IEA Bioenergy
Technology Collaboration Programme

EMPYRO - biomass to pyrolysis oil

Hengelo, the Netherlands

Best Practices on flexible bioenergy

IEA Bioenergy: Task 44: 11/2024
Author: Bert van de Beld

Project description

Fast pyrolysis is a process in which organic material is rapidly heated to 450 - 600 °C in the absence of air. Under these conditions, organic vapours, permanent gases and charcoal are produced. The vapours are then quickly condensed to pyrolysis oil. Typically, 50-75 wt% of the feedstock can be converted into fast pyrolysis bio-oil (FPBO). On an energy basis this corresponds to 45-70% and a similar value holds for the carbon yield.

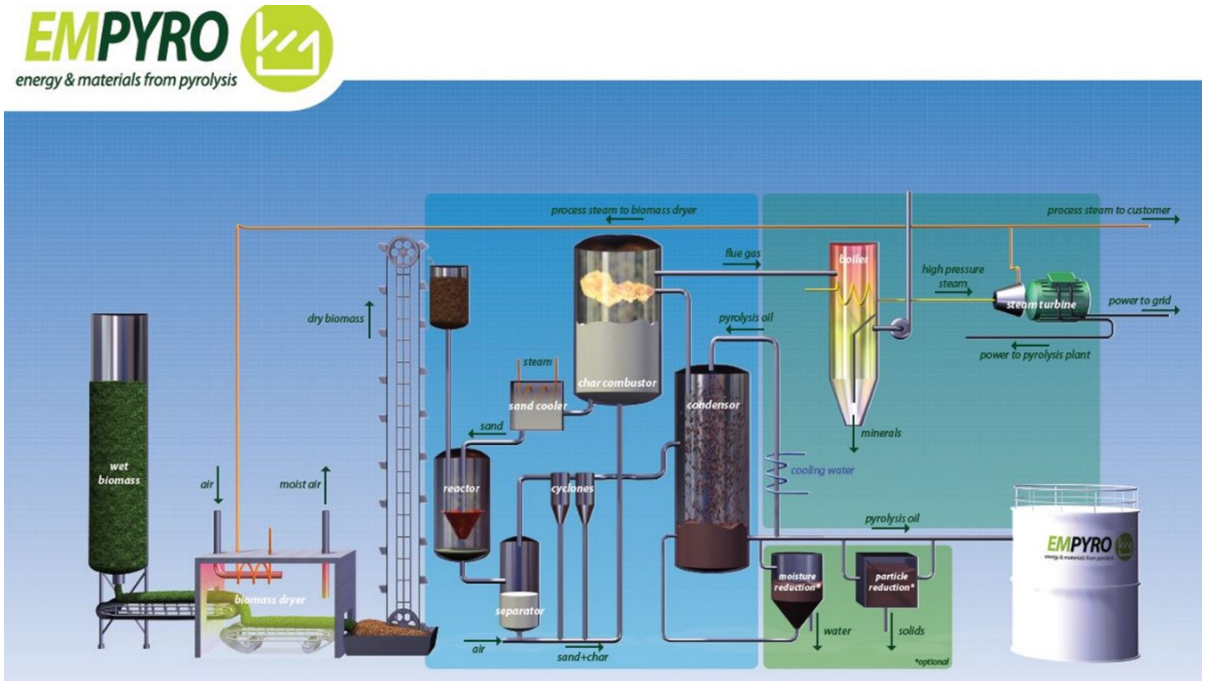

Fig. 1: Flowsheet of the Empyro fast pyrolysis process.

Empyro has been established with the aim to demonstrate the fast pyrolysis technology of BTG Bioliquids on a commercially relevant scale of 25 MW_{th}. Preparations already started in 2009, but the actual construction of the pyrolysis oil production plant just began early 2014, and the first pyrolysis oil was produced in March 2015. The Empyro plant is designed for feeding woody biomass, and in particular woody crumbles and fines –a byproduct from pellet handling and storage in the Netherlands- are utilized. This feedstock hardly needs any further pre-treatment. The particle size is already suitable for feeding the pyrolysis process, whereas the moisture content is just above 10 wt%. A relatively small dryer has been installed to dry the feedstock to a moisture content of 5 wt%.

The Empyro plant can be considered as a polygeneration unit as it produces three different products simultaneously. Regarding plant capacity, 5 t/h of clean wood is converted into about 3.2 t/h of pyrolysis oil. Excess heat generated from the combustion of the by-products (gas and char) is used for the generation of steam. Subsequently, this steam is used to provide the heat for the biomass dryer, and to run a steam turbine for generating electricity. Excess steam is delivered to a neighbouring company and excess electricity sold to the grid.

The pyrolysis oil is transported from Empyro to FrieslandCampina by tank truck; a distance of only 30 km. A new natural gas fired boiler was designed and constructed for FrieslandCampina, suitable to co-fire pyrolysis oil. In the boiler, process steam is produced (40 t/h at 20 bar) for the milk powder process. The boiler can accept up to 70 wt% of pyrolysis oil (which is equal to the full capacity of Empyro), but 100% back-up of natural gas is always available guaranteeing continuous steam supply to the core processes of FrieslandCampina (see IEA report on Industrial heat – case study 3)[i].

Base information	
Link for more information	www.btg-bioliquids.com
Contact person, email	ardy.toussaint@btg-bioliquids.com
Location (city, country)	Hengelo, the Netherlands
Owner/Operator	Twence
Technology supplier	BTG Bioliquids
Construction year	2015
Status	> 130 million litres of fast pyrolysis bio-oil (FPBO) > 50,000 operational/production hours
Feedstock	Clean woody biomass, mainly woody crumbles and fines (a byproduct from pellet handling and storage)
Products	Fast pyrolysis bio-oil (FPBO), Electricity & Steam
Avoided emissions per year	20 kton CO_2/year
Type of flexibility provided	The plant is designed for woody feedstock and for operation at design capacity. Flexibility is mainly foreseen in the use of FPBO.
Plant characteristics	Standard capacity is 5 t/h dry feedstock (~25 MW_{input}), self-sustaining (no external energy input)
Investment cost of the plant (€)	Total investment: 20 MEURO (2014 price level)

Technical and Commercial Details

The pyrolysis plant is based on a modular concept. Empyro was built by Zeton in their workshop and in parallel site preparation were performed. Re-assembly of the pyrolysis plant on site took less than 4 weeks. The same approach was used for the plants in Sweden and Finland.

The total investment in the Empyro project was around 20 M€ (2014 price level). This figure includes site preparation, engineering, permitting, equipment plant construction and steam connection. The financing was based on a combination of public grants (~40%), loans (~40%) and equity (~20%). Public grants were provided by the European Commission (FP7), National programme (TKI) and the regional government (Province of Overijssel). The use of the oil at FrieslandCampina was supported by the Dutch support scheme for renewable heat (SDE+).

Market Opportunities

BTG Bioliquids is a technology supplier and delivers EPCM or turn-key installations. A standard capacity of 5 ton biomass per hour (at 5 wt% moisture) is used. This medium-scale capacity in combination with modular construction enables the implementation at multiple locations and preferably at sites with matching availability of suitable biomass.

The Empyro plant has been copied and implemented in Sweden and Finland, see Fig 2. In both cases sawdust from a sawmill is used as the feedstock. In Gävle in Sweden, Pyrocell, a joint venture of the wood industry company Setra and the oil company Preem, utilises BTG Bioliquids technology to produce oil as a feedstock for Preems refinery in Lysekil since 2021. In Lieksa in Finland, Green Fuel Nordic Lieksa produces bio-oil for heating applications since 2020.

Fig. 2: Fast pyrolysis plants in the Netherlands, Sweden and Finland. Capacity 5 t/h biomass feedstock.

Basically, the design is similar, but some improvements (e.g. integration, lay-out) were implemented based on the experience from the Empyro plant. Recently, a lot of effort has been put into standardizing the design. This results in reduced cost and faster delivery times. FPBO is used in heating applications (e.g. replacement of natural gas and/or fuel oil) or as feedstock for a Fluid Catalytic Cracking (FCC) unit as demonstrated by Preem in Sweden.

Flexibility provided by the use of FPBO

Fast pyrolysis and the use of the resulting FPBO may bring various flexibility options to the energy and materials system. First, the process is relatively flexible to the type of biomass and in principle, many types of biomass like forestry and agro-residues can be processed into a stable liquid bioenergy carrier. In this way, feedstock availability and use can be decoupled in time, location and scale. This allows various short term flexibility options, like in the Empyro case with the use of the FPBO at FrieslandCampina, but may also provide seasonal flexibility in heating applications.

Moreover, FPBO can be used in multiple applications and can be the basis for a so-called “Bioliquids refinery”, see Fig. 3. In a first step, sustainable biomass is converted into the pyrolysis oil liquid (FPBO). Minerals can be left on-site and optionally, the CO_2 released during the pyrolysis process (as part of the flue gas) may be captured and either used or stored. The FPBO can be directly used for power and heat or as a feedstock for syngas/hydrogen production. Co-feeding of the crude FPBO in a refinery is a possibility as well as further upgrading by hydrotreatment. Both approaches can contribute to the production of advanced biofuels including aviation fuel, road diesel or marine fuel.

Furthermore, it has been shown that FPBO can be efficiently fractionated into a pyrolytic lignin and a sugar fraction, and each one can be the starting point for production of fuels, chemicals and/or materials.

In addition to the flexibility options described above, FPBO might also allow the flexible uptake of electricity or hydrogen, including direct use of (excess) electricity in the electrochemical conversion of FPBO, and the use of hydrogen for stabilization and hydrotreatment of FPBO. This is described more extensively in the IEA Bioenergy report "Flexibility by fast pyrolysis in renewable energy systems".[ii]

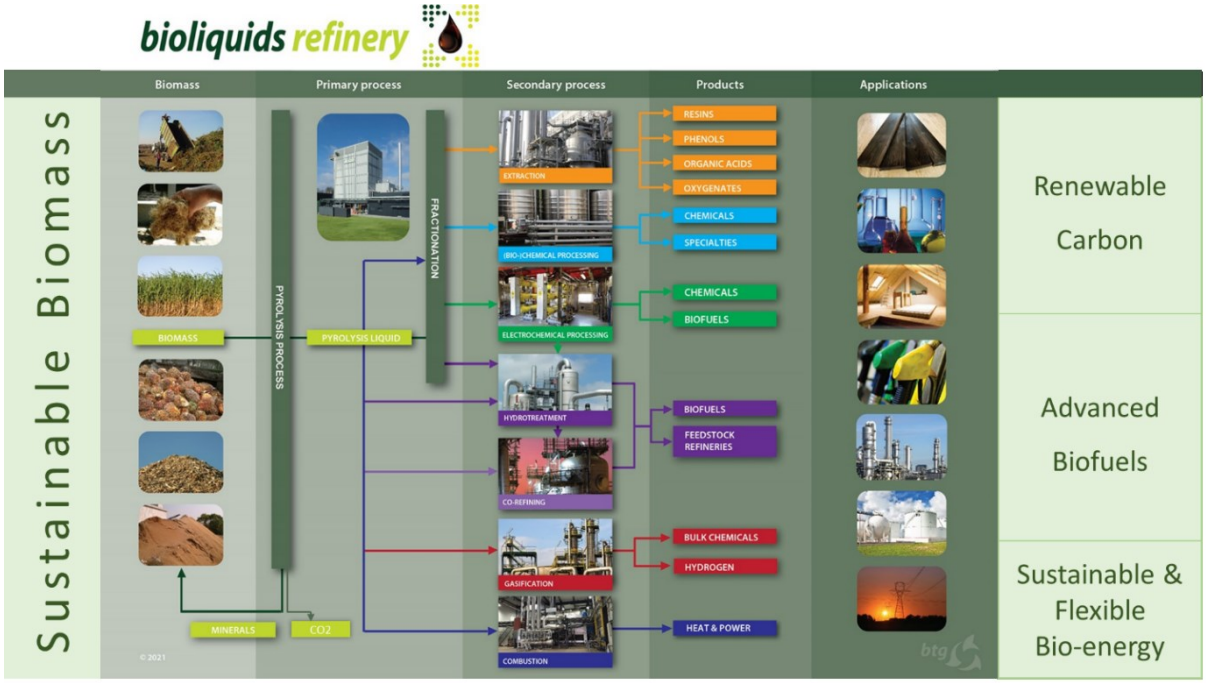

Fig. 3: Bioliquids refinery based on biomass fast pyrolysis, source BTG Bioliquids.

Lessons learned

Solid contracts for the supply of biomass and off-take of the FPBO are important for successful operation of the fast pyrolysis unit. Training of the operators and guidance during operation and maintenance will help to quickly reach full performance of the installation.

Challenges

The FPBO process has been demonstrated on full scale using clean woody biomass and many locations do exist in Europe, where such a feedstock is available. Extending the portfolio to other sustainable biomass feeds including for example agro-residues will greatly extend the potential of the technology. BTL's pyrolysis installation has a quite wide operating window with respect to oil yield and heat production, allowing a reasonable range in ash content. Nevertheless, testing and engineering work will be required when going to new types of feedstock.

[i] https://itp-hightemperatureheat.ieabioenergy.com/wp-content/uploads/sites/14/2020/10/CS3_T34_-High-temperature-heat-from-pyrolysis-oil-final.pdf
[ii] https://task34.ieabioenergy.com/wp-content/uploads/sites/3/2024/10/Flexibility-by-FPBO-2024-Final.pdf