TECHNOLOGY FACTSHEET

UPGRADE OF PYROLYSIS BIO-OIL FROM FAST PYROLYSIS TO BIOFUELS

Date of factsheet	27-12-2019 (23-09-2020 update)
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Sector	Refineries
ETS / Non-ETS	ETS
Type of Technology	Biomass
Description	The bio-oil resulting from pyrolysis is acidic, corrosive, high in oxygen and moderate in water content. Details of the pyrolysis bio-oil production via fast pyrolysis of woody biomass can be found at Oliveira (2020). Therefore, the raw bio-oil is not suitable for direct mixing with fossil oils and cannot be used for engines without upgrading it to a fuel with similar properties as more conventional liquid fuels (JRC, 2019). The Pyrolysis bio-oil upgrading route is currently being developed, some in an earlier stage and others in a more advanced stage of development. These treatments involve putting the bio-oil in contact with a large excess of hydrogen in the presence of a catalyst. The raw bio-oil can be directly upgraded in a hydrodeoxygenation unit integrated with the pyrolys plant facility. The process aims to reduce or eliminate oxygen, sulphur and nitrogen content in the bio-oil, with the use of hydrogen. The resulting streams of this process are a gas rich in light hydrocarbons and carbon dioxide, an aqueous phase and the deoxygenated bio-oil (PNNL, 2013). The upgrading system is composed by a two stage hydrotreatment process, the first stage is carried under mild temperature (180-250 ˚C) and the second one operates in more severe conditions (350-425 ˚C) (PNNL,2013). This scheme is reported in literature to prevent catalyst coking and allow higher yields than systems with single hydrotreatment (PNNL,2013). The upgraded bio-oil can reach an oxygen concentration below 2% vol., which can be directly processed in a distillation column in order to recover products such as bio-naphtha and bio-diesel. The off-gases pass through a PSA (pressure swing adsorption) unit in order to recover the remaining hydrogen and recycle it back to the hydrotreatment reactors. The remaining gases can be used as fuel or for hydrogen production in a SMR (steam methane reformer), however, none of these options are included in the scope of this factsheet. For this reason, the off-gases are considered as a by-product of the system. Extra hydrogen is needed and, in this process scheme, it is assumed that this hydrogen is outsourced. The extra steam and electricity produced in the fast pyrolysis unit can be utilized by the upgrading system since both processes are considered to be integrated. This facsheet considers only the upgrading system without the pyrolysis bio-oil production unit.
TRL level 2020	TRL 5
	Pilot scale available as indicated at Lammens, T. (2018).

TECHNICAL DIMENSIONS

	Functional Unit	Value and Range		
Capacity	MW	22.00		
		22.00	-	22.00

			Current			2030			2050		
Potential	EU	MW	-			-			-		
			Min	–	*Max*	*Min*	–	*Max*	*Min*	–	*Max*
Market share		%	-			-			-		
			Min	–	*Max*	*Min*	–	*Max*	*Min*	–	*Max*

Capacity utlization factor	0.85
Full-load running hours per year	7,500.00
Unit of Activity	PJ/year
Technical lifetime (years)	30.00
Progress ratio	0.56
Hourly profile	No
Explanation	Capacity value is based on biofuel products. No specific potential in the EU for this technology has been found in literature. Currently, no pyrolysis oil upgrade plant is under operation, however, there are several demo-plant studies accross the world. In co-operation with the Boreskov Institute of Catalysis (Russia) and the RijksUniversiteit Groningen (The Netherlands), the first hydrotreating has been further developed. This cooperation led to a joint patent and currently the catalyst is used by BTG-BTL (The Netherlands) in the 1st hydrotreating step of the pyrolysis bio-oil upgrading process. The capacity is given in terms of biofuels output and it is based on Uslu, A., Oliveira Machado dos Santos, C. & Lensink, S. (2020). Capacity utlization factor, full load hours per year and technical lifetime were considered to be the same as the values related to the fast pyrolysis technology, based on the factsheet "Production of pyrolysis bio-oil from solid biomass via fast pyrolysis process" (Oliveira, C., 2020). Progress ratio is calculated based on the learning rate found for this process (0.44) on Daugaard et al. (2015).

COSTS

Year of Euro	2015

	Euro per Functional Unit	Current			2030			2050		
Investment costs	mln. € / MW	1.62			-			-		
		1.62	–	1.62	*Min*	–	*Max*	*Min*	–	*Max*
Other costs per year	mln. € / MW	-			-			-		
		Min	–	*Max*	*Min*	–	*Max*	*Min*	–	*Max*
Fixed operational costs per year (excl. fuel costs)	mln. € / MW	0.08			-			-		
		0.08	–	0.08	*Min*	–	*Max*	*Min*	–	*Max*
Variable costs per year	mln. € /	-			-			-		
		Min	–	*Max*	*Min*	–	*Max*	*Min*	–	*Max*

Costs explanation	Costs include both fast pyrolysis and hydrotreating systems and they are based on Uslu, A., Oliveira Machado dos Santos, C. & Lensink, S. (2020). OPEX values do not include utilities costs and it is assumed to be 5% of CAPEX. Projections for 2030 and 2050 were not estimated due to lack of information in literature for future developments of the pyrolysis bio-oil hydrotreating technology.

ENERGY IN- AND OUTPUTS

	Energy carrier	Unit	Current			2030			2050		
Energy carriers (per unit of main output)	*Main output:* Biofuels	PJ	-1.00			-			-		
			-1.00	–	-1.00	*Min*	–	*Max*	*Min*	–	*Max*
	Pyrolysis bio-oil	PJ	1.13			-			-		
			1.13	–	1.13	*Min*	–	*Max*	*Min*	–	*Max*
	Hydrogen	PJ	0.58			-			-		
			0.58	–	0.58	*Min*	–	*Max*	*Min*	–	*Max*
	Steam	PJ	0.30			-			-		
			0.30	–	0.30	*Min*	–	*Max*	*Min*	–	*Max*

Energy in- and Outputs explanation	The main output is the biofuels mix and this mix consists of bio-gasoline and bio-diesel in the ratio of 44.7% for bio-gasoline and 55.3% for bio-diesel. Low heating value (LHV) for Hydrogen is assumed as 10.8 MJ/Nm^3 and the conversion factor is 0.0841 kg/Nm^3; it was considered that both bio-gasoline and bio-diesel have the same LHVs as fossil gasoline (44 MJ/kg) and fossil diesel (42.7 MJ/kg). The PNNL (2013) study indicates the off-gases composition as being: 0.2%wt water, 6.4%wt hydrogen, 1.9%wt CO, 37.1% wt CO2, 17.7%wt methane and 36.8%wt mix of hydrocarbons (from C2-C5).

MATERIAL FLOWS (OPTIONAL)

	Material	Unit	Current			2030			2050		
Material flows			-			-			-		
			Min	–	*Max*	*Min*	–	*Max*	*Min*	–	*Max*
			-			-			-		
			Min	–	*Max*	*Min*	–	*Max*	*Min*	–	*Max*
Material flows explanation											

EMISSIONS (Non-fuel/energy-related emissions or emissions reductions (e.g. CCS))

	Substance	Unit	Current			2030			2050		
Emissions			-			-			-		
			Min	–	*Max*	*Min*	–	*Max*	*Min*	–	*Max*
			-			-			-		
			Min	–	*Max*	*Min*	–	*Max*	*Min*	–	*Max*
			-			-			-		
			Min	–	*Max*	*Min*	–	*Max*	*Min*	–	*Max*
			-			-			-		
			Min	–	*Max*	*Min*	–	*Max*	*Min*	–	*Max*
Emissions explanation	In these systems, only steam and electricity are needed as utilities and no direct emissions are expected. The utilities production is not considered as part of the system. Also, it is assumed that the hydrogen is provided externally, therefore, no hydrogen production facility is included in this factsheet. Since the off-gases are assumed to not be used on site, the CO2 emissions related to their use are present. However, the biogenic CO2 content of this stream is equal to 0.371 t CO2/t off-gases.										

OTHER

Parameter	Unit	Current			2030			2050		
		-			-			-		
		Min	–	*Max*	*Min*	–	*Max*	*Min*	–	*Max*
		-			-			-		
		Min	–	*Max*	*Min*	–	*Max*	*Min*	–	*Max*
		-			-			-		
		Min	–	*Max*	*Min*	–	*Max*	*Min*	–	*Max*
		-			-			-		
		Min	–	*Max*	*Min*	–	*Max*	*Min*	–	*Max*
Explanation										

REFERENCES AND SOURCES

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