TECHNOLOGY FACTSHEET

TNO

PYROLYSIS OIL PRODUCTION FROM PLASTIC WASTE

Date of factsheet	23-12-2019 (28-09-2020 updated)
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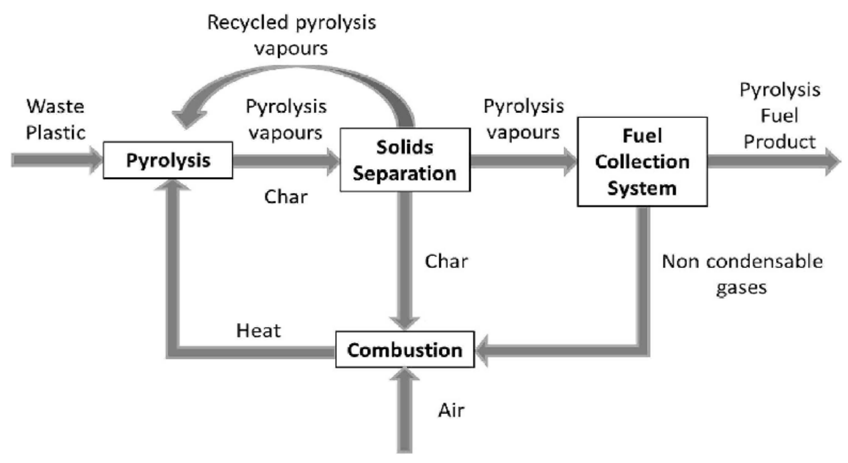
Sector	Industry: Petrochemics
ETS / Non-ETS	ETS
Type of Technology	Circular economy
Description	Pyrolysis is a process where plastic is thermally cracked due to rapid heating in the absence of oxygen, reducing the plastics long polymer chains into much shorter hydrocarbons. The process takes place in four stages: initiation, transfer, decomposition and termination, resulting in the production of vapours and char. The pyrolysis process occurs in a fluidised bed reactor, in an inert atmosphere, at atmospheric pressure and at a fixed reaction temperature. Thermal cracking of plastics can occur within the temperature range of 450-650 °C, depending on the heating rate and the composition of the plastic waste. The reaction temperature influences directly the pyrolysis product yields. The pyrolysis vapours include both condensable and non-condensable gases. The condensable gases deliver the oil composed by thermal cracking products. Char is a solid product rich in carbon which can be used to produce heat to the pyrolysis reaction. The non-condensable gas composition depends on the mixture of plastic waste that is pyrolyzed, although some studies say that the main gas components are hydrogen, C1, C2, C3 and C4 hydrocarbons. The pyrolysis thermal energy demand is provided by combusting the pyrolysis by-products (i.e. char, non-condensable gases), no external source of heat is needed and a surplus of heat can be delivered outsite the system. However, electricity demand should be outsourced. If PVC is included in the mix, hydrogen chloride is also produced and it requires chlorine removal before this gas can be used. Figure by Fivga & Dimitriou (2018).



TRL level 2020	TRL 6
	Demo plants were constructed in the 90's by BP and BASF and then decommissioned due to low availability of feedstock. The capacity range of these plants was 15-25 kton/y. Currently, several large petrochemicals companies are developing partnerships with plastic waste pyrolysis oil providers or technology developers. PLATIC ENERGY and SABIC are building together a demo-plant in The Netherlands to produce 20 kton/y of plastic waste oil by 2021 (SABIC website, 2019). Dow made an agreement with Fuenix Ecogy Group under which the latter would supply plastic waste oil to the steam crackers of Dow located in Terneuzen, The Netherlands. Dow's goal is to be able to incorporate 100 ktons of plastic waste in its products by 2025 (Dow website, 2020) . Nexus Fuels LLC started supplying plastic waste oil to Shell's chemical plant in Norco, Louisiana, USA in 2019. Shell claims their ambition is to be able to use 1000 kton/y of plastic waste globally by 2025 (Shell website, 2020).

TECHNICAL DIMENSIONS

	Functional Unit		Value and Range								
Capacity	PJ		0.88								
			0.88			-			0.88		
Potential	EU	kton	Current			2030			2050		
			15.00			120.00			-		
			15.00	–	25.00	120.00	–	120.00	*Min*	–	*Max*
Market share		%	-			-			-		
			Min	–	*Max*	*Min*	–	*Max*	*Min*	–	*Max*
Capacity utlization factor	0.90										
Full-load running hours per year	7,012.00										
Unit of Activity	kton/year	-									
Technical lifetime (years)	30.00										
Progress ratio	0.75										
Hourly profile	No										
Explanation	One of the most important pyrolysis processes is the BP polymer cracking process (Tukker et al., 1999). After a series of pilot trials (between 1994 and 1998), a plant was established in Scotland with a capacity of 25 kton/year in the refinery complex currently owned by INEOS. This process was designed to handle mixed plastic waste, as supplied by the DSD (Duales System Deutschland) green dot packaging collection system. A large pilot plant, with a substantial capacity of 15 kton/yr, started running at Ludwigshafen in 1994. At that time DSD estimated the total volume of mixed packaging plastics available for feedstock recycling at around 750 kton/yr. BASF offered to erect a full-scale industrial plant with a capacity of 300 kton/yr, but decided in 1996 to shutdown the pilot plant, since no agreement could be reached on a guaranteed long-term waste supply and a gate fee sufficient to cover the costs (Al-Salem et al., 2009). By 2025 it is expected that both SABIC and Dow will be processing together around 120 kt/y of pyrolysis plastic waste oil in their steam crackers in the Netherlands. Capacity in this factsheet is based on SABIC's demo plant and it reffers to plastic waste input (20 kt/yr); a low heating value (LHV) of 44.06 MJ/kg (Fivga & Dimitriou, 2018) was considered.										

COSTS

	Euro per Functional Unit	Current			2030			2050		
Year of Euro	2015									
Investment costs	mln. € / PJ	9.40			9.03			8.33		
		9.40	–	9.40	9.03	–	9.03	8.33	–	8.33
Other costs per year	mln. € / PJ	-			-			-		
		Min	–	*Max*	*Min*	–	*Max*	*Min*	–	*Max*
Fixed operational costs per year (excl. fuel costs)	mln. € / PJ	2.74			2.60			2.33		
		2.74	–	2.74	2.60	–	2.60	2.33	–	2.33
Variable costs per year	mln. € /	-			-			-		
		Min	–	*Max*	*Min*	–	*Max*	*Min*	–	*Max*
Costs explanation	Costs include all the steps shown in the process scheme presented. Fixed operational costs does not consider utilities and feedstock. For 2020, the capacity value considered was 0.88 PJ of plastic waste intake/ year, this is equivalent to around 20 kton/year. For the following the years, the costs were calculated assuming capacity growth of 10% per 10 years between 2020 and 2050. The reduction in costs is based on the progress ratio of 0.75, which was calculated considering the information found in Fiviga & Dimitriou (2018) about how the economies of scale for this technology behaves.									

ENERGY IN- AND OUTPUTS

	Energy carrier	Unit	Current			2030			2050		
Energy carriers (per unit of main output)	*Main output:* Plastics pyrolysis oil	PJ	-1.00			-1.00			-1.00		
			-1.00	–	-1.00	-1.00	–	-1.00	-1.00	–	-1.00
	Heat	PJ	-0.11			-0.11			-0.11		
			-0.11	–	-0.11	-0.11	–	-0.11	-0.11	–	-0.11
	Plastics waste mix	PJ	1.15			1.15			1.15		
			1.15	–	1.15	1.15	–	1.15	1.15	–	1.15
	Electricity	PJ	0.03			0.03			0.03		
			0.03	–	0.03	0.03	–	0.03	0.03	–	0.03
Energy in- and Outputs explanation	A low heating value (LHV) of 44.06 MJ/kg was considered for the plastic waste input and, for the plastic pyrolysis oil, the LHV considered was 44.6 MJ/kg (Fiviga & Dimitriou, 2018). Same authors state that the mass yields and pyrolysis fuel energy efficiency of the entire system does not change with scaling-up. The scale-up study investigates the economic benefits derived from economies of scale (i.e. production cost reductions due to expenditures, like labour and equipment, spreading out over more units of output). For this reason, the ratios for inputs and outputs per main output are considered constant along the years, despite the reduction cost projection.										

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		
	CO_2	kton		9.03			11.57			11.57	
			9.03	–	9.03	11.57	–	11.57	11.57	–	11.57
				-			-			-	
			Min	–	*Max*	*Min*	–	*Max*	*Min*	–	*Max*
				-			-			-	
			Min	–	*Max*	*Min*	–	*Max*	*Min*	–	*Max*
				-			-			-	
			Min	–	*Max*	*Min*	–	*Max*	*Min*	–	*Max*
Emissions explanation	Emissions expressed in kton CO_2/ PJ of plastic pyrolysis oil. Only direct emissions (scope 1) were considered. Both non-condensable gas and char (by-products from the pyrolysis) are used as fuel to provide energy to the system. Since the plastic waste intake is considered to be 100% fossil, the CO_2 emissions originated from the combustion of the by-products are also fossil. For the emissions calculation, the combusted flows considered were: 1.6 kt/y for non-condensable gases (low heating value 45,2 MJ/kg) and 1.4 kt/y for char (heating value 18.9 MJ/kg). Also, the emission factors assumed were 61.60 kg CO_2/GJ for the non-condensable gases and 96.1 kg CO_2/GJ for char. Values are constant over time because the process efficiency was considered to be constant. No information on emissions of other pollutants (e.g. NOx, SOx) was found in the literature.										

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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