ETIP Bioenergy

European Technology and Innovation Platform

CURRENT STATUS OF ADVANCED BIOFUELS DEMONSTRATIONS IN EUROPE

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1 INTRODUCTION

This report lists all current demonstration and first commercial facilities for the production of advanced biofuels in Europe, which the ETIP-B-SABS2 project team and the ETIP Bioenergy WG 2 are aware of and which are planned, under construction, or operational. The TRL of the listed facilities is TRL 6-7 (Demonstration), TRL 8 (First of a kind commercial) or TRL 9 (Commercial). It is worth noting that the list is based on publicly available information. The authors do not have the ability to access the details of all Member States regarding their national definition for feedstocks listed in the Directive (EU) 2018/2001 (RED II), Annex IX Part A under (b), (c), and (d), nor do we have the ability to trace all rather small quantities of other feedstocks listed there.

Technologies covered include those priority value chains (PVC) as defined by ETIP Bioenergy, which produce advanced biofuels. In addition to these, important facilities for the production of advanced biofuels via other technologies are also listed. Facilities for the production of biogas from RED II Annex IX Part A feedstock are not listed in this document, as a very comprehensive overview developed by IEA Bioenergy Task 37 already exists, see: http://task37.ieabioenergy.com/plant-list.html

A full list of value chains as defined by ETIP Bioenergy in line with the Renewable Energy Directive Recast

Priority Value Chains (PVC)
PVC1: Transport fuels via gasification
PVC2: Power and heat via gasification
PVC3: Transport fuels via pyrolytic and thermolytic conversion
PVC4: Intermediate bioenergy carriers for power and heat
PVC5: Alcohol fuels from cellulosic sugars
PVC6: Hydrocarbon fuels from sugars and alcohols

Established Value Chains (EVC)
EVC1: Transesterification to biodiesel
EVC2: Hydrotreatment to HVO
EVC3: Sugar and starch fermentation to ethanol
EVC4: Anaerobic digestion to biogas
EVC5: Small-scale combustion for residential heat
EVC6: Large-scale combustion for heat and power
EVC7: Biomass co-firing for heat and power

Development Pathways (DP)
DP1: Conversion of aquatic biomass

Figure 1: Value Chains as defined by ETIP Bioenergy

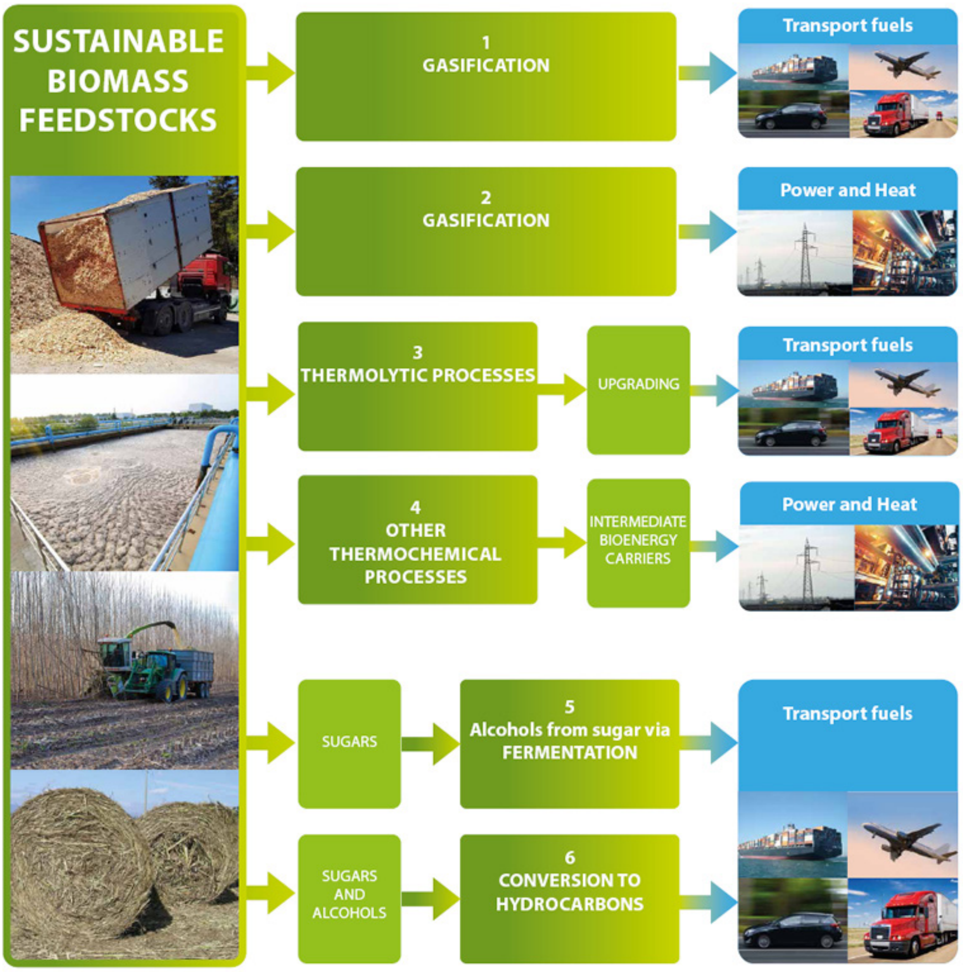

Figure 2: Priority Value Chains (PVC) as defined by ETIP Bioenergy

As this report focuses on the production of advanced biofuels (and not bioenergy or biogas), only the following pathways are fully covered:

- PVC1: Transport fuels via gasification
- PVC3: Transport fuels via pyrolytic and thermolytic conversion
    - Pyrolysis to bioliquid intermediates
    - Hydrothermal liquefaction (HTL) to bioliquid intermediates
    - Lignin to bioliquid intermediates
- PVC5: Alcohol fuels from cellulosic sugars
- PVC6: Hydrocarbon fuels from sugars and alcohols

In addition, the report lists a limited number of other production facilities via pathways that do not fall into one of the priority value chains. The report reflects the state of play at the time of its writing (March 2020).

In the Directive (EU) 2018/2001 (RED II), advanced biofuels are defined as shown in figure 3.

> 'advanced biofuels' means biofuels that are produced from the feedstock listed in Part A of Annex IX

Figure 3: Definition of advanced biofuels in RED II

Annex IX Part A includes an exhaustive list of feedstocks from which advanced biofuels can be produced, see Figure 4.

ANNEX IX Part A.
Feedstocks for the production of biogas for transport and advanced biofuels, the contribution of which towards the minimum shares referred to in the first and fourth subparagraphs of Article 25(1) may be considered to be twice their energy content:

(a) Algae if cultivated on land in ponds or photobioreactors;
(b) Biomass fraction of mixed municipal waste, but not separated household waste subject to recycling targets under point (a) of Article 11(2) of Directive 2008/98/EC;
(c) Biowaste as defined in point (4) of Article 3 of Directive 2008/98/EC from private households subject to separate collection as defined in point (11) of Article 3 of that Directive;
(d) Biomass fraction of industrial waste not fit for use in the food or feed chain, including material from retail and wholesale and the agro-food and fish and aquaculture industry, and excluding feedstocks listed in part B of this Annex;
(e) Straw;
(f) Animal manure and sewage sludge;
(g) Palm oil mill effluent and empty palm fruit bunches;
(h) Tall oil pitch;
(i) Crude glycerine;
(j) Bagasse;
(k) Grape marcs and wine lees;
(l) Nut shells;
(m) Husks;
(n) Cobs cleaned of kernels of corn;
(o) Biomass fraction of wastes and residues from forestry and forest-based industries, namely, bark, branches, pre- commercial thinnings, leaves, needles, tree tops, saw dust, cutter shavings, black liquor, brown liquor, fibre sludge, lignin and tall oil;
(p) Other non-food cellulosic material;
(q) Other ligno-cellulosic material except saw logs and veneer logs.

Figure 4: Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources (REDII), Annex IX Part A.

2 PVC1: TRANSPORT FUELS VIA GASIFICATION

A range of different fuels such as methane (SNG), methanol, DME, FT liquids (diesel, gasoline and jet fractions) and hydrogen can be produced from gasification-derived syngas.

Table 1: Operational gasification facilities

COMPANY	COUNTRY	CITY	TRL	START-UP YEAR	INSTALLED CAPACITY [T/Y]	PRODUCT
Karlsruhe Institute of Technology (KIT) bioliq	Germany	Eggenstein-Leopoldshafen	TRL 6-7	2014	608	DME

Table 2: Gasification facilities under construction

COMPANY	COUNTRY	CITY	TRL	START-UP YEAR	PLANNED CAPACITY [T/Y]	PRODUCT
Advanced Biofuels Solutions* GoGreenGas	United Kingdom	Swindon	TRL 8	2020	1 500	SNG
Total** BioTfueL demo	France	Dunkirk	TRL 6-7	2020	Not available	FT liquids

* Advanced Biofuels Solutions acquired the project from Go Green Fuels Ltd
** Facility is currently under commissioning; each step of the full pathway is being demonstrated at the necessary scale, thus the FT-liquids production is lab scale only

Table 3: Planned gasification facilities

COMPANY	COUNTRY	CITY	TRL	START-UP YEAR	PLANNED CAPACITY [T/Y]	PRODUCT
Joint Venture of Air Liquide, Nouryon, Enerkem, Port of Rotterdam and Shell W2C	Netherlands	Rotterdam	TRL 8	2022	220 000	methanol
Enerkem and Suez Ecoplanta Molecular Recycling Solutions	Spain	El Morell	TRL 8	2022	265 000	methanol
VaermlandsMetanol AB Vaermlandsmetanol Hagfors	Sweden	Hagfors	TRL 9		130 000	methanol
formerly Goteborg Energi AB GoBiGas Phase 1 restart	Sweden	Gothenburg	TRL 8		11 200	SNG
Velocys Altalto	United Kingdom	Immingham	TRL 8		58 000	jet fuel component
Eni Waste to Hydrogen	Italy	Porto Marghera	TRL 8		not available	hydrogen
TNO Ambigo	Netherlands	Alkmaar	TRL 6-7		1 560	SNG

3 PVC3: TRANSPORT FUELS VIA PYROLYTIC AND THERMOLYTIC CONVERSION

In this section, three different pathways for the production of liquid intermediates are highlighted.

a. Pyrolysis to bioliquid intermediates

Pyrolysis oil can be used in stationary power stations, but must be upgraded to produce a transport fuel. All facilities listed here produce pyrolysis oil which needs to be further upgraded. Pyrolysis oil of the KIT facility is gasified to produce DME; pyrolysis oil from the Pyrocell and the Biozin facilities will be upgraded by Preem. The facilities of Twence, Green Fuel Nordic and Pyrocell (JV of Setra and Preem) all use BTG-BTL technology.

Table 4: Operational pyrolysis oil production facilities

COMPANY	COUNTRY	CITY	TRL	START-UP YEAR	INSTALLED CAPACITY [T/Y]
Twence Hengelo	Netherlands	Enschede	TRL 9	2015	24 000
Fortum Fortum Joensuu	Finland	Joensuu	TRL 6-7	2013	50 000
Karlsruhe Institute of Technology (KIT)* bioliq	Germany	Eggenstein-Leopold-shafen	TRL 6-7	2013	24 000

* Same facility as in Table 1; the facility has a fast pyrolysis step (mentioned here), which is followed by gasification of the pyrolysis oil (mentioned in Table 1)

Table 5: Pyrolysis oil production facilities under construction

COMPANY	COUNTRY	CITY	TRL	START-UP YEAR	PLANNED CAPACITY [T/Y]
Green Fuel Nordic	Finland	Lieksa	TRL 9	2020	24 000
Pyrocell (JV of Setra and Preem)	Sweden	Gavle	TRL 9	2021	24 000

Table 6: Planned pyrolysis oil production facilities

COMPANY	COUNTRY	CITY	TRL	START-UP YEAR	PLANNED CAPACITY [T/Y]
Biozin	Norway	Amli	TRL 8	2022	100 000
Susteen technologies TCR500	Germany		TRL 6-7	2020	

b. Hydrothermal liquefaction (HTL) to bioliquid intermediates

So far no operational bio-oil production facilities using hydrothermal liquefaction at demonstration scale or larger exist. However, there is a large number of EU projects aiming to further develop the technology. One demonstration facility is currently under construction by Silva Green fuel, based on Steeper Energy technology, see next page.

Table 7: Bio-oil production facilities under construction

COMPANY	COUNTRY	CITY	TRL	START-UP YEAR	PLANNED CAPACITY [T/Y]
Silva Green Fuel (JV of Statkraft and Sodra)	Norway	Tofte	TRL 6-7	2021	1 400

Another company developing hydrothermal liquefaction at large scale is Licella. Their planned demonstration facility (owned by Renew ELP in the UK) however will use waste plastic bottles as feedstock und is thus not listed here.

c. Lignin to bioliquid intermediates

Currently only one company, RenFuel, has large scale demonstration of a lignin depolymerisation technology. The company operates a demonstration facility and has plans for a facility at commercial scale. The technology includes the depolymerisation of lignin e.g. from tall oil. The resulting liquid (known as Lignol) has to be upgraded in a refinery.

Table 8: Operational bio-oil production facilities

COMPANY	COUNTRY	CITY	TRL	START-UP YEAR	INSTALLED CAPACITY [T/Y]
RenFuel Bäckhammar	Sweden	Backhammar	TRL 6-7	2016	3 200

Table 9: Planned bio-oil production facilities

COMPANY	COUNTRY	CITY	TRL	START-UP YEAR	PLANNED CAPACITY [T/Y]
RenFuel Vallvik	Sweden	Vallvik	TRL 8	2021	77 000

Figure 5: The Empyro pyrolysis plant in Hengelo (NL)
Copyright: BTG BioLiquids

Figure 6: Bioliq plant at KIT in Eggenstein-Leopoldshafen (DE)
Copyright: KIT

4 PVC5: ALCOHOL FUELS FROM CELLULOSIC SUGARS

Most companies listed here produce ethanol from agricultural residues such as wheat straw and corn stover. However, Borregaard, Domsjö fabriker and AustroCel Hallein produce ethanol from brown liquor from their wood pulping operations. St1 also operates 6 facilities fermenting organic wastes to ethanol, but these do not fall under the cellulosic ethanol category and are mentioned in the section on other technologies to produce advanced biofuels.

Table 10: Operational fermentative alcohol production facilities

COMPANY	COUNTRY	CITY	TRL	START-UP YEAR	INSTALLED CAPACITY [T/Y]
Borregaard* Industries ChemCell Ethanol	Norway	Sarpsborg	TRL 9	1938	15 800
Domsjoe Fabriker	Sweden	Ornskoldsvik	TRL 8	1940	19 000
St1 Cellulonix Kajaani	Finland	Kajaani	TRL 6-7	2017	8 000
Chempolis Ltd. Biorefining Plant	Finland	Oulu	TRL 6-7	2008	5 000
Clariant sunliquid	Germany	Straubing	TRL 6-7	2012	1 000
IFP Futurol	France	Bucy-Le-Long	TRL 6-7	2016	350
SEKAB Biorefinery Demo Plant	Sweden	Ornskoldsvik	TRL 8	2004	160
Borregaard* BALI Biorefinery Demo	Norway	Sarpsborg	TRL 6-7	2012	110

*Borregaard uses spent sulphite liquor from pulping processes as feedstock

Table 11: Fermentative alcohol production facilities under construction

COMPANY	COUNTRY	CITY	TRL	START-UP YEAR	PLANNED CAPACITY [T/Y]
Clariant Romania	Romania	Podari	TRL 8	2021	50 000
AustroCel Hallein*	Austria	Hallein	TRL 8	2020	30 000

*AustroCel Hallein uses spent sulphite liquor as feedstock, just like Borregaard

Table 12: Planned fermentative alcohol production facilities

COMPANY	COUNTRY	CITY	TRL	START-UP YEAR	PLANNED CAPACITY [T/Y]
Enviral* Leopoldov Site	Slovakia	Leopoldov	TRL 9		50 000
ORLEN Poludnie (part of ORLEN GROUP)* Jedlicze Site	Poland	Jedlicze	TRL 9		25 000
INA	Croatia	Sisak	TRL 8		55 000
St1 Cellulonix Kajaani 2	Finland	Kajaani	TRL 8	2024	40 000
St1 Cellulonix Pietarsaari	Norway	Pietarsaari	TRL 8	2024	40 000
St1 Cellulonix Follum	Norway	Ringerike	TRL 8	2024	40 000
Versalis (former Beta Renewables/Biochemtex facility) Crescentino restart	Italy	Crescentino	TRL 8	2020	40 000
Sainc Energy Limited Cordoba	Spain	Villaralto	TRL 8	2020	25 000
Kanteleen Voima ** Nordfuel biorefinery	Finland	Haapavesi	TRL 6-7	2021	65 000

*Enviral and ORLEN both license Clariant's sunliquid technology

** The Nordfuel project is based on SEKAB´s CelluApp technology

5 PVC6: HYDROCARBON FUELS FROM SUGARS AND ALCOHOLS

Currently only one company, IBN-One, which is a joint venture of Cristal Union and Global Bioenergies, has large scale demonstration of a hydrocarbon fuel production technology. The starting point so far is beet sugar. However, the H2020 projects OPTISOCHEM and REWOFUEL, both coordinated by Global Bioenergies, aim to develop the technology for use with agricultural materials and softwood, respectively.

Table 13: Operational hydrocarbon fuel production facilities

COMPANY	COUNTRY	CITY	TRL	START-UP YEAR	INSTALLED CAPACITY [T/Y]
Global Bioenergies Isobutene demo	Germany	Leuna	TRL 6-7	2017	100
Ekobenz Bogumilow plant	Poland	Kleszczow	TRL 8	2019	22 500

Table 14: Planned hydrocarbon fuel production facilities

COMPANY	COUNTRY	CITY	TRL	START-UP YEAR	PLANNED CAPACITY [T/Y]
IBN-One (JV of Cristal Union and Global Bioenergies) Isobutene commercial	France		TRL 8	2017	50 000

6 OTHER TECHNOLOGIES TO PRODUCE ADVANCED BIOFUELS AND RECYCLED CARBON FUELS

Other technologies to produce advanced biofuels, which have reached at least demonstration scale include the following:

- UPM Biofuels facilities for the production of HVO from tall oil in Finland
- St1 Etanolix facilities at five locations in Finland and Sweden, fermenting food industry waste, process residues and bread waste to ethanol
- BioMCN facility for the production of methanol from glycerine (by-product from FAME production) in the Netherlands; however currently producing from biogas at much lower capacity
- ArcelorMittal facility in Belgium, fermenting industrial waste gases to ethanol using LanzaTech technology
- Södra Cell pulp mill in Monsteras, Sweden, purifying the methanol that forms during the pulping process and upgrading it to fuel or chemical grade methanol

Table 15: Operational production facilities

COMPANY	COUNTRY	CITY	TRL	START-UP YEAR	INSTALLED CAPACITY [T/Y]	PRODUCT
UPM Biofuels	Finland	Lappeenranta	TRL 8	2015	130 000	HVO
St1 Etanolix Hamina	Finland	Hamina	TRL 9	2008	1 000	ethanol
St1 Etanolix Vantaa	Finland	Vantaa	TRL 9	2009	1 000	ethanol
St1 Etanolix Lahti	Finland	Lahti	TRL 9	2009	1 000	ethanol
St1 Etanolix Jokioinen	Finland	Jokioinen	TRL 9	2011	7 000	ethanol
St1 Etanolix Gothenburg	Sweden	Gothenburg	TRL 9	2015	4 000	ethanol
BioMCN BioMCN commercial	Netherlands	Farmsum	TRL 8	2009	65 000	methanol

Table 16: Production facilities under construction

COMPANY	COUNTRY	CITY	TRL	START-UP YEAR	PLANNED CAPACITY [T/Y]	PRODUCTS
ArcelorMittal Ghent Steelanol	Belgium	Ghent	TRL 9	2020	16 000	ethanol
Södra Cell Södra methanol	Sweden	Monsteras	TRL 9	2020	5 000	methanol

Table 17: Planned production facilities

COMPANY	COUNTRY	CITY	TRL	START-UP YEAR	PLANNED CAPACITY [T/Y]	PRODUCTS
UPM Biofuels	Finland	Kotka	TRL 8		500 000	HVO

* Not all feedstock used for the stated production capacity may be Annex IX Part A feedstock

7 SUMMARY

The analysis of data shows that all pathways together currently provide a capacity for the production of 358 828 t of advanced biofuels per year; another 151 900 t/y are currently under construction, and plans for another 1 742 760 t/y have been announced, see Figure 7.

In terms of pathways, most operational capacity stems from pyrolysis oil production (74 000 t/y), followed by production of alcohols from cellulosic sugars (49 420 t/y). Gasification pathways provide most planned capacity (685 760 t/y in total over a variety of pathways and products), followed by alcohols from cellulosic sugars (380 000 t/y), see Figure 8. The large contribution of other technologies to the planned capacity is due to the planned production of 500 000 t/y of tall oil diesel.

The most important fuel products are ethanol, followed by pyrolysis oil and methanol. Upgrading of pyrolysis oil in refineries and the integration of advanced biofuel production into pulp mills become increasingly attractive.

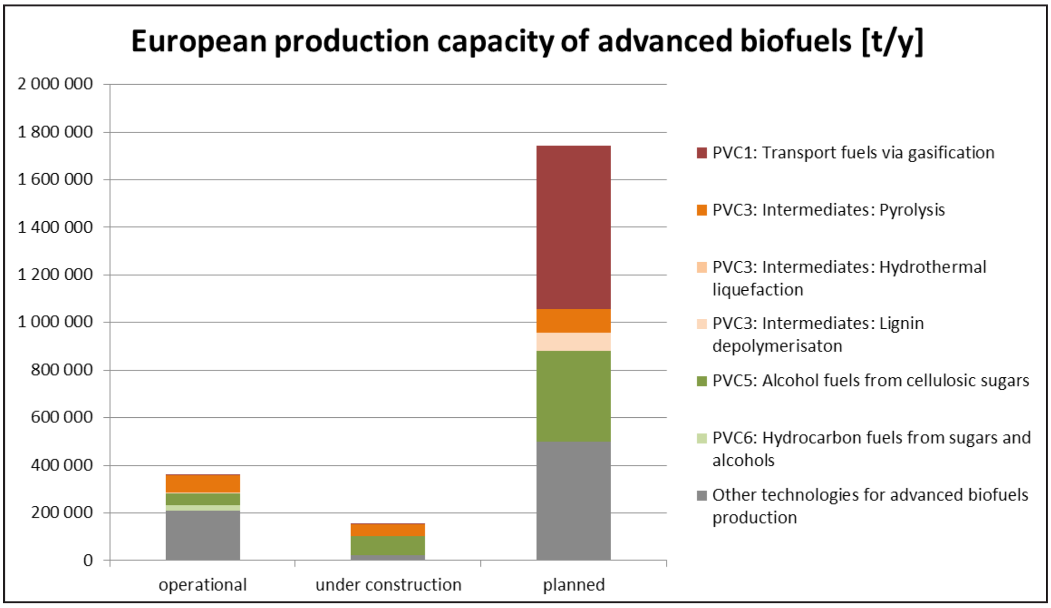

Figure 7: European production capacity of advanced biofuels by status

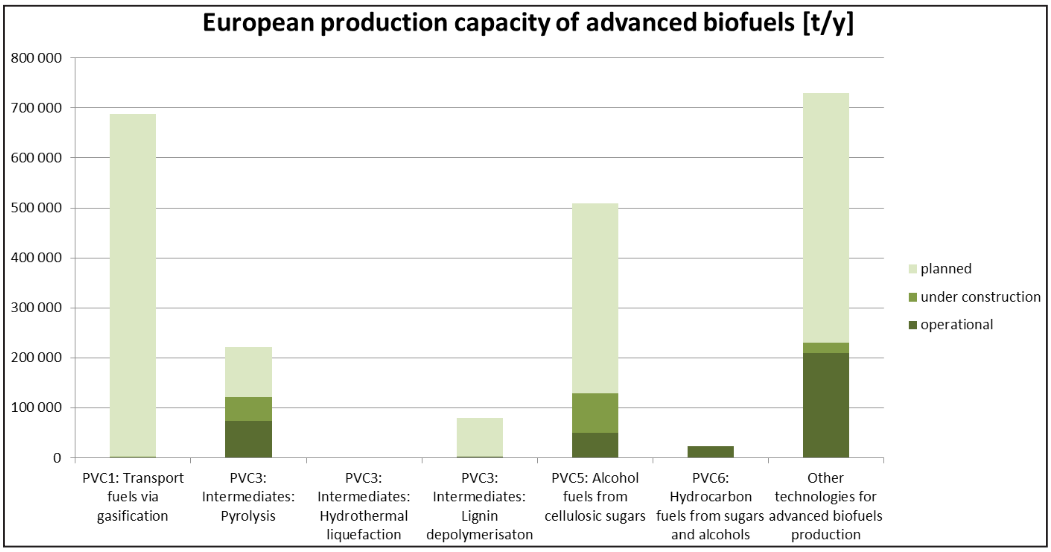

Figure 8: European production capacity of advanced biofuels by pathway