longer usable for shipping) is burned into a 1-MWe movable-grate boiler by Herz which feeds heat to a ZE-150-LT ORC module.

The versatility of the ZE ORC modules in handling partial loads has come to fruition in this plant, where the generator has been **derated to 135 kWe** from the nominal 150 to meet the client needs. An **economizer** placed on the flue line also **recovers part of the heat to dry and preheat the wooden biomass.**

The system, as every ORC module we supply, is mounted on a self-supporting frame ("skid") that includes exchangers,turbogenerator, and control panel. The skid, in indoor configuration, is housed in a purpose-built building that also hosts the boiler and the biomass hopper, while excess heat is dissipated by an external evaporative cooling tower. The system is **entirely remote operated** and does not require the presence of an operator.

It is also interesting to note the **financing formula** that has been used to build the plant. With our collaboration, the client has been put in contact with an E.S.Co. that **financed the whole plant** in exchange for its ownership and earnings for the first years of the plant's life, during which the client will supply the biomass at zero cost. On expiry of the payback period, plant ownership **will be given back to the client**, which will have then **acquired the plant practically for free**.

Wooden biomass is an environmentally compatible and renewable fuel, with zero CO_2 impact, as the CO_2 released when burning is the same CO_2 the plants captured during their growth.

An aerial view of the plant; on the right, the shed under which the plant is located.

The ZE-100-LT skid being loaded for shipping.

The ZE-100-LT ORC module being installed in its noise-absorbing enclosure.

The ZE-100-LT skid enclosure.

General view from the north side - L to R: woodchip storage (green), wastewood hopper (red), chipper (white), cooling tower (metal).

A detail of the conveyor between the chipper and the woodchip storage bin.

Detail of the storage-to-boiler fuel conveyor. Skid enclosure is in the background.

A detail of the fully insulated thermal connections to the boiler.

The cooling tower. A small one is sufficient, as residual heat is used to dry the wood chips.

Lombardy 02: General view - L to R: ORC module enclosure (white), boiler (red), chip storage and conveyor (green)

Lombardy 02: The ZE-100-LT soundproofed skid enclosure (white) and the movable grate boiler (red)

Germany 01

Manager: *Private Germany Firm* • ***Location:*** *Germany*
Plant: *1 x ZE-50-ULH LT-ORC Module*
Application: *Heat recovery from engines* *(MAN biogas-fueled genset)*

This plant, managed by a private German firm, is located in a small German town in the Harz district of the Saxony-Anhalt länder. Its purpose is to **optimize the efficiency of a micro-thermoelectric powerplant** based on a biogas-fueled MAN genset. The plant is thus eligible for the incentives set forth by the Federal german government for those who set up a microgeneration plant based on renewable energy sources.

The system used in this installation is a **ZE-50-ULH ORC power module**, with a nominal output of **50 kWE,** which operates recovering waste heat from the **cooling jackets and flue gases of the genset,** thus giving a significant contribution to the overall system efficiency

The skid-mounted ORC system is hosted, together with the genset it recovers heat from, in a very small prefabricated concrete building placed in a field beside the main road of a small industrial area. The plant is **fully operator-independent as it is managed entirely by remote control via the Web**. The **compactness** of the ZE system has made it possible to host both the skid – including turbine, heat exchangers, and control panels – and the genset in a shed **about the size of two shipping containers placed end-to-end**. Cooling for the ORC condensation stage is granted by a dry cooler system placed on the building's roof.

The fuel used by the genset (i.e. biogas) is an **environmentally friendly, renewable energy** source made even more competitive by local an state incentives. It has near zero environmental impact regarding CO_2 emissions, as the CO_2 released in the atmosphere is the same which was captured before by the plants the animals grazed upon.

The plant in a satellite photo.

The plant's north side as seen from the main road.

The east side of the plant. Note the roof-installed dry cooler.

The west side of the plant with the acces door.

The skid seen from the access door.

The ZE-50-ULH ORC skid in its place inside the prefabricated shed.

The same skid some time before, being packaged for delivery.

The south side of the plant.

A close-up of the dry coolers on the roof.

Germany 01: *The west side of the plant with the access door*

Germany 01: *The ZE-50-ULH ORC module in place inside the prefabricated shed. In the foreground, the turbine*

Friuli 01

Manager: *Private Italian Firm* • ***Location:*** *Friuli, Italy*
Plant: *1x ZE-150-LT power generation module*
Application: *Power generation from biomass* *(poultry manure)*

The core business of the poultry farm in the province of Pordenone which commissioned this plant is to raise broilers, i.e. meat chickens. They chose to solve their **poultry manure disposal problem** by burning said manure into a special boiler, producing overheated water which is fed to an ORC system to produce electric power, thus taking advantage of the incentivated tariffs awarded by the Italian government to newly built small power plants fueled by renewable sources.

The system used in this installation is a **ZE-150-LT ORC power generation module**, downgraded from 150 to 140 kWE for fiscal reasons, that operates using the heat fed to it by the boiler via a safe and efficient overheated water loop.

The ORC system is hosted indoors, in a dedicated room. As the client has a low-voltage connection to the power grid, the inverter system is hosted in external cabinets instead of on board the skid as usual. Another peculiarity is the use of an **air cooling system** (aka dry cooler) to cool the fluid in the condensation phase of the ORC instead of the commonly used evaporative cooling tower.

The fuel used in this plant is the so-called "pollina", i.e. a mix of poultry manure, litter, feed residues and feathers. A recent Italian court ruling has confirmed that this material can be considered as biomass and as such can be used to fuel renewable energy plants.

The use of this biomass to to produce electric power is very interesting with regards to performance and gives access to state incentives; it is, however, quite a dirty-burning material, so the plant was equipped with a state-of-the-art flue gas processing system which makes it conform with atmospheric emission standards.

A general view of the firm.

The fuel storage area.

The boiler (L) and the exhaust treatment system.

The exhaust treatment system with its cover removed showing the cyclonic filters.

The fuel feeding hopper and the chimney.

General view of the fuel loading screw.

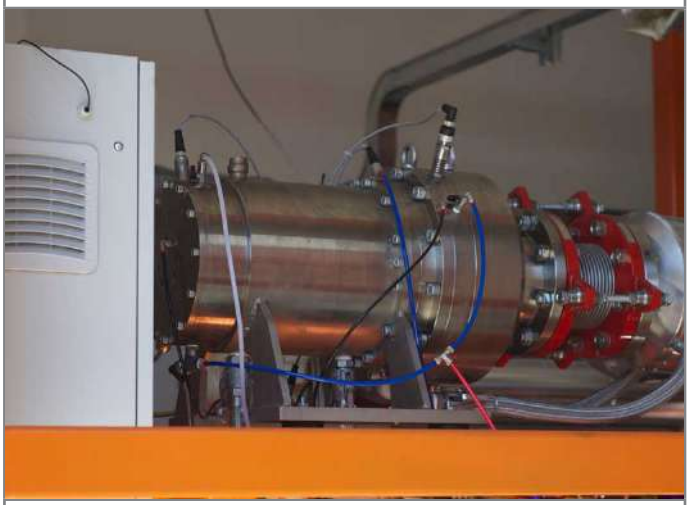
Detail of the loading screw and the burner.

General view of the dry cooler.

A detail of the dry cooler.

A general view of the ZE-150-LT module in its room.

A detail of the ZE-150-LT ORC system.



The 150 kWE turbine at the heart of the ZE-150-LT system.

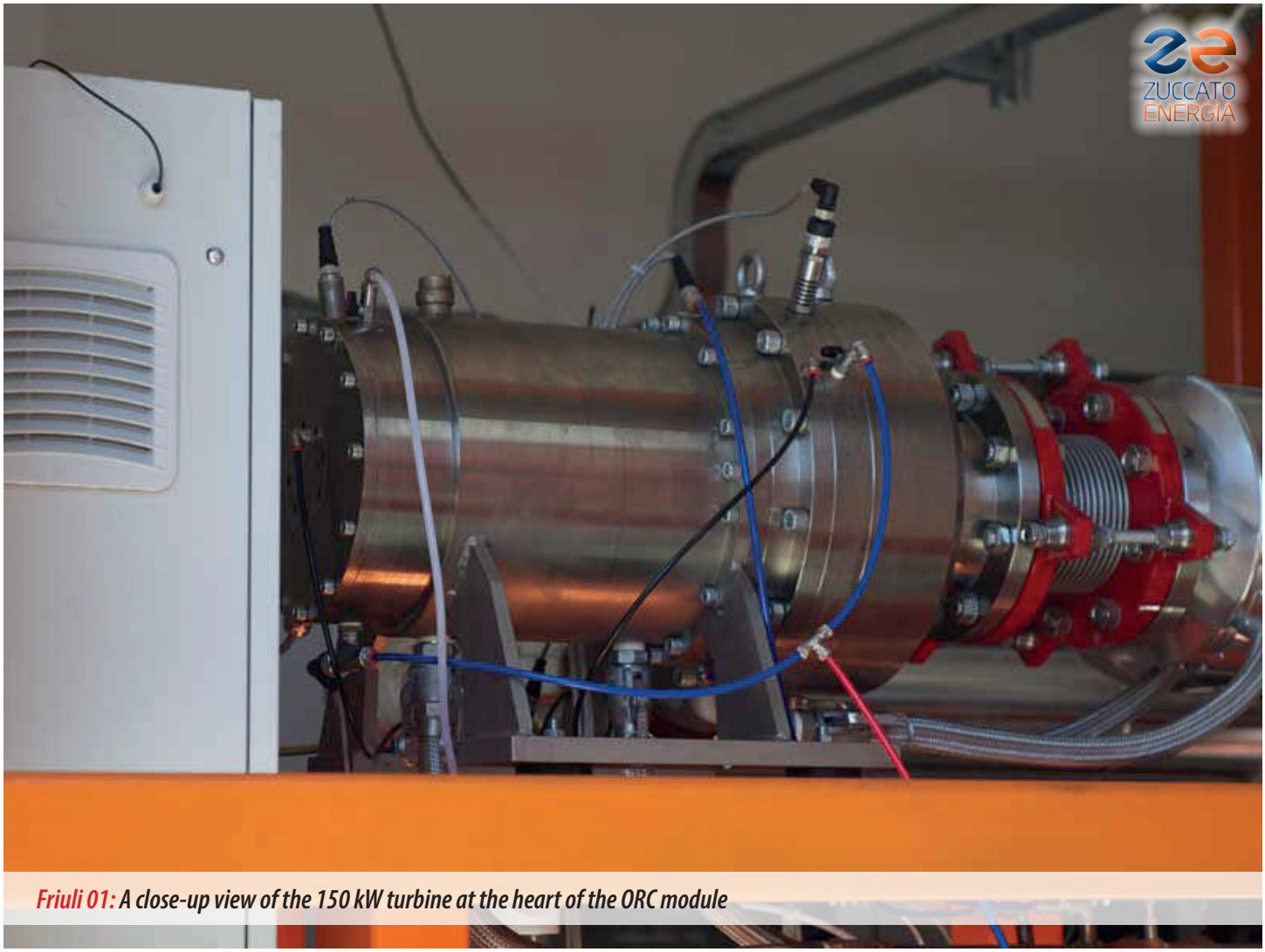
The control panel of the ORC skid.

Friuli 01: The fuel feeding hopper (right) and the chimney system

Friuli 01 : The boiler fueled by chicken dung (left) and the flue gas treatment system

Friuli 01: A general view of the dry cooler supplying the condensation stage of the ZE-150-LT ORC module

Friuli 01: *A general view of the 150-kWe ORC module in its room*



Friuli 01: *A close-up view of the 150 kW turbine at the heart of the ORC module*

Aosta Valley 01

Manager: *Private Italian Firm* • ***Location:*** *Aosta Valley, Italy*
Plant: *1 x ZE-40-ULH energy module*
Application: *Heat recovery from engines* *(Daewoo vegetable oil-fueled genset)*

The client who commissioned us this plant is a **mountain hotel located in the mountains of the Aosta Valley** on the road from Aosta to Courmayeur. The plant is a small-scale power station born to take advantage of the favorable incentives (such as an extremely competitive omnicomprehensive tariff) given by the italian state and the local province for small-scale power generation plants fueled by biomass or other renewable sources.

The LT – ORC system at the heart of this plant is a **single ZE-40-ULH module, i.e. a standard ZE-50 ULH downrated from 50 to 40 kWe output** to take advantage of the smaller thermal input. It operates using waste heat recovered from cooling jackets and exhaust gases of a genset based on single DOOSAN DAEWOO P222LE engine, modified to run on vegetable oil and connected to a 420 kWE generator.

A peculiarity of this installation is that the skid on which the ORC module is mounted has been f**actory-modified to fit the available space**, otherwise insufficient for our standard skids or competitor systems. **The skid layout was modified, making the skid shorter than the standard ones**, to fit in the underground boiler room used in this installation to reduce its visual and environmental impact

The biofuel currently used by this and other similar power plants (rapeseed oil from certified and tracked EU sources) is **an environmentally friendly and renewable power source**, made highly competitive by state and regional incentives. Such oil can easily be used as fuel in modified marine engines normally fueled by diesel fuel. The mechanical energy produced is used to operate the plant's main generator, and the energy produced is output to the national distribution grid.

The Hotel from the front.

The back and the new boiler room being built.

A general view of the boiler room.

The vegetable-oil-fueled MAN 420 engine.

The engine in detail.

The "puffer" (thermal flywheel) and the ORC module.

Overall view of the ZE-40-ULH ORC module.

The ZE-40-ULH ORC module in detail.

The cooling tower in its grid-ceiling room.

Aosta Valley 01: *A general view of the underground boiler room with engines (green), heat buffer (red) and ORC module*

Aosta Valley 01: *The ZE-40-ULH Organic Rankine Cycle module in detail*

Alto Adige 04

Manager: *Private Italian Firm* • ***Location:*** *Alto Adige, Italy*
Plant: *2 x ZE-50-ULH LT-ORC modules*
Application: *Heat recovery from engines* *(MAN vegetable oil-fueled gensets)*

The client who commissioned this plant is a **well-known construction** company having its seat in a small village in the Alps near Bozen, in South Tyrol, northern Italy. Like many other in the region, this plant was born from the desire to take advantage of the **favorable incentives** (such as an extremely competitive omnicomprehensive tariff) given by the italian state and the provincial administration for small-scale power generation plants fueled by biomass or other renewable sources.

In this particular case the supplied Organic Rankine Cycle system is composed of ***two ZE-50-ULH ORC modules*** having an output of 50 kWe each, fed by waste heat recovered from **the cooling jackets and the exhaust fumes** of two MAN 420 model 2842 LE 211 gensets, fueled by vegetable oil and rated at 420kWE electrical output. The addition of the ORC modules **raises the overall output from 840 to 940 kWE**, a productivity and efficiency boost of more than 10%.

An interesting detail of this plant is that the ORC modules are mounted on **two custom-designed skids**, **longer and narrower than standard ones**, allowing to better take advantage of the tight available spaces, otherwise insufficient to contain a plant this size, either ours or our competitors'. Factory modification made it possible to alter skid geometry to fit the plant to the available space.

The electric output of the plant is injected into to the national distribution grid, as required by Italian law, while **residual thermal energy is used to heat the firm's offices, sanitary water and concrete mixing plant.** It is also supplied on request to the **local district heating system**.

The biofuel used by this and other similar power plants (**rapeseed oil from certified EU sources)** is an environmentally friendly and renewable power source, made highly competitive by state and regional incentives. Such oil can easily be used as fuel in modified marine engines designed to burn heavy fuel oil.

As with all biomass-derived fuels, rapeseed oil is CO_2-neutral, as the CO_2 released during combustion is the same the plant captured when growing. Furthermore, the residue from rapeseed seed pressing can be used as a high-protein foodstuff for cattle.

The firm.

Panorama from the upper forecourt.

The ZE-50-ULH LT-ORC skid being unloaded.

The cooling towers, installed behind the building.

Alto Adige 04 : The first LT-ORC skid being installed

Alto Adige 04: The LT-ORC installation complete

Lazio 01

Manager: *Private Italian Firm* • ***Location:*** *Lazio, Italy*
Plant: *1 x ZE-50-ULH LT-ORC Module*
Application: *Heat recovery from processes (pyrolitic gasification) and engines (syngas-fueled genset)*

The firm who commissioned this plant is the manager of a **large cinema multiplex and related mall** located in the province of Rome, along a main highway.

The plant to which the ORC module is connected is composed of **two Burkhardt gasifiers** pyrolyzing wood pellet to produce the combustible gas (syngas) used to fuel t**wo customized MAN gensets** having an overall power output of 360kWE.

The supplied Low Temperature Organic Rankine Cycle (LT-ORC) module runs on **waste** heat recovered b**oth from the flue gases of the Burkhardt gasifiers and from the cooling jackets and flue gases of the gensets** the gasifiers supply syngas to.

The module – **a standard ZE-50-ULH system** – adds a further 45 kWE to the 360 kWE produced by the gasifier/engine plant, thus raising total power output to 405 kWE and **increasing performance** by about 9% with respect to the "naked" system. Due to the **compactness and quiet operation** of the skid-mounted ORC module, it was possible to install it into a **technical underground space located under one of the theatres**, while gasifiers, engines, generators and cooling tower are installed above ground outdoors

The wood processed by the gasifiers is **locally-produced wood pellet**. As is the case for all biomass fuels, it is CO-2 neutral, as the carbon dioxide released during gasification and combustion is the same which was captured during the growth of the trees the pellet comes from.

A general view of the firm.

A side detail of the Burkhardt CHP generators.

The Burkhardt CHP generators and the blue cooling tower.

The gasifiers housing: in the foreground, its ash disposal system.

Lazio 01: The ZE-50-ULH ORC module in its undergrtound space below one of the cinema theaters

Lazio 01: The ZE-50-ULH module seen from the heat exchangers side

Alto Adige 03

Manager: *Private Italian Firm* • ***Location:*** *Allto Adige, Italy*
Plant: *1 x ZE-50-ULH LT-ORC Module*
Application: *Heat recovery from wood-pellet-fueled Burkhardt gasifiers and from the cooling jacket and flue gases of the MAN engines fueled by the syngas produced by said gasifiers.*

The client who commissioned this plant is **an ad-hoc enterprise** located in a suburb of Merano/Meran, a large town in the province of Bolzano/Bozen, not far from the northern border of Italy. The plant was created for the purpose of producing electric power as a **technological demonstrator for the efficient combination of Burkhardt gasifiers with ORC systems**.

The client who commissioned this plant is an **ad-hoc enterprise** located in a suburb of Merano/Meran, a large town in the province of Bolzano/Bozen, not far from the northern border of Italy. The plant was created for the purpose of producing electric power as a **technological demonstrator for the efficient combination of Burkhardt gasifiers with ORC systems**.

The plant served by the supplied ORC system is composed of **two Burkhardt wood pellet gasifiers** producing combustible gas fuel (syngas) feeding **two MAN gensets** with an overall power output of 360kWe.

The **standard ZE-50-ULH ORC module** installed in this plant recovers waste heat from **both the pyrolitic process** (which would otherwise be lost in the output gases) and from **the cooling jackets and flue gases of the MAN gensets**, and converts it into electricity.

A general view of the plant.

The ZE-50-ULH skid in place.

A general view of the Burkhardt gasifiers.

A perspective view of the plant.

Alto Adige 03 : The ZE-50-ULH skid in place - seen from the side

Alto Adige 03: One of the gasifiers in closer view

Veneto 03

Manager: *Private Italian Firm* • ***Location:*** *Veneto, Italy*
Plant: *1 x ZE-50-ULH LT-ORC Module*
Application: *Mixed - Power generation from biomass (boiler fueled by wood prunings) / Heat recovery (from hot-air-turbines)*

The client who commissioned this plant is **one of the largest Italian multiutility companies**. It is a fully public company, owned by a consortium whose shareholders are fifty-odd municipalities of the Veneto region, and its core business is to supply **environmental services, water and power** to its shareholding municipalities.

In its managerial and operational center two biomass-fueled boilers generate a total thermal power around 1,3 MWT used for heating and sanitary uses as well as for power generation through two Turbec hot-air turbines which can produce up to 160 kWE.

The supplied system – **a standard ZE-50-ULH Low Temperature Organic Rankine Cycle module** – adds a further 50 kWE to the overall grid output of the aforementioned system, raising the total power output to 210 kWE and **increasing overall power output by 30%** with respect to the "naked" system.

The versatility of our ORC modules made it possible to run the system in **mixed mode** : during pitch times, when the hot-air turbines are operating, it runs on **waste heat recovered from the turbines, while when the turbines** are offline it runs directly on **heat produced by the biomass-fed boilers** and fed to it by the automated control system. The compactness of this standard skid-mounted ORC system allowed its installation in a technical space (a steel-grating mezzanine) within the same building which hosts boilers and turbines

All produced electric power goes into the national distribution grid and contributes to **make the complex entirely self-sufficient** from the energy standpoint together with a photovoltaic array. Residual thermal energy is also used to heat – through a small district-heating network – **the different buildings which make up the managerial complex.**

The boilers are fueled by **wood chips obtained from forest cleaning and mowing.** As all biomass-fueled systems, this plant is CO_2-neutral, as the CO_2 released by combustion is equivalent to that captured by the plants during their growth.

Entrance to the plant.

The building which hosts the entire system.

Overall view. Boilers are below, ORC plant in on mezzanine.

The ZE-50-ULH ORC system seen from above.

The hot-air turbines to which the ZE-50-ULH may be connectedv.

Detail view of one of the Turbec hot-air turbines.

Veneto 03: The ZE-50-ULH low-temperature ORC module seen from above

Veneto 03: A detail of the heat exchangers of the ZE-50-ULH low-temperature organic Rankine cycle module

Alto Adige 02

Manager: *Private Italian Firm* • ***Location:*** *Alto Adige, Italy*
Plant: *1 x ZE-50-ULH LT-ORC Module*
Application: *Heat recovery from engines* *(vegetable oil - fueled genset)*

The private firm which commissioned this plant is located near Bolzano/ Bozen, in Northern Italy, and has installed a **micro thermolectric power plant** on its premises to take advantage of incentives the Italian government offers for newly-built power generation plants fueled by biomass or renewable sources.

In this particular case, the supplied system is a **ZE-50-ULH ORC** module, having a 50-kWe power output, which operates using waste heat recovered from the cooling jackets and exhaust gases of a 420-kWE MAN 420 model 2842 LE 211 genset fueled by vegetable oil. The addition of the ORC module increases overall productivity by more than 10%

The MAN 420 genset is derived from a marine engine, **optimized to burn biofuel (rapeseed oil) instead of the original heavy oil** and connected to a generator to convert the developed mechanical energy into electricity. The rapeseed oil used comes **from certified and tracked EU sources** and is a sustainable and renewable energy source made very competitive for power production by state and regional incentive.

As all biomass-derived fuels, rapeseed oil has **zero impact for what regards CO_2 emissions**, as the CO_2 released during combustion was the same CO_2 captured by the plants during their growth. Furthermore, the residue from rapeseed pressing can be used as a healthy, high-protein foodstuff for cattle.

A general view of the firm.

The control room.

The control room sen from inside.

The vegetable oil reservoirs being installed.

Alto Adige 02: *The control room as seen from the inside*

Alto Adige 02 : *The ZE-50-ULH low-temperature ORC module in its place*

Veneto 02

Manager: *Private Italian Firm* • ***Location:*** *Veneto, Italy*
Plant: *1 x ZE-50-ULH LT-ORC Module*
Application: *Heat recovery from engines* *(two MAN biogas-fueled gensets)*

The **cattle farm** which commissioned this plant lies in a small village in a corner of the province of Padua adjoining the province of Vicenza. It is equipped with a **biogas generation facility**, and the biogas produced by the fermentation of the manure produced by their **1000+ head of cattle is used to fuel two MAN gensets**.

The supplied ORC system has the purpose to **increase the efficiency** of this small-scale thermoelectric power plant, born to take advantage of the favorable incentives for small-scale energy production from renewable sources.

This heat-recovery system – based on a ZE-50-ULH Organic Rankine Cycle module – produces an additional 50kWE by **converting residual heat from the cooling jackets and exhaust fumes** of the above mentioned gensets **into electricity,** thus increasing overall plant output and efficiency.

The ORC module is in this case located **outdoors**, under a lean-to. Upon client request, **the ORC control system has been customized**, to allow its placement inside a nearby existing shelter (which also hosts the control boards for the engines and the fermentation plant) instead of being installed on board the skid as usual.

The **cooling system** used in this plant is peculiar, as it uses **neither cooling towers nor dry coolers**: cooling water – potable but very cold water taken from a local well – is just fed as drinking water to the cows after being brought to room temperature by passing through the heat exchangers of the ORC cooling stage, thus avoiding the gastrointestinal problems drinking too cold water can give them. The **food-grade stainless steel** walls of the exchanger give rise to no contamination.

The fuel used in this plant (biogas) is an **environment-friendly, renewable power source**, made cost-effective also by state ad regional incentives. It is also CO_2-neutral, as the CO_2 its combustion releases is the same that was captured by the plants upon which which the cattle fed.

A general view of the firm.

The ZE-50-ULH skid being unloaded.

The ZE-50-ULH skid being unloaded.

Contact box and green "control room" container.

Detail of the 50 kWE turbogenerator.

The cooling towers.

The ORC module under its protective lean-to.

The complete installation (north side).

The complete installation (south side).

Veneto 02: The ORC module (orange) with its contact box (white) and the containerized control room (green)

Veneto 02: The ZE-50-ULH low-temperature ORC installation seen from the front

Lombardy 01

Manager: *Private Italian Firm* • ***Location:*** *Veneto, Italy*
Plant: *1 x ZE-50-ULH LT-ORC Module*
Application: *Heat recovery from engines* *(two Jenbacher biogas-fueled gensets)*

The client, located in the province of Mantua, Lombardy, Italy is a livestock farm specializing in pigs, which has decided to acquire a **biogas production system** fueled by the fermentation of the sewage created by its 10,000-odd pigs.

The biogas produced in the fermenting tanks is used as fuel for a micro power plant based on a 637-kW engine by the german firm, Jenbacher. Said plant takes advantage of the favorable all-comprehensive tariff the Italian government grants to new small power plants powered by renewable energy sources.

The system used for heat recovery is a ZE-50-ULH low temperature Organic Rankine-cycle module which produces 50 kWE of electricity **by recovering waste heat from flue gases and cooling jackets** of the forementioned Jenbacher engine, thus contributing significantly to the overall system efficiency and productivity.

The ORC module used in this plant is **entirely contained in a custom container**, located outdoors, which is both **compact** (4,2 x 1,5 x h 3,1m) and **totally weatherproof**. This container hosts the whole ORC system, including turbine, secondary heat excangers and control panel, as well as a climatization system for the control panels. Cooling for the condensation part of the cycle is ensured by an EvapCo cooling tower located beside the container.

The fuel used by the Jenbacher engine (biogas) is an **environment-friendly and renewable energy source** made competitive by state and regional incentives. It is also CO_2-neutral, as burning biogas releases in the atmosphere the same quantity of CO_2 that was once captured by the plants that went to feed the animals.

The main fermenter tanks.

The screw feeding sewage to the fermenters.

A side view of the ORC module container.

The right side of the ORC module. Control panel is on the short side.

Lombardy 01: A general view of the fermenters, the engines and the containerized ZE-50-ULH ORC module

Lombardy 01: The containerized, weatherproof ZE-50-ULH ORC module; in the background, the cooling tower

Veneto 01

Manager: *Private Italian Firm* • ***Location:*** *Veneto, Italy*
Plant: *1 x ZE-50-ULH LT-ORC Module*
Application: *Heat recovery from engines (Jenbacher biogas-fueled genset)*

The client who commissioned this plant is a livestock farm specializing in cattle and located in the province of Venice, Italy, which has decided to acquire a **biogas production system** fueled by the fermentation of the sewage created by its cows.

The biogas produced in the fermenting tanks is used as fuel for a **micro power plant** based on a 637-kW engine by the german firm Jenbacher. Said plant takes advantage of the favorable all-comprehensive tariff the Italian government grants to new small power plants powered by renewable energy sources

The ORC system supplied – a ZE-50-ULH low temperature organic Rankine-cycle module – recovers waste heat from **flue gases and cooling jackets** of the forementioned Jenbacher engine, thus contributing significantly to the overall system efficiency and productivity.

The LT-ORC module is **entirely contained in a custom container,** located outdoors, which is both **compact** (4,2 x 1,5 x h 3,1m) and **totally weatherproof.** This container hosts the whole ORC system, including turbine, secondary heat excangers and control panel, as well as a climatization system for the control panels. Cooling for the condensation part of the cycle is ensured by an EvapCo cooling tower located beside the container.

The fuel used by the Jenbacher engine (biogas) is an environment-friendly, renewable energy source made competitive by state and regional incentives. It is also CO_2-neutral, as burning biogas releases in the atmosphere the same quantity of CO_2 which was once captured by the plants that went to feed the animals.

A general overview of the plant.

The plant as seen from one of the stables.

One of two fermenters with its load screw.

The container hosting the biogas - flued engine.

The ORC module (control panel side).

The ORC module (connectors side).

The ORC module (back side).

The cooling tower supplying the condenser.

A general view of the plant seen from the back.

Veneto 01: The ORC module (control panel side)

Veneto 01: A general view of the plant seen from the back

Alto Adige 01

Manager: *Private Italian Firm* • ***Location:*** *Veneto, Italy*
Plant: *1 x ZE-50-ULH LT-ORC Module*
Application: *Heat recovery from engines* *(Jenbacher biogas-fueled genset)*

The owner of this plant, **a SME located near Bolzano/Bozen, Italy,** decided to install a micro-thermolectric power plant on its premises to take advantage of the very interesting all-comprehensive tariff the Italian government offers for newly-built power generation plants fueled by biomass or renewable sources.

In this particular case, the module we supplied is a **ZE-50-ULH Organic Rankine Cycle power generation module** having a 50-kWe power output. It operates by using heat recovered from **the cooling jackets and the exhaust gases** of a MAN 420 model 2842 LE 211 genset fueled by vegetable oil with a power output of 420 kWE. The addition of the ORC module to the existing system increases overall productivity by more than 10%.

The MAN 420 genset **derives from a heavy-oil fueled marine engine modified to burn biofuel** and connected to a generator to convert the developed mechanical energy into electricity. The biofuel it burns (rapeseed oil from certified and tracked EU sources) is a sustainable and renewable energy source made very competitive for power production by state and regional incentives

As all biomass-derived fuels, rapeseed oil is CO_2-neutral, as the CO_2 it releases during combustion is the same CO_2 captured by rapeseed plants during their growth. Furthermore, the residue from rapeseed pressing can be used as a healthy, high-protein foodstuff for cattle.

The firm.

The ZE-50-ULH skid on the delivery truck.

The LT - ORC skid being placed near its final location.

The shelter hosting the engine and the skid.

Alto Adige 01: The vegetable-oil-fueled engine (left) and the ZE-50-ULH low-temperature ORC module (right) in their shelter

Alto Adige 01: A detail of the ZE-50-ULH low-temperature organic Rankine cycle module in its room

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