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# BEYOND COMBINED HEAT AND POWER: POLIGENERATIVE SMALL SCALE RENEWABLE PLANT

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Yanmar Research Europe has installed a small-scale biomass gasification system integrating a gasifier in a factory to produce Heat, Power, Cooling and Biochar.
The paper describe the system and the results of a 4-year experience of conveniently operating the bioenergy system into a local energy and biochar network.
The system has been recently completed with an absorption chiller plant: thus it is a renewable tri-generation by Maya (CCHP).

Keywords: decentralized generation, CCHP, biochar, gasification, wood chip

## 1 INTRODUCTION

Yanmar Co. Ltd, a Japanese engine manufacturer funded in 1912, has been involved in biomass gasification for more than 10 years now.
The Yanmar European R&D branch, based in Italy (Yanmar R&D Europe, YRE), which focuses on local and renewable energy systems, during 2014 installed and commissioned a cost-effective poligenerative system running on local wood chips.
A Polygeneration system is an upgraded version of a trigeneration system in which, together with electricity, heat and biochar, an absorption chiller for cold production is coupled to satisfy and optimize energy needs during summer time, in which heat demand is naturally lower.

## 2 THE BIOMASS GASIFICATION SYSTEM AND THE LOCAL ENERGY NETWORK

The local grid comprehends:

- A manufacturing factory
- The Italian electrical grid
- An innovative biomass gasifier
- 2XCombined Heat and Power units (CHP, 20kWe and 33kWth each)</li>
- A wood chips drier and storage system
- Local poligenerative network

### 2.1 The manufacturing factory

The factory is Yanmar Italy S.p.A, located in Cassano Magnago (VA), a Diesel engine manufacturing division of Yanmar Co. Ltd with head office in Osaka.
Yanmar Italy has a need of electrical energy and heat for manufacturing process, and cold for engine test benches rooms.

### 2.2 Innovative biomass gasifier

The biomass gasification system has been developed by Yanmar Research Japan (YRJ) one of the 3 research centres of Yanmar Co. Ltd.
Wood chips delivered from local suppliers feed the small-scale system.
The gasifier has an average feed rate of 47 kg/h and represents the first installation outside Japan.
The fixed-bed reactor is downdraft open-top, based on a specific innovative design coupled to a large number of control sensors that allows high automation and flexibility.
Furthermore, the particular design makes possible to process high ash content biomass like rice husk.

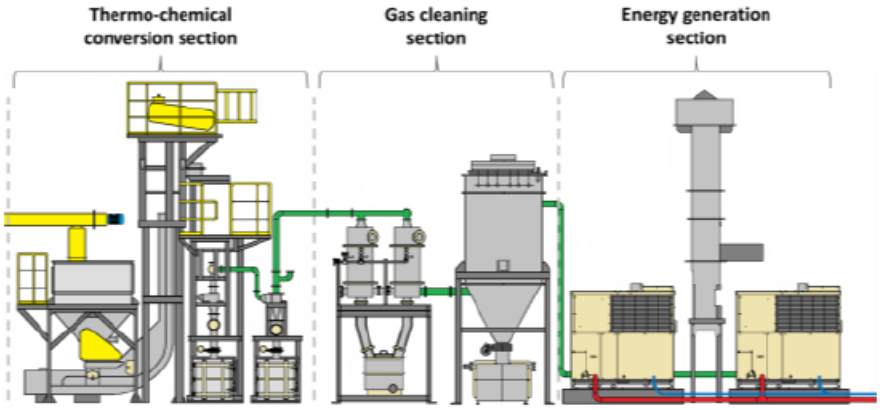



*Figure 1.PNG*

**Figure 1:** Scheme of biomass gasification system developed by YRJ

In Figure 1, a scheme of the main layout of the gasification system is reported.
In the thermochemical conversion section (on the left) is visible the bottom hopper, the reactor, two cyclones and relative char&ash bins.
In the centre of the scheme of Figure 1 is depicted the gas cleaning section, carbon particles in the hot gas are filtered and then gas coolers and scrubbers remove tars.
Finally, the cleaned and dry producer gas is used as a fuel into cogeneration units. The gasifier has more than 2400 cumulated operating hours since its installation.

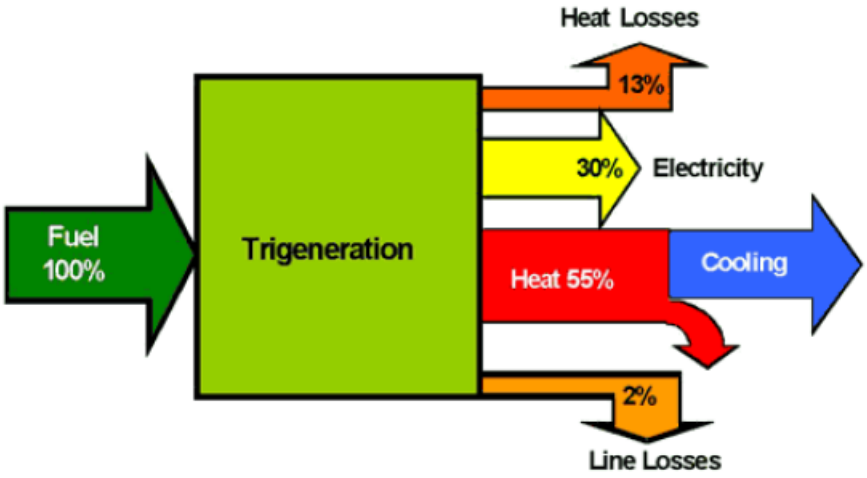
### 2.3 Combined heat and power units (CHP)

Yanmar CP25VB3Z natural gas cogeneration unit has been adapted to use producer gas as a fuel [3].
The four-cylinder reciprocating engine produces 20kWe.
33kWth are recovered and sent through the heat network to end local users, for either direct use inside the factory during winter time, or indirect use, via an absorption chiller, during summer time inside engine test benches rooms.

### 2.4 Absorption chiller: Combined Cooling, Heat and Power system (CCHP)

Cogeneration and trigeneration are currently matters of great interest.
Recently a number of norms and legislative measures have been introduced which are apt for promoting extensive use of these technologies and consequently significant application developments are expected.

The topics examined in this project concern small cogeneration plants powered by syngas.
The use of the recovered heat in commercial buildings (office complexes, shopping centers, hotels, etc.) must on the other hand be considered differently.
Whilst the winter months probably provide good opportunities for the utilization of the heat for comfort space heating and for sanitary hot water, the same cannot be said of the summer months.
The great majority of the recovered heat available would otherwise be totally wasted if it were not possible to profitably utilize it in an absorption chiller.
In this case one should speak not of cogeneration but rather trigeneration or CHCP = combined heat, cool & power.




*img1.PNG*

The YAZAKI WFC SC 20 absorption chiller unit is installed on a pre-engineered skid module by MAYA and use as the working fluid an aqueous solution of lithium bromide.
The characteristic COP (coefficient of performance) is 0.7, operating as a single effect absorption cycle, producing chilled water at 7 °C, when fed with hot water from the CHP plant at about 90 °C.
The very unique characteristic of this absorption chiller is the wide acceptable hot water temperature range from only 70 °C to 95 °C.

*img2.jpg*

*Figure 2.JPG*

**Figure 2:** Yanmar CP25VB3Z, hot water pipes (red and blue) of heat networks are visible

### 2.5 Wood chips dryer

The novel dryer and storage system has been designed during joint research project between University of Florence and YRE.
The innovative concept, that has been optimized through fluid dynamic studies, aims to control the fuel stratification thanks to a peculiar inner geometry and wood extraction system.

*Figure 3.JPG*

**Figure 3:** Patented drying system, the vertical screw is for load of wet wood chips
The drying medium is air, heated up to 81°C by water-air counter-flow heat exchanger.
The box capacity is 24 m3 and has an average wood chips residence time of about 96 hours.
Adjustable outlet air gates (figure 4) and variable frequency drive of fan can modify the drying medium velocity and direction.
Furthermore, a specific control logic, a relative humidity of ambient air, and a variable speed blower can exploit the natural drying potentials during some hours of the day.
Thanks to this features the hot water consumes for dry the biomass is decreased and, as a consequence, the heat and cooling power used for other purposes inside the factory increased.

*Figure 4.JPG*

**Figure 4:** Detail of opening gate for dryer medium exhausts

### 2.6 Local poligenerative Network

Polygeneration consists in simultaneous production of electric energy, thermal energy (heat or cool) and biochar.
The best advantage by installing such a kind of technology can be achieved by exploiting simultaneously different energy forms or byproducts.

Thermal power is transmitted through a hot water ring and its supply is controlled by means of a three way valve that is actuated automatically by a PLC.During winter season the heat is mostly addressed to the biomass dryer.
On the other hand, during middle and summer season, the heat request by the dryer drastically decreases thanks to the natural drying process previously described and simultaneously, the cooling request by the factory finds its seasonal peak.
As a consequence, the heat is supplied to an absorption chiller that is capable of generate the cooling power to be sent to the factory loads.
Thanks to natural drying process the system can valorize heat both during summer and winter season and can optimize the running hours of both CHPs.

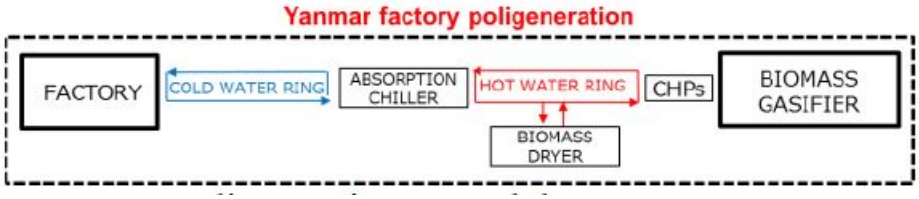



*Figure 5.JPG*

Figure 5: Poligenerative network layout

The last beneficial aspect of the network is represented by biochar production.

In fact, biomass gasification is a carbon negative technology that allows to store durably carbon into the soil in the form of a fertilizer called biochar.

The Biochar produced by the Yanmar technology is compliant with the Italian fertilizer regulation recent update (DL75/10) and can be used directly as a fertilizer.

## 3 Conclusions

Yanmar presented a novel concept of combined energy and biochar poligenerative system.

Thanks to the development of an innovative system, it is possible to produce simultaneously electric energy, thermal heating energy, thermal cooling energy and furthermore a bio-fertilizer.

In conclusion, the technology consists in a biomass dryer that operates in an energy save mode during middle and summer season.

The simultaneous production of electricity and heat that is converted into cooling energy is used to satisfy the factory energy loads according with seasonal load request.

The overall balance is translated into an increase of both sustainability and thermal-electrical savings for the entire network.


*Logos.JPG*