# Aactor© !GT© for Polygeneration: Biochar, Power, Vacuum and Heat from Waste Biomass with the Pyreg® Biochar Process

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## Purpose of Work

In 2010, Aactor© !GT©, a novel microturbine basing on the inverted brayton cycle (iGT) for the power production on landfill sites with lean gas, has been presented. 2011 one of many more possible applications is being presented. The pyrolysis process Pyreg® is a modern, clean conversion method, to turn waste biomass waste into valuable biochar, to be used for soil improvement, stable CO2-sequestration and deposit, as well as closing loops for important minerals for the soil. While showing a carbon retention rate of about 70%, far more heat than needed in the process is released from the pyrolysis gas combustion. Therefore Aactor !GT and the patented Xhost Harvester® are a great help to use the excess heat to draw the air flow through the process (act as exhaust fan) and generate power or vacuum. The vacuum could be used to run a vacuum dryer (to be used in wood industry or food processing and other applications).

## Background I: Carbon Sequestration and Soil Improvement

Not only in tropical lands, also in Europe, agricultural soils suffer from a very low or lowering carbon content. Carbon is a very important element in the soil as a controller and storage for humidity and fertilizers, as well as minerals. With the traditional and intensive plow treatment, the soils are regularly exposed to free air and therefore loose carbon as vapors of hydrocarbons and oxides (CO2) from composted biomass. With the “terra pretta” discovery in the Amazon Basin and the growing concern about climate change and the world’s food production, the importance of carbon in agricultural soil has become an important topic.

Nevetheless, as the use of biomass for energy has as well regained importance, several types of biomass residues remain not suitable for direct combustion, such as: sand containing driftwood from the screens of river power plants or screen waste wood from compost producers and dry fermenting biogas plants (Kompogas®), certain residues from grain mills. Such biomass residues can be pyrolysed without problems, as the process is heated with the absence of oxygen, slagging has not been observed..

**Figure 1** First commercial Pyreg 500 plant near Lausanne (right) and typical biowaste which is not suitable for other use than Biochar: sand containing screen residues from a Kompogas-plant.

In summary, closing recycling loops for biomass waste streams with high ash-content via biochar can create synergistic benefits and environmentally and economically sound solutions. With the biochar, not only carbon but also the minerals are given back to the soil. Additionally such biomass waste treatment processes are usually placed

on composting places, far from heat users except drying wood chips. A very efficient drying technology is vacuum drying.

## Background II: Inverted Brayton Cycle

The following chapter is all about: Why using an inefficient thermodynamic process, which is already known for decades, but was never applied so far? It seems as if other researchers have found out already earlier, why this process is not usefull to be applied. However the literature study discovered, that it was always studied for multi-MWe units. In decentralized units and micro turbines, other aspects gain importance:
The inverted brayton cycle does not invert the sequence of the strokes, but begins with a different stroke: it starts with the heating stroke at ambient pressure. This has the great advantage, that many kind hot gases can be inhaled directly into the turbine:

- Exhaust gases from stationary engines, gas turbines;
- burned anode-off gas from atmospheric fuel cell stacks,
- flaring gases from landfills, oil platforms, methanisation plants (biogas-to-gas-grid)
- hot air and gases from industrial furnaces (steel industry, gas industry)
- hot air from an atmospheric receiver of a concentrated solar combined cycle power plant (air/gas and steam)
- exhaust gases from pyrolysis reactor Pyreg® 500.

With the compressor acting as an exhaust fan or a vacuum pump, the security and fail-safe-security of a inverted-brayton-cycle turbine is very high. In case of compressor stall, the gas flow does not reverse but will stopp in few seconds. Due to the lack of vacuum after the turbine, it will slow down as well in a very short time. Compaired to the significantly more complex and cost-intensive EFGT (externally fired gas turbine), the theoretically lower thermodynamic efficiency through the loss of the compression enthalpy will be at least compensated or over-compensated by the potentially higher turbine inlet temperature.

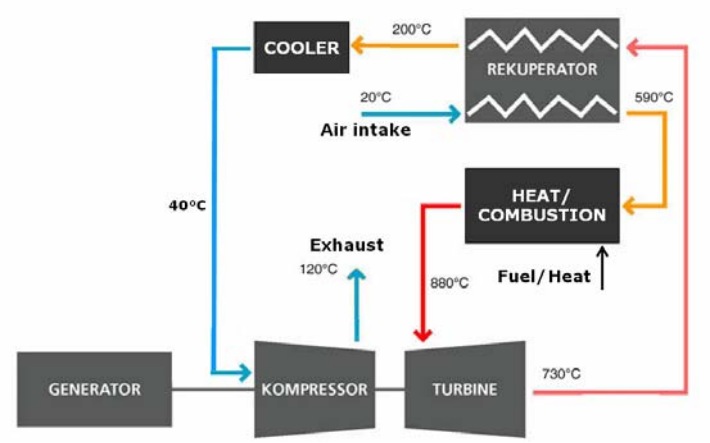


**Figure 2** Scheme of an Aactor !GT inverted gas turbine

## Innovation and Relevance

**Innovation:** The Pyreg® Process is developed and with the Pyreg500 unit, three plants are in pilot-service in central Europe already. However so far, the waste heat could not be used and the unit has electricity needs to run exhaust fans, blower and conveyors. With Aactor !GT or Xhost Harvester® the exhaust heat of a process like Pyreg500 is being converted to power and vacuum economically efficient. With the vacuum, not only the fans and blowers of the Pyreg500 plant can be saved, however there is still excess energy – either to be converted to electricity with a micro gasturbine or the vaccum can be used to evacuate a vacuum dryer.

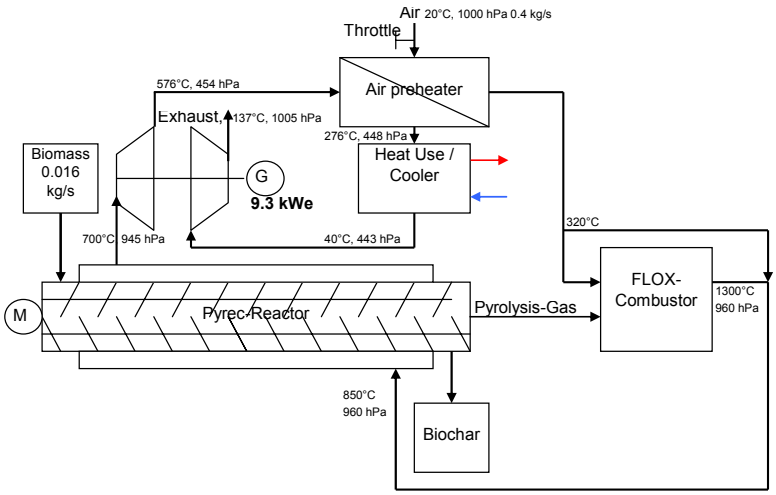


**Figure 3** Pyreg 500 Biowaste-to-Biochar plant with integrated iGT acting as exhaust fan and generating additional power (9 kWe). Please remark, that the 9 kWe is not the only gain of e-power – thus additional 4 kWe of power consumption of fans and blower can be safed.

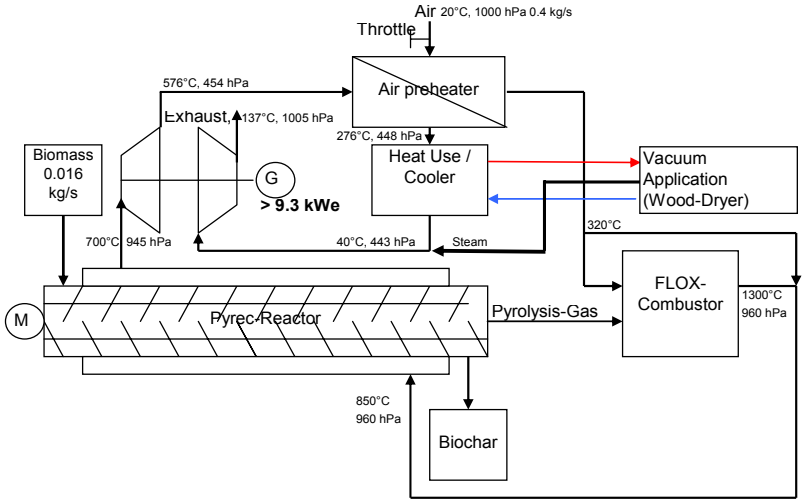


**Figure 4** Find the difference: Pyreg 500 with Aactor !GT and additional steam intake from a vacuum application such as a vacuum dryer for furniture industry or food and drug processing.

**Relevance:** Only in Europe EU27, a typical hectare of agricultural land is lacking estimated 10 tons of carbon, which equals to a potential GHG-reduction (ER) of 36 tons per hectare. The total amount of stable carbon deposit potential in European agricultural soil is exceeding 6 billion tons of CO2 equivalent – which is about the total emission of the EU27 per year, and therefore a significant value. And a very significant value for the agriculture itself: With a GHG-emission price of only 14 €/t CO2 equivalent, agriculture could benefit from a one-time contribution of 450 €/ha through emission trade and an all-time increase of the harvest through the soil improvement. Additionally, the socialized costs of climate change could potentially be reduced through the improved water retention and erosion prevention of the improved soils.

On the scale of one Pyreg500 plant, the Xhost Harvester® unit can save electricity costs per year in the height of the additional investment costs.

## Results

Aactor !GT and Xhost Harvester® has been tested successfully in the laboratory in 2009 and on a commercial CHP-plant fired with natural gas in 2010. The tests showed a very high correspondence of measured and calculated performances.

**Figure 5** Aactor !GT turbine acting only as a vacuum producer „Xhost Harvester ®“ on a very efficient natural gas CHP-plant of 90 kWe from Avesco. Together with the vacuum effect of “Xhost Harvester ®”, the CHP-plant reaches 40.1% (DIN) of electrical efficiency, which is very high for the engine size.

In 2011 a 4 kWe field testing unit of Aactor !GT microturbine will be tested on a landfill site with only 11% $CH_4$ content in Switzerland and Xhost Harvester will be tested on a Pyreg pilot biochar plant in Bingen, Germany: The pilot market for Aactor !GT will be lean landfill gas. Why is this market so attractive?

Landfill sites are emitting greenhouse-relevant gases for almost 100 years after closing the site. Only 15 to 20 years, the gas could be used with conventional technologies. Landfill site gas extraction installations are usually not “rentable”. They cost much more than the value of the energy, which is being generated. For every additional investment, the “additionality” for emission-trading can be proven, as long as no clean air act limits are injured. If the infrastructure of the gas collection is already there, Aactor !GT will be the perfect follow up technology, when the gas quality is weakening, reaching $CH_4$-contents lower than 30% dwon to 5%. Assuming 13 €ct/kWh for the electric power sold and only 13 €/t $CO_2$eq for the certificates, Aactor !èGT would earn 50% via power production and 50% via CO2-trade.

In other words: If the potentially weakening landfill sites in the EU27 could be reached with Aactor !GT inverted gas turbines, “only” about 1 GWe (9 TWh/a) electrical power could be generated, however 75 million tons of GHG-emissions could be reduced per year. Each market would represent a turnover of roughly 1 billion €/a.

**Figure 6** 200 kWth pilot plant for the combustion of lean landfill gas. The connection for an Aactor !GT turbine is prepaired. The LPG-gas (in the foreground) are only used to preheat the system. The nominal service is autotherm down to a 6% $CH_4$ / 94 % $CO_2$.

## Conclusion/Outlook

The vacuum turbines are a promising and simple technology for distributed power generation from lean gas and or to generate power and vacuum from all kind of waste heat. Besides, the ability of Aactor !GT to directly use hot and atmospheric gases could also be applied for concentrated solar power (hot-air/steam combined cycle), industrial exhaust heat or domestic micro-CHP applications. Investors are still welcomed in the consortium. Commercialization starts end 2012.

## Acknoledgements

This may, Aavtor !GT started its 5th year as a development project. It started as a completely private financed project thanks to the visionary Walter Schmid. Later, the project gained confidence among other industrial partners and investors and was divied into several development consortia for each application mentioned.

- W. Schmid AG
- WS Wärmeprozesstechnik GmbH
- Swiss Federal Ministery of Energy
- M. Giovanelli
- Groupe E Greenwatt SA
- Klimastiftung Schweiz
- Stadtwerk Winterthur
- Acrona-Systems Ltd.
- Fischer Engineering Solutions AG
- Avesco BHKW-Energiesysteme GmbH
- Reckerth GmbH
- Oester Messtechnik
- First Climate (Switzerland) AG
- E-Flox GmbH
- Wenko AG Swissauto
- Pyreg GmbH
- Kaskad-E GmbH

Thank you all for helping to push Aactor !GT and Xhost Harvester ® forward!