TECHNOLOGY FACTSHEET

TNO

5%WT CO-PROCESSING OF FAST PYROLYSIS BIO-OIL IN A CONVENTIONAL FLUIDIZED CATALYTIC CRACKING UNIT IN AN EXISTING REFINERY

Date of factsheet	23-12-2019 (21-9-2020 update)
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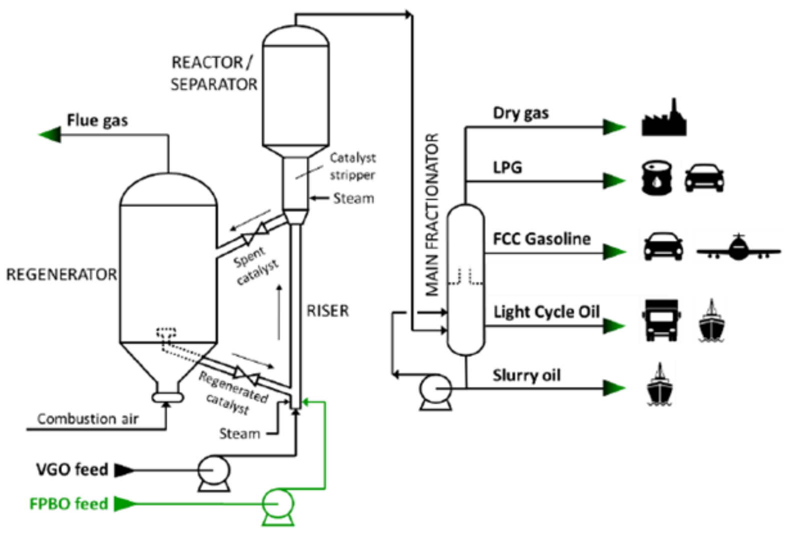
Sector	Industry: Generic
ETS / Non-ETS	ETS
Type of Technology	Biomass
Description	There is the possibility of processing fast pyrolysis bio-oil (FPBO) in existing refineries. The most studied application currently is to co-process the bio-oil together with vacuum gasoil (VGO) in a FCC unit (fluidized catalytic cracking), which is normally present in complex refineries. FPBO is injected into the riser from a separate feed line so to keep its temperature below 60˚C. In the riser, the FPBO is catalytically cracked together with the VGO (or other regular FCC feed). The biocarbon in the FPBO is distributed across the various FCC products and the coke. The resulting product is a mix of fossil and biofuels, being gasoline and diesel the main outputs. As in a conventional FCC, the coke deposits on the catalyst, which is burned in the regenerator. This combustion supplies the needed energy for the cracking reactions. Worldwide experiments claim that minor changes in the products yields are noticed in the FCC with co-processing up to 10%wt bio-oil. Few additional installations are needed to the refineries, however, due to the acidity of the pyrolysis bio-oil, new pipelines, feed nozzle and storage tank would be necessary. The investment costs for this application are, therefore, only related the new units. Picture was extracted from Lammens, T., Talebi, G., Gbordzoe, E. (2019).



TRL level 2020	TRL 6
	Lammens, T. (2018) mentions indicates that the technology development is currently under demo phase.

TECHNICAL DIMENSIONS

	Functional Unit		Value and Range								
Capacity	MWth		0.89								
			0.89			-			0.89		
Potential	Global	MW	Current			2030			2050		
			0.89			14.00			-		
			0.89	–	0.89	14.00	–	14.00	Min	–	Max
Market share		%	-			-			-		
			Min	–	Max	Min	–	Max	Min	–	Max

Capacity utlization factor		0.90
Full-load running hours per year		7,884.00
Unit of Activity	PJ/year	
Technical lifetime (years)		30.00
Progress ratio		0.37
Hourly profile	No	
Explanation	Capacity and potential values based on pyrolysis bio-oil intake. Low heating value of the bio-oil was considered to be 16 MJ/kg (Venderbosch, R., 2017). Currently, there is a demo plant in Brazil, with 200 kg/h of input (vacuum gasoil + pyrolysis bio-oil), which is able to co-process up 5 to 10% wt (Pinho et al., 2015). Technip, FMC and BTG-BTL started in 2018 to build bio-oil production in Sweden (PyroCell) and this pyrolysis bio-oil will be co-processed at Preem's refinery in Lysekil; the production start-up is scheduled to Q4/2021 (BTG-BTL website, 2019). The installations needed for the co-processing are composed by well established technologies, therefore, the progress ratio is considered to be driven mainly by the pyrolysis bio-oil production cost. For this reason, the progress ratio was assumed to be the same as the one for pyrsolysis bio-oil production via solid biomass (Oliveira, C., 2020).	

COSTS

Year of Euro	2015								
	Euro per Functional Unit	Current			2030			2050		

	Euro per Functional Unit	Current			2030			2050		
Investment costs	mln. € / MWth	0.39			0.31			-		
		0.39	–	0.39	0.31	–	0.35	Min	–	Max
Other costs per year	mln. € / MWth	-			-			-		
		Min	–	Max	Min	–	Max	Min	–	Max
Fixed operational costs per year (excl. fuel costs)	mln. € / MWth	0.01			0.01			-		
		0.01	–	0.01	0.01	–	0.01	Min	–	Max
Variable costs per year	mln. € /	-			-			-		
		Min	–	Max	Min	–	Max	Min	–	Max

Costs explanation	The investment costs include only the additional installations needed for the co-processing of the bio-oil in an existent refinery,hence the costs of the pre-existent FCC system is excluded. The new installations would consist mainly in new feed nozzles, a dedicated pipeline for the bio-oil (more acidic than vacuum gas oil) and a new feedstock tank. Since the co-processing is assumed to take place in an existent refinery, the additional fixed operational costs would be mainly related to maintenance, which was considered to be around 2% of the investment costs. No feedstock costs were included. Medium-term costs reductions for co-processing pyrolysis bio-oil were considered to be the same as those estimated for pyrolysis bio-oil production, which can be in the range 10-20% (IEA, 2020). No long-term reduction costs were found in the literature for this 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	–	-1.00	-1.00	–	-1.00	Min	–	Max
	Pyrolysis bio-oil	PJ	0.98			0.98			-		
			0.98	–	0.98	0.98	–	0.98	Min	–	Max
	Vacuum gasoil	PJ	49.50			49.50			-		
			49.50	–	49.50	49.50	–	49.50	Min	–	Max
	Oil products	PJ	-47.37			-47.37			-		
			-47.37	–	-47.37	-47.37	–	-47.37	Min	–	Max

Energy in- and Outputs explanation	The yields are based on low heating values (LHV) and the bio-oil LHV was considered to be 16 MJ/kg (Venderbosch, R., 2017). As in a conventional FCC unit, the energy for the cracking reactions is provided by coke burning, this coke is produced in the process itself and it deposits in the catalyst. Around 6%wt of the total feed becomes coke. The main output is the biofuels mix, which is composed by bio gas, bio LPG, bio gasoline, bio diesel and bio heavy fuel oil (HFO). The oil products output is also a mix of fuel gas, LPG, gasoline, diesel and HFO. The ratio in the bio mix is expected to be roughly the same as in the conventional FCC (gas: 3 wt%, LPG: 15 %wt, gasoline: 45 wt%, diesel: 21 wt% and HFO: 16wt%), for this reason, the yields in 2030 were assumed to be the same as the values for 2020.

MATERIAL FLOWS (OPTIONAL)											
Material flows	Material	Unit	Current			2030			2050		
			-			-			-		
			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)											
Emissions	Substance	Unit	Current			2030			2050		
	CO2	kton	238.71			-			-		
			238.71	–	238.71	Min	–	Max	Min	–	Max
	CO2-biogenic	kton	12.56			-			-		
			12.56	–	12.56	Min	–	Max	Min	–	Max
			-			-			-		
			Min	–	Max	Min	–	Max	Min	–	Max
			-			-			-		
			Min	–	Max	Min	–	Max	Min	–	Max
Emissions explanation	Emissions expressed in kton CO2/PJ of biofuels mix. The coke produced in a FCC unit is used as fuel for the process. In a co-processing system, part of this coke is bio sourced, therefore, there are biogenic CO2 emissions. The calculations were based on the yields obtained by the brazilian demo-plant when 5%wt of co-processing take place (Pinho et al., 2015), which around 6%wt of the feedstock is converted to coke (fossil+ biocoke). It was assumed a liner relationship between the co-processing percentage and the yield for bio-coke, i.e. for a 5%wt co-processing of bio-oil, 5%wt of the total coke produced was considered to be bio-based. The emission factor value considered for the coke was 97.5 kg CO2/GJ coke (RVO, 2019).										
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											

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