Advance Biofuels in India:

A comparative analysis between India and the EU for cooperation and investment

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List of abbreviations

Acronym	Meaning
ART	Alternative Renewable Transport
BALI	Borregaard Advanced Lignin
BBI JU	Bio-Based Industries Joint Undertaking
BRIC	Brazil, Russia, India and China
BTG	Biomass Technology Group
BTL	Biomass-to-liquid
CCU	Carbon Capture and Utilisation
CEN	European Centre for Standardisation
CFM	Co-Funding Mechanism
CHP	Combined Heat & Power
CNG	Compressed natural gas
CO_2-eq.	CO_2 equivalent
CTL	Catalytic Thermo-Liquefaction
DBT	Department of Biotechnology, India
DBT-ICT	The Department of Biotechnology of the Institute of Chemical Technology, Mumbai
DHDS	Diesel Hydrodesulfurization
DHDT	Diesel Hydrotreating
DME	Dimethyl Ether
DST	Indian Department of Science
EBP	Ethanol Blending Programme
EIB	European Investment Bank
EIF	European Investment Fund
EMPYRO	Energy & Materials from Pyrolysis
ETBE	Ethyl tertiary butyl ether
EU	European Union
EUA	European Union Allowance
EU ETS	EU Emissions Trading System
EUR/GJ	Euro / gigajoule
EUR/MWh	Euro / megawatt hour
FOAK	First-of-a-kind
FP	Framework Programme
FQD	Fuel Quality Directive
FT Liquids	Fischer-Tropsh Liquids
GDP	Gross domestic product
GHG	Greenhouse gas
GTI	Gas Technology Institute, Chicago
GTI	Gas Technology Institute
HEFA	Hydroprocessed Esters and Fatty Acids
HMU	hydrogen manufacturing unit
HVO	Hydrotreated Vegetable Oils
HVO	Hydrotreated vegetable oils
ICT	Institute of Chemical Technology, India
IFPEN	IFP Energies nouvelles
IGL	India Glycol Ltd
ILUC	Indirect land use change
IMPRINT	Impacting Research Innovation & Technology

Acronym	Meaning
INNOFIN	Innovative financial instrument
IOCL	Indian Oil Corporation Ltd.
JAP	EU-India Joint Action Plan
KIT	Karlsruhe Institute of Technology
LPG	Liquefied Petroleum Gas
MJ	Megajoule
MMTPA	Million Metric Tonne Per Annum
MNRE	Ministry of New and Renewable Energy
MoES	Ministry of Earth Sciences
MoPNG	Ministry of Petroleum and Natural Gas
MPP	Minimum Purchase Price
MSW	Municipal Solid Waste
NASA	National Aeronautics and Space Administration
NBCC	National Biofuel Co-ordination Committee
NBP 2009	National Biofuel Policy 2009
NEOT	North European Oil Trade Oy
NER	New Entrants' Reserve
NEXBTL	Neste Renewable Diesel
NPB 2018	National Policy on Biofuels 2018
PERC	Phycospectrum Environmental Research Centre
RCR	Rotating Cone Reactor
RDF	Refuse Derived Fuel
RECORD	Renewable Energy Consortium for Research and Demonstration
RED	Renewable Energy Directive
RED-II	Recast of the Renewable Energy Directive
S&T	Science & Technology
SHF	Separate Hydrolysis and Fermentation
SIRA	Strategic Innovation and Research Agenda
SSF	Simultaneous Saccharification and Fermentation
TPA	Tonnes per annum
TPD	Tonnes per day
TRL	Technology readiness level
UCOME	Used Cooking Oils Methyl Ester
VGF	Viability Gap Funding
WTO	World Trade Organization

1 EXECUTIVE SUMMARY

This study on advanced biofuels in the EU and India was commissioned by Exergia S.A. in the context of the ART-Fuels Forum. Its purpose is to obtain a better understanding of the current policy and legal situation in the EU and India, as well as facilitating contacts and trade between relevant technology developers and industry players in both jurisdictions.

Whereas the EU has a longstanding biofuels policy and legislative framework that has culminated in the soon to be adopted recast of the Renewable Energy Directive ("RED-II"), India's approach has been more ad hoc. In particular, it is currently based on its National Policy on Biofuels 2018 ("NPB 2018"), which is yet to be transposed into legislation.

The primary source of legislation on biofuels in the EU currently is the Renewable Energy Directive ("RED"), which is the result of several preceding policies and legislative acts. It sets a 10% target for renewable energy in transport. The RED will soon be replaced by the RED-II, which imposes an obligation on EU Member States to require fuel suppliers to include a minimum share of 14% energy from liquid and gaseous biofuels in the total amount of transport fuels. In India the primary instrument is the recent NPB 2018, which replaced the National Biofuel Policy 2009 ("NBP 2009"). It proposes an indicative target of 20% blending of ethanol in petrol and 5% blending of biodiesel in diesel. With the approval of the NPB 2018 India's biofuels program has undergone a much-needed update.

The present study provides an overview of the approaches in the two jurisdictions. It provides an analysis of recent changes, by comparing the RED-II to the RED and the NPB 2019 to the NBP 2009. It also engages in a comparative analysis between the RED-II and the NPB 2018, comparing and contrasting the updated approaches in the two jurisdictions. Whereas there are certain clear differences, there are also similarities.

With respect to the comparative analysis between the RED-II and the NPB 2018, as a first point it is pertinent to note that the RED-II is a legislative Act, while the NPB 2018 is merely a policy rather than legislation. Furthermore, while both the instruments recognise the role of biofuels in achieving similar goals of climate change mitigation, energy security as well as creating employment opportunities, the key goal of the RED-II is climate change mitigation, while the NPB 2018 focuses more on energy security. The NPB 2018 recognises biofuels as environmentally friendly fuels and therefore does not specifically provide for sustainability criteria or a greenhouse gas emission saving criteria for biofuels. It does however provide that advanced biofuels should have low CO_2 emission or high GHG reduction and do not compete with food crops for land use. This significantly differs from the EU approach, which has set sustainability and greenhouse gas emission saving criteria in the RED-II. Such criteria are currently missing from the Indian biofuel policy as it stands today.

Whereas both instruments have significant differences, there are also several similarities. Overall, they both aim to progress in a similar direction. The key difference is the degree to which this is done. For instance, whereas both instruments encourage the development of advanced or second-generation biofuels, the RED-II goes further than the NPB 2018. The NPB 2018 merely places a focus on financial incentives and R&D for advanced biofuels, whereas the RED-II goes a step further and double counts the use thereof and sets a specific 3,5% mandatory target for advanced biofuels by 2030. In addition, whereas both instruments provide for a framework, in the case of the EU the Member States must implement this in their national legislation, whereas the Indian states do not have to implement anything in their state legislation. An additional key point of difference to note is that the Indian biofuel policy does not currently allow imports and exports of biofuels however this is not the case for the EU.

With respect to cooperation between the EU and India, there is a long established cooperation on Energy and Science and Technology that has facilitated collaboration at various levels. This cooperation was strengthened by the EU-India Clean Energy and Climate Partnership following the Paris agreement. The EU-India Energy Panel meets annually and an energy security working group was launched in 2016. The EU-India joint Statement on Clean Energy & Climate Change of 6 October 2017 added the topic of advanced biofuels as one of mutual importance aiming to step up cooperation between the two sides. As a first step the EU-India Conference on Advanced Biofuels was held on 6-8 March 2018 facilitating contacts from key technology and industry players from both sides.

Both EU and Indian technology developers have achieved significant progress on several value chains of advanced biofuels and innovative technologies have reached the commercialization level or a high TRL level:

- Hydrotreated Vegetable Oils is a commercial technology and several EU oil companies are either building new biorefineries or are modifying existing ones to produce HVO fuels. HVO has limited market in India due to the scarcity of vegetable oils of used cooking oils.
- Biomethane from anaerobic digestion is a commercial technology. Technology developers exist both in the EU and India and this is considered as a key area in both jurisdictions.
- Cellulosic ethanol of agricultural residues has been developed successfully by several technology developers in the EU and India and the first steps of commercialization are under way. Discussions on licensing the technology are underway. Cellulosic ethanol of forestry residues has been developed in Finland but at present it has few prospects in India.
- Fast pyrolysis of biomass has reached the first commercialization steps in the EU while in India the thermochemical catalytic process has progressed significantly and is at TRL 8.
- Synthetic biofuels via the gasification process still have to reach large scale demonstration with the exception of synthetic biomethane. This value chain at present is lagging behind due to the relative high costs for first-of-a-kind plants.
- Algal biofuels are considered relatively expensive and in the near future there are little prospects for their commercialisation except those used in waste water facilities for biomethane production.

- Carbon capture and utilisation ("CCU") fuels in combination with blast furnaces offer interesting prospects.
- Power-to-X is in the early stages of development and they have very little prospects in India due to the power poverty of the country.

In the EU the Framework Programmes have provided for long term continuity for the research community and the technology developers in developing and optimizing the various technology and value chains. In India too, there have been national programmes to support innovation in the area of biofuels and several research centres have benefited. However it is clear that new and dedicated financial instruments are needed to support the significant investments necessary to build the first-of-a-kind plants for advanced biofuels, or otherwise the governments have to provide adequate funds to close the financial envelops.

2 PREAMBLE

The conceptualisation for this study came out of discussions that took place during the first plenary meeting of the Alternative Renewable Transport Fuels Forum[1] (ART Fuels Forum) in Brussels on 04-05/05/2017 between MM YB Ramakrishna, at the time in his capacity as Chairman of the Working Group on Bio Fuels in India, representing India in the ART Fuels Forum; Theodore Goumas, CEO of EXERGIA S.A[2]., Coordinator of the ART Fuels Forum; Professor David Chiaramonti of the University of Florence and RECORD[3], Technical Coordinator of the ART Fuels Forum; and Kyriakos Maniatis of the European Commission, principal administrator in Directorate General for Energy[4] for the ART Fuels Forum.

The participation of India in the ART Fuels Forum provided the basis for closer cooperation between technology developers and industrial players on both sides via direct contacts. At the same time, it became apparent that the Indian government had started the implementation of a national program to accelerate the deployment of advanced biofuels under the management of the Ministry of Petroleum and Natural Gas of India. This national program[5]aims to construct 12 biorefineries in India by 2025 in an effort to improve the security of energy supply for the country.

It became apparent during the above mentioned discussion that a study i) analysing the policies and legislation in India and the EU, and ii) providing for a reliable understanding of the status and readiness of the various technologies and the related costs for advanced biofuels, was necessary to facilitate the cooperation between technology developers and industrial players on both sides.

The ART Fuels Forum management decided to undertake this study to:

- Facilitate the exchange of information between technology developers and key industry players in India and the EU,
- Assist all interested parties from India and the EU to understand the policies and existing legislation in the other jurisdiction,
- Provide opportunities for EU technology developers to cooperate directly with their Indian counterparts in entering in joint ventures and/or licencing agreements for participating in the Indian government's drive to build the 12 biorefineries,
- Inform key stakeholders of funding opportunities for innovation support across the whole value chain (from biomass production to the production of advanced biofuels) in both India and the EU.

1 See http://artfuelsforum.eu.
2 See http://exergia.gr/.
3 See http://www.re-cord.org.
4 See https://ec.europa.eu/energy/en/home.
5 See Section 8.3, Financing mechanisms in India.

3 AIMS AND OBJECTIVES OF THE STUDY

This report addresses advanced biofuels in India and the EU with the main aim being to provide a reliable basis for the understanding of the:

- policies
- existing legislation
- status and reliability of the various value chains and technologies
- basic costs
- various opportunities for financial support
- key technology developers and industry players

India and the EU have developed reliable technologies for crop based biofuels, the so called *first generation biofuels* or those based on vegetable oils, sugars and grains. Consequently, the technical analysis of this study excludes any crop-based biofuel as out of scope and addresses only advanced biofuels.

The study furthermore only addresses value chains and advanced biofuels that are close to industrial deployment or large-scale demonstration since these can be reasonably expected to reach market deployment in the very near future and can contribute to the national program of India and the policies in the EU.

Via the work undertaken herewith and the overall results of the EU-India Conference on Advanced Biofuels[6] this study provides a basis to understand the opportunities and prospects for promoting the deployment of advanced biofuels in both India and the EU. It is clear that Indian technology providers have achieved significant progress in some of the value chains and intensive cooperation already exists between parties from both sides. Realistic options therefore exist for technology providers from both sides in deploying their technologies in the other's market through joint ventures and licensing agreements.

The main objective of the present study has been to provide a clear view of the landscape of advanced biofuels so as to facilitate the deployment of advanced biofuel technologies in both India and the EU, while at the same time promoting and facilitating cooperation amongst the several stakeholders.

[6] See https://ec.europa.eu/info/events/eu-india-conference-advanced-biofuels-2018-mar-07_en.

4 OVERVIEW AND COMPARISON OF EXISTING LEGISLATION AND POLICIES IN THE EU AND INDIA

4.1 Introduction

This section will provide an overview of the past and current legislation and/or policies on biofuels in the EU and India. It will also briefly discuss possible legislation that is in the pipeline, and provide an overview of key differences between the old and new instruments.

The aim is to provide an overview of the key elements of the biofuels legislation and/or policies in the EU and India. The section does not aim to give an exhaustive overview of every provision applicable to biofuels. For instance, issues related to standards, taxation or customs duties are not covered as these are considered to be out of the scope of the present study.

After having provided the overview of the key elements in each of the two jurisdictions, a comparative analysis between the key elements in the EU and in India will be provided. For the purpose of the comparative analysis, the focus will lie on the updated instruments in both jurisdictions.

4.2 Overview of EU policies and legislation

This section provides an overview of past, current and future EU policies and legislation on biofuels. It shows how the EU biofuels policy has evolved over the past two decades, and how the first EU legislation on biofuels emerged in 2003 and eventually evolved from the 2009 EU Renewable Energy Directive ("RED") to the soon to be adopted recast of the Renewable Energy Directive ("RED-II"). Finally, it provides an overview of key differences between the RED and RED-II.

4.2.1 Renewable Energy: Green Paper and White Paper

As a first step towards forming a comprehensive strategy for renewable energy the European Commission adopted a Green Paper on renewable energy sources in November 1996[7] proposing a 12% penetration of renewables in the energy mix by 2010. In its Resolution on the Green Paper, the European Parliament recognised the importance of renewable energy in combating the greenhouse gas effect, contributing to the security of energy supplies and creating jobs in small and medium enterprises and rural regions and went even further proposing a goal of a 15% share of renewables for the European Union by the year 2010. This was followed by another communication the following year on the

[7] Commission Green Paper of 20 November 1996 on renewable sources of energy, Available at https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=LEGISSUM:l27018&from=EN.

'Energy Dimension of Climate Change' aiming to identify a series of energy actions - including a prominent role for renewables in view of fighting climate change.[8]

In November 1997 the European Commission issued the Communication 'Energy for the future: Renewable sources of energy – White Paper for a Community Strategy and Action Plan'[9] which put forward specific targets for renewable energy. The European Union had recognised the urgent need to tackle climate change and had also adopted a negotiating position of 15% greenhouse gas emissions reduction target for industrialised countries by the year 2010 from the 1990 level.

In the Green Paper on Renewables the Commission sought views on the setting of an indicative objective of 12% for the contribution by renewable sources of energy to the European Union's gross inland energy consumption by 2010. The White Paper went further, proposing specific targets for renewable electricity and recommending action on biofuels[10]:

> *Specific measures are needed in order to help increase the market share for liquid biofuels from the current 0.3% to a significantly higher percentage, in collaboration with Member States.*

It further placed the car and oil industry in a central position as the key stakeholders and clearly stated the need for taking into account the full cycle of environmental cost/benefits to avoid adverse effects on the environment:

> *The overall environmental effect varies from biofuel to biofuel and depends, amongst others, on the crop cultivated and the crops replaced. Promotion of biofuels has to be coherent with the AutoOil Programme[11] and the European policy on fuel quality, and should take account of the full cycle of environmental costs/benefits.*

The White Paper also proposed that a market-share of 2% for liquid biofuels could still be considered as a pilot phase.[12]

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8 COM (97) 196 final, 14 May 1997, 'The Energy Dimension of Climate Change'.

9 COM(97)599 final, 26 November 1997, 'Energy for the future: Renewable sources of energy – White Paper for a Community Strategy and Action Plan'.

10 The White Paper put forward several key messages: 1) 'According to the particular, scenario outlined, the main contribution of RES growth (90 Milllion tons of oil equivalent) could come from biomass, tripling its level of utilisation; and 2) '… .plus a significant increase of biofuel in transport fuel use by 2010 are important elements in the scenario for achieving the overall Union objective.'

11 The aims of the European Auto-Oil II Programme were to make an assessment of the future trends in emissions and air quality and establish a consistent framework within which different policy options to reduce emissions can be assessed using the principles of cost-effectiveness, sound science and transparency; and to provide a foundation (in terms of data and modelling tools) for the transition towards longer term air quality studies covering all emission sources, see: http://ec.europa.eu/environment/archives/autooil/index.htm.

12 See footnote 5, section 2.2.3 New Bioenergy Initiative for Transport, Heat and Electricity.

In the meantime the White paper on Transport[13] identified that the transport sector accounted for more than 30 % of final energy consumption in the Community, which was only expanding. It also estimated that CO_2 emissions from transport were to rise by 50 % between 1990 and 2010, to around 1,113 million tonnes, the main responsibility resting with road transport, which accounted for 84 % of transport-related CO_2 emissions. From an ecological point of view, the White Paper therefore called for the heavy dependence on oil in the transport sector to be reduced by using alternative fuels such as biofuels. Moreover, the White Paper on Transport placed sustainable development as a new imperative.

4.2.2 Directive 2003/30/EC on the Promotion and use of biofuels and other renewable fuels for transport

The first specific legislative action for biofuels was the Biofuels Directive of 8 May 2003 that set indicative targets for a minimum proportion of biofuels to be placed on the market: 2% in 2005 and 5.75% in 2010[14]. In its first recital the directive makes reference to the Community strategy for sustainable development as agreed by the European Council meeting at Gothenburg on 15 and 16 June 2001 "for sustainable development consisting in a set of measures, which include the development of biofuels." In its Article 3(b) the Directive put forward reference values of 2% and 5.75%[15] respectively to be achieved by the end of 2005 and the end of 2010. However, since the reference values carried no serious legal consequences they had no strong effect on the deployment of biofuels in the EU, with the exception of few countries (e.g. Germany and France).

4.2.3 Fuel Quality Directive

The Fuel Quality Directive (FQD)[16] sets technical standards for road transport fuels. It applies to petrol, diesel and biofuels used in road transport as well as to gasoil used in non-road-mobile machinery (e.g. tractors and agricultural machinery). Together with the RED, it also regulates the sustainability of biofuels. In particular, Article 7a requires suppliers to reduce the greenhouse gas (GHG) intensity of automotive fuels that they market in the EU. By the end of 2020, fuels suppliers are obliged to reduce these fuels' lifecycle GHG intensity by at least 6% compared to 2010.

The greenhouse gas intensity of fuels is calculated on a life-cycle basis, covering emissions from extraction, processing and distribution. Emissions reductions are calculated from a 2010 baseline. The 6% reduction target is likely to be mainly achieved through:

- the use of biofuels, electricity, less carbon intense (often gaseous) fossil fuels, and renewable fuels of non-biological origin (such as e-fuels)

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13 COM(2001) 370 final, of 12 September 2001, White Paper 'European transport policy for 2010: time to decide'.

14 Directive 2003/30/EC of the European Parliament and of the Council of 8 May 2003 on the promotion of the use of biofuels and other renewable fuels for transport.

15 Note: the percentage targets were based on energy basis and not volume basis.

16 Directive 98/70/EC of the European Parliament and of the Council of 13 October 1998 relating to the quality of petrol and diesel fuels and amending Council Directive 93/12/EEC, as amended.

- a reduction of flaring and venting at the extraction stage of fossil fuel feedstocks.

There are currently no plans to extend the greenhouse gas reduction target beyond year 2020. Instead, the Commission has proposed to address the decarbonisation of transport fuels after 2020 in the framework of the RED-II.

4.2.4 Renewable Energy Directive 2009

The primary source of EU legislation currently in force regarding biofuels is the RED,[17] which establishes an overall policy for the production and promotion of energy from renewable sources in the EU. It entered into force on 25 June 2009 and works towards the objectives of promoting the reduction of greenhouse gas emissions through the use of renewable energy sources, security of energy supply as well as providing opportunities for employment and regional development, especially in rural and isolated areas.

The RED distinguishes between biofuels and bioliquids.[18] Whereas "biofuels" are limited to "liquid or gaseous fuel for transport produced for biomass", "bioliquids" are defined as "liquid fuel for energy purposes other than for transport, including electricity and heating and cooling, produced from biomass". In essence, biofuels and bioliquids are the same product, the only difference being their usage.

A requirement is imposed on EU Member States to obtain a share of energy from renewable sources in all forms of transport of at least 10% by 2020.[19] It is generally accepted that biofuels will be the main renewable energy source in attempting to reach this target.[20] By means of an amendment implemented in 2015, a limit of 7% has been imposed for biofuels produced from crops grown on agricultural land for the purpose of the calculation of the 10% target. There is an exception for certain specific feedstocks and fuels, which include advanced biofuels as well as biofuels produced from used cooking oil and animal fats. These fall outside the 7% limit.[21] This 7% limit was introduced to address concerns related to indirect land use change ("ILUC").[22] There is also an indicative target of 0.5% for advanced biofuels.[23] Finally, advanced biofuels, as well as biofuels produced from used cooking oil and animal fats are double counted towards the 10% target.[24]

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17 Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC, as amended.

18 RED Article 2(h) and (i).

19 RED Article 3(4).

20 Directive (EU) 2015/1513 of the European Parliament and of the Council of 9 September 2015 amending Directive 98/70/EC relating to the quality of petrol and diesel fuels and amending Directive 2009/28/EC on the promotion of the use of energy from renewable sources, OJ L239, 15.9.2015, p.1, recital 1.

21 RED Article 3(4)(d) and Annex IX.

22 ILUC concerns the displacement of agricultural production from land that was previously used to grow food or feed and that is subsequently used to produce biofuels, to other land that was previously non-cropland such as grasslands and forests.

23 RED Article 3(4)(e).

24 RED Article 3(4)(f) and Annex IX.

In order to be counted towards the target biofuels must meet certain sustainability criteria, irrespective of whether they were produced using raw materials cultivated inside or outside the EU.[25] This is to ensure that the biofuels consumed in the EU are sustainable. The sustainability criteria consist of various requirements. First, the GHG emission savings from the use of biofuels as compared to the use of fossil fuels must amount to at least 60% for biofuels produced in installations starting operation after 5 October 2015. With respect to installations that were in operation on or prior to this date, the GHG emission savings had to amount to at least 35% until 31 December 2017, and since then they must amount to at least 50%. Furthermore, in order to meet the sustainability criteria biofuels may not be made from raw material deriving from land with high biodiversity value, high carbon stock, or peatland, as defined in the RED.[26]

The RED provides for several possibilities for producers to calculate the GHG emission saving levels of a particular type of biofuel, namely by:

- relying on default values for GHG emission savings that assign a standard GHG emission saving value for each type of biofuel depending on the raw material used;
- calculating the actual GHG emission savings themselves, using a method provided for in the Directive; or
- calculating actual values for one or more steps in the production process, while relying on disaggregate default values for the remaining steps.

Details regarding the calculation of the default values are provided in the RED.

In order to further increase the flexibility of the measure, the Commission can approve independent voluntary certification schemes through comitology.[27] There are several approved voluntary certification schemes that market operators can use.[28] A fuel supplier that is certified by such voluntary schemes is assumed to meet the requirements of the Directive and need not provide any further information regarding the sustainability of its biofuels. The Commission may also enter into international agreements with other countries on the matter. Biofuels produced with raw materials originating from signatory countries may also be assumed to meet the sustainability criteria of the RED.[29]

Finally, financial support for the consumption of biofuels may only be given to biofuels meeting the sustainability criteria.[30]

EU Member States must report to the European Commission every two years the progress they have achieved with respect to their implementation of the RED, including with respect to biofuels.[31] The European Commission must monitor several elements under the RED in

25 RED Articles 5(1) and 17.
26 RED Article 17.
27 RED Article 18(4).
28 See https://ec.europa.eu/energy/en/topics/renewable-energy/biofuels/voluntary-schemes.
29 RED Article 18(4).
30 RED Article 17(1)(c).
31 RED Article 22.

general, but also specifically related to biofuels, and publish consolidated reports for the EU based on its monitoring as well as the Member State reports.[32]

4.2.5 Legislation and policies in the pipeline

The Energy Union

The Energy Union[33] of 2015 identified the policies and strategies that are needed for Europe's transition to a low-carbon society while delivering jobs, growth and investments. The Energy Union has to support a socially fair clean energy transition. On 24 November 2017 the European Commission adopted the 3rd Report on the State of the Energy Union,[34] which shows that Europe's transition to a low-carbon society is becoming the new reality. This Report also confirmed that energy transition is not possible without adapting the infrastructure to the needs of the future energy system. Energy, transport and telecommunication infrastructure are more and more interlinked. Local networks will become ever more important in the daily lives of European citizens, who will increasingly switch to electro-mobility, decentralised energy production and demand response.

The 2016 Winter Package

On 30 November 2016 the European Commission presented a package of measures and policy initiatives, the so-called "Winter Package"[35], to keep the EU competitive as the clean energy transition changes global energy markets. The European Commission wants the EU to lead the clean energy transition, not only adapt to it. In taking the initiative for global leadership, the EU has committed to cut CO2 emissions by at least 40% by 2030. The proposals have three main goals: putting energy efficiency first, achieving global leadership in renewable energies and providing a fair deal for consumers. The Commission's proposals aim to place the European Consumers at the centre of the energy markets of the future especially for the production and supply of renewable electricity. Consumers across the EU will in the future be active energy market players with a better choice of supply and the possibility to produce and sell their own electricity. Increased transparency and better regulation give more opportunities for civil society to become more involved in the energy system and respond to price signals. The package also contains a number of measures aimed at protecting the most vulnerable consumers.

The Winter Package included eight proposals to facilitate the transition to a clean energy economy and to reform the EU energy systems along the policy directions of the Energy Union. Among the proposals some proposed amendments to existing energy market

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32 RED Article 23. These reports can be found at: https://ec.europa.eu/energy/en/topics/renewable-energy/progress-reports.

33 COM(2015) 80 final, of 25/02/2015, A Framework Strategy for a Resilient Energy Union with a Forward-Looking Climate Change Policy.

34 See https://ec.europa.eu/commission/publications/third-report-state-energy-union_en.

35 See https://ec.europa.eu/energy/en/news/commission-proposes-new-rules-consumer-centred-clean-energy-transition.

legislation, others proposed amendments to existing climate change legislation, and there were a few proposals for new measures.

The Winter Package included among the other initiatives the proposal for the RED-II[36]. This directive is discussed in detail in the following section.

The recast of the Renewable Energy Directive – RED-II

Introduction

On 27 June 2018 the Council circulated the consolidated compromise text of the RED-II as agreed between the Council and the European Parliament.[37] This is the text that will normally be adopted and enter into force in the near future, subject to revisions by the legal linguists of both Institutions. The Member States will have to transpose the RED-II by 30 June 2021, and the original RED will be repealed as from 1 July 2021. This will then be the primary source of EU legislation regarding biofuels.

The RED-II establishes sustainability and greenhouse gas emissions saving criteria for biofuels, bioliquids and biomass fuels. It recognises the objectives as laid down in the RED and works towards the providing sustainable energy at affordable prices as well as establishing technological and industrial leadership while providing environmental, social and health benefits.

The RED-II like the RED distinguishes between biofuels and bioliquids on the basis of their usage. It further defines advanced biofuels as biofuels that are produced from feedstocks as listed under part A of Annex IV[38]. The definitions are further elaborated upon in the subsequent sections on comparison.

Overall targets

The RED-II puts forth a Union binding overall target to ensure that the share of energy from renewable sources in 2030 is at least 32%.[39] Furthermore, a requirement is imposed on EU Member States to require fuel suppliers to ensure that the share of renewable energy supplied for final consumption in the transport sector is at least 14% by 2030.[40] This share is calculated as the sum of all biofuels, biomass fuels (subject to fulfilling the sustainability and greenhouse gas emissions saving criteria set out in the directive) and gaseous transport fuels of non-biological origin used in the transport sector.[41]

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36 See http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52016PC0767R(01)&from=EN.

37 See Proposal for a Directive of the European Parliament and of the Council on the promotion of the use of energy from renewable sources (recast), Interinstitutional File: 2016/0381 (COD), available at http://www.europarl.europa.eu/RegData/commissions/itre/inag/2018/06-27/ITRE_AG(2018)625378_EN.pdf.

38 RED-II Article 5(ff).

39 RED-II Article 3(1).

40 RED-II Article 25(1).

41 RED-II Article 7(1) & (4).

For the purpose of the calculation of the 14% target, the use of biofuels and biogas produced from feedstocks listed in Part B of Annex IX i.e. used cooking oil and animal fat, is limited to 1.7%.[42] This contribution will be double-counted towards the 14% target.[43] The Commission can add feedstocks to Part B of Annex IX, but not remove them. The feedstocks it can add to Part B of Annex IX are those that can be processed with mature technologies.[44] Similarly, for the purpose of the calculation of the 14% target, the contribution of fuels supplied in the aviation and maritime sector will be considered to be 1.2 times their energy content.[45]

The share of biofuels, bioliquids and biomass fuels produced from food or feed crops in each Member State may not be more than 1% higher than their share in 2020. However their share is capped at 7% of the gross final consumption in road and rail transport. Moreover, in case this share is below 1%, the contribution may be increased to a maximum of 2%.[46]

If a Member State's share of biofuels, bioliquids, biomass fuels produced from food or feed crops is less than the aforementioned 7%, the Member State may reduce the overall 14% target accordingly by maximal 7 percentage points. For example, in case a Member State has limited the contribution from biofuels, bioliquids, biomass fuels produced from food or feed crops to 2%, it may reduce the overall 14% target to 9%.

Advanced Biofuels specific targets

The RED-II defines advanced biofuels as biofuels that are produced from feedstocks listed in Part A of Annex IX of the directive. It provides that biofuels and biogas produced from these feedstocks shall equal to at least 0.2% in 2022, 1% in 2025 and 3.5% in 2030,[47] gradually increasing their share over time. Furthermore, the contribution of advanced biofuels will be double-counted towards the 14% target.[48]

The Commission can add feedstocks to Part A of Annex IX, but not remove them. In other words, the Commission can add feedstocks to the list of advanced biofuels. The feedstocks it can add to Part A of Annex IX are those that can only be processed with advanced technologies.[49]

Sustainability and greenhouse gas emissions saving criteria

The RED-II lays down certain sustainability and greenhouse gas emissions saving criteria for biofuels, bioliquids and biomass fuels in order for them to be:

- Counted for the contribution towards the Union target and Member States renewable energy share;

42 RED-II Article 25(1)(b).
43 RED-II Article 25(1).
44 RED-II Article 25(8).
45 RED-II Article 25(1).
46 RED-II Article 25(1).
47 RED-II Article 25(1).
48 RED-II Article 25(1).
49 RED-II Article 25(8).

- In compliance with renewable energy obligations; and
- Eligible for financial support.[50]

These criteria apply irrespective of the geographical origin of the biomass.[51] The directive further provides that biofuels, bioliquids and biomass fuels produced from waste and residues, other than agricultural, aquaculture, fisheries and forestry residues, only need to fulfil the greenhouse gas emissions saving criteria as discussed later in this section.

The RED-II for the purposes of the sustainability criteria differentiates between biofuels, bioliquids and biomass fuels produced from agricultural biomass and those produced from forest biomass. Therefore the sustainability criteria for the two differ.

As regards the sustainability criteria for biofuels, bioliquids and biomass fuels produced from agricultural biomass, the biomass taken into account for the production thereof shall not be made from raw material obtained from:

- Land with high biodiversity value. The directive provides a detailed list of such areas with high biodiversity value.[52]
- Land with high carbon stock. The directive provides a detailed list of such areas with high carbon stock.[53]
- Land that was peatland in January 2008, unless evidence is provided that the cultivation and harvesting of that raw material does not involve drainage of previously undrained soil.[54]

As regards the sustainability criteria for biofuels, bioliquids and biomass fuels produced from forest biomass, the biomass taken into account for the production thereof must meet the following:

- Requirements to minimise the risk of using forest biomass derived from unsustainable production:
  - The country wherein the biomass is harvested should have certain national and/or sub-national laws and monitoring and enforcement systems in place, as further elaborated in the directive.[55]
  - In cases where evidence of these national or subnational laws and enforcement systems is not available, there must be management systems in place at the forest sourcing area level to ensure the same level of protection.[56]
- Land use, Land-use change and Forestry (LULUCF) requirements:

50 RED-II Article 26(1).
51 RED-II Article 26(1).
52 RED-II Article 26(2).
53 RED-II Article 26(3).
54 RED-II Article 26(4).
55 RED-II Article 26(5)(a).
56 RED-II Article 26(5)(b).

- The country of origin of the forest biomass is a party to and follows certain international climate change agreements such as the Paris Agreement.[57]
- In cases where evidence as to the above is not available, there should be management systems in place at forest sourcing area level to ensure that carbon stocks and sinks levels in the forest are maintained, or strengthened over the long term.[58]

The RED-II also requires the following greenhouse gas emission saving from the use of biofuels, bioliquids and biomass fuels:

- At least 50 % for biofuels, biogas consumed in transport and bioliquids produced in installations in operation on or before 5 October 2015;[59]
- At least 60 % for biofuels, biogas consumed in transport and bioliquids produced in installations starting operation from 5 October 2015;[60]
- At least 65 % for biofuels, biogas consumed in transport and bioliquids produced in installations starting operation after 1 January 2021;[61]
- At least 70 % for electricity, heating and cooling production from biomass fuels used in installations starting operation after 1 January 2021 and 80 % for installations starting operation after 1 January 2026.[62]

Member States may not place additional sustainability criteria on biofuels and bioliquids,[63] but can do so for biomass fuels.[64]

The RED-II contains detailed provisions on the verification of compliance with the sustainability and greenhouse gas emissions saving criteria[65] as well as on the calculation of the greenhouse gas impact of biofuels, bioliquids and biomass fuels[66].

Finally, the RED-II also establishes the Committee on the Sustainability of Biofuels, Bioliquids and Biomass fuels, which shall assist the Commission on matters relating to the sustainability of biofuels, bioliquids and biomass fuels.[67]

4.2.6 Key differences between the RED and the RED-II

Scope and subject

Both the RED and the RED-II establish a common framework for the promotion of energy from renewable sources and in doing so establish sustainability criteria for biofuels and

57 RED-II Article 26(6)(a).
58 RED-II Article 26(6)(b).
59 RED-II Article 26(7)(a).
60 RED-II Article 26(7)(b).
61 RED-II Article 26(7)(c).
62 RED-II Article 26(7)(d).
63 RED-II Article 26(9).
64 RED-II Article 26(11).
65 RED-II Article 27.
66 RED-II Article 28 and Annex V.
67 RED-II Article 31(2).

bioliquids. Whereas the RED treats greenhouse gas emissions saving criteria for biofuels and bioliquids as a part of the sustainability criteria, the RED-II treats these as two different sets of criteria, also extending these to biomass fuels.

Definitions

Both the RED and RED-II provide their defined terms in their respective Article 2. Below an overview is provided of certain key differences in the definitions relevant to biofuels:

Biofuels

The RED-II limits the definition of biofuels to liquid fuel for transport produced from biomass, whereas the RED, included gaseous fuel for transport produced from biomass also within the definition of biofuels.[68]

Biogas fuels

The Red-II defines gaseous fuels produced from biomass as biogas fuels.[69] The RED considered gaseous fuels produced from biomass to be biofuels, and did not provide for a separate definition thereof.

Biomass fuels

The RED-II also provides a definition of biomass fuels. They are defined as gaseous and solid fuels produced from biomass.[70] Biogas fuels are therefore a subset of biomass fuels. The RED also did not provide for a separate definition for biomass fuels.

Advanced Biofuels

The RED-II specifically provides a definition for advanced biofuels. They are defined as biofuels produced from feedstocks as listed in part A of Annex IX. Although the RED does not specifically refer to advanced biofuels, it does refer to biofuels produced from feedstocks listed under a similar part A of Annex IX (which are double counted and in effect given the same treatment as advanced biofuels in RED-II). This part A of Annex IX of the RED is similar to the part A of Annex of the RED-II with certain exceptions. Part A of Annex IX of the RED-II does not include the following feedstocks which were included in part A of Annex IX of the RED:

- Renewable liquid and gaseous transport fuel of non-biological origin;
- Carbon capture and utilisation for transport purposes; and
- Bacteria.

68 RED-II Article 2(h).
69 RED-II Article 2(qq).
70 RED-II Article 2(pp).

Low indirect land-use change biofuels and bioliquids

The RED-II largely keeps the same definition for low indirect land-use change biofuels and bioliquids, but makes it somewhat more stringent and clarifies it as compared to the RED.

Food and feed crops

The RED-II defines food and feed crops[71] in order to limit the production of biofuels, bioliquids and biomass fuels from these aforementioned crops. The RED although does refer to food and feed crops, but does not provide a specific definition of food and feed crops.

Union binding Targets

The RED provides Union binding targets for, *inter alia*, the share of energy from renewable sources in transport up to 2020. The RED-II builds upon these targets and provides these up to 2030.

A key difference is that, whereas the RED places an obligation on Member States to ensure that the share of energy from renewable sources in transport reaches the target, the RED-II requires Member States to place an obligation on fuel suppliers to ensure that the target is reached.

Another important difference is that, whereas the RED encouraged the Member States to endeavour to reach a minimum target of 0,5% for what are today called advanced biofuels (i.e. the biofuels produced from feedstocks as listed in part A of Annex IX), the RED-II places an obligation on Member States to reach a mandatory target for advanced biofuels, namely i) 0,2% by 2022; ii) 1% by 2025; and iii) 3,5% by 2030. This shows a significantly increased focus on advanced biofuels.

Finally, whereas the RED placed a limit on the use of "starch-rich crops", the RED-II expands this limit to "food and feed crops", which include starch-rich crops, but also sugars and oil crops.

Sustainability criteria

As discussed above, both the RED and the RED-II establish sustainability criteria for biofuels and bioliquids. A key difference is that the RED-II treats greenhouse gas emissions saving criteria as separate criteria from the sustainability criteria, the RED treated them as part of the sustainability criteria. This places a stronger focus on each of the elements of the two different sets of criteria. The RED-II also extends these criteria to biomass fuels.

Furthermore, while the RED-II builds upon the sustainability criteria of the RED, it significantly expands and clarifies these. For instance, there is a much stronger focus on international agreements and standards in the field of climate change.

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71 RED-II Article 2(ee).

Finally, the RED-II also differentiates between biofuels, bioliquids and biomass fuels produced from agricultural biomass and those produced from forest biomass for the purpose of the sustainability criteria. In particular, the sustainability criteria that these need to meet differ depending on the feedstock used.

4.3 Overview of Indian policies and legislation

This section aims to trace India's experience with biofuels and how it found place in its laws and policy. It delves into what were the main driving factors behind the formulation of a comprehensive policy on biofuels as it stands today, the fundamental aspects of the policy as well as India's general approach to biofuels.

4.3.1 The Power Alcohol Act, 1948

The Act came into force with the main objectives of developing the molasses based ethanol industry thereby cutting down wastage of molasses as well as reducing the dependence on petrol imports. The Act emphasized on the blending of petrol with power alcohol (molasses based ethanol). It stipulated that the Central Government had the power to direct up to 25% blending of power alcohol with petrol for motor vehicles. The power alcohol to be used in such blends was to be specified by the Central Government.[72]

The Act was however repealed in August 2000 on recommendation of the PC Jain Commission on the Review of the Administrative Laws, 1998 on account of it not being in use over the last several years preceding the Report. Furthermore, it was observed that the blending of petrol with ethanol would be possible without the support of an enactment through various other incentives such as fiscal incentives.[73]

4.3.2 Auto Fuel Policy 2003

The policy was brought into place with the main aim of adopting measures, which reduced emissions from in-use vehicles as well as provided an assured supply of auto fuels. The policy provided for changes in vehicular technology and thereby improving fuel quality in the entire country. Among other things the policy recommended drawing up financial and fiscal measures to encourage R&D in technologies producing ethanol/bio fuels for use in vehicles.[74]

4.3.3 Ethanol Blending Program

In September 2002, the Ministry of Petroleum and Natural Gas launched the Ethanol Blending Programme ("EBP"). The programme mandated a 5% blending of ethanol in nine States and four Union Territories with effect from 1st January 2003.[75] Subsequently, the

72 See http://164.100.47.194/Loksabha/Debates/Result13.aspx?dbsl=1225.
73 Ibid.
74 See http://pib.nic.in/newsite/erelcontent.aspx?relid=128.
75 The states included Maharashtra, Gujarat, Goa, Utter Pradesh, Haryana, Punjab, Karnataka, Andhra Pradesh, Tamil Nadu, Chandigarh, Puducherry, Dadra & Nagar Haveli, Daman 1 Diu

Planning Commission Report of the Committee on Development of Bio-Fuel was released in April 2003 which recommended among other things that while the decision to blend 5% ethanol with petrol in the major cities was a step in the right direction, a phased out approach with a gradual increase in the ratio from 5% to 20% over a period of time, applicable to the rest of the country would help in strengthening the ethanol blending programme.[76]

The 5% blending mandate could not be realized due to the shortage of bioethanol supply in 2003-2004 therefore the mandate was amended, requiring the blend only when adequate supplies of ethanol were available.[77] By October 2007, the 5% ethanol blending was made mandatory across the country, with the exception of J&K, the Northeast and Island Territories.[78]

4.3.4 National Mission on Biodiesel

The Planning Commission Report of the Committee on Development of Bio-Fuel also recommended the blending of biodiesel processed from the oil extracted from seeds of plants like Jatropha curcas with petroleum diesel. Developing this biodiesel could turn into a major poverty alleviation programme as well as provide energy security to the country. The report suggested the formulation of a National Mission on Biodiesel covering all the aspects of plantation, procurement of seed, oil extraction, trans-esterification, blending and trade, and research and development.

4.3.5 National Biofuel Policy, 2009

In December 2009 the government consolidated its policies on biofuels and released the National Biofuel Policy, formulated by the Ministry of New and Renewable Energy (MNRE). The major goals of the policy as enumerated by the MNRE are:[79]

- Development and utilization of indigenous non-food feed-stocks raised on degraded or waste lands
- Focus research and development on cultivation, processing and production of biofuels
- To ensure a minimum level of biofuels which are readily available in the market. An indicative blending mandate of 20% for both bio-ethanol and Bio-diesel by 2017.[80]

Government Notification available at http://ppac.org.in/WriteReadData/userfiles/file/Govt_Link12.pdf.

76 Planning Commission Report of the Committee on Development of Biofuel, April 2003, Available at http://planningcommission.nic.in/reports/genrep/cmtt_bio.pdf.

77 Bandyopadhyay, K.R., Policy Brief on Biofuels promotion in India for Transport: Exploring the grey areas, The Energy Research Institute, New Delhi, 2015.

78 Ray S., Miglani S., Goldar A., Ethanol Blending Policy in India: Demand and Supply Issues, ICRIER Policy Series, No.9, December 2011.

79 See https://mnre.gov.in/biofuels.

80 The blending levels for bio-diesel were intended to be recommendatory whereas the blending level for bio-ethanol had already been made mandatory up to 5%.

The policy sets forth a framework of technological, financial and institutional interventions and enabling mechanisms for the development of the next generation of more efficient biofuel conversion technologies based on new feedstocks. The main features of the biofuel policy include:[81]

- Recognition of biofuels as a means to providing energy security in India.
- The Policy recognizes biofuels as environmentally friendly fuels and therefore their use in the transportation sector would contribute towards the mitigation of air pollution as well as address the global concerns of reduction of carbon emissions.
- The Indian approach to biofuels recognizes the possible food security issues therefore bases the production of biofuels solely from non-food feedstocks, raised on degraded or wastelands that are not suited to agriculture.
- The Cultivation and plantation of non-edible seed oil seeds used to produce bio-diesel would be supported by a Minimum support price.
- The responsibility of storage, distribution and marketing of biofuels would rest with the Oil Marketing Companies ("OMCs").
- The policy also proposed the set-up of a National Biofuel Co-ordination Committee ("NBCC")[82] and a Biofuel Steering Committee[83] which would coordinate between the multiple departments and agencies and provide an overall policy guidance on the different aspects of biofuel development.
- The Minimum Purchase Price ("MPP") for bio-diesel by the OMCs will be linked to the prevailing retail diesel price and the MPP for bio-ethanol will be based on the actual cost of production and the import price of bio-ethanol. The MPP for both bio-diesel and bio-ethanol would be determined by the Biofuel steering Committee and the NBCC.
- The policy also paves way for international scientific and technical cooperation in the area of biofuel production, conversion and utilization.
- The Policy provides that, the Ministry of New and Renewable Energy is the nodal Ministry for carrying out the National Biofuel Programme.

The Policy defines Biofuels as 'liquid or gaseous fuels produced from biomass resources and used in place of, or in addition to, diesel, petrol or other fossil fuels for transport, stationery, portable and other applications'[84]. It includes within its scope

1. Bio-ethanol: ethanol produced from biomass such as

   - Sugar containing materials, like sugar cane, sugar beet, sweet sorghum, etc.,
   - Starch containing materials such as corn, cassava, algae etc.,

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81 National Biofuel Policy, 2009 available at https://mnre.gov.in/sites/default/files/uploads/biofuel_policy_0.pdf.

82 The NBCC would be headed by the Prime Minister and the members would include all the Ministers of the concerned Ministries.

83 The Biofuel Steering Committee would be headed by the Cabinet Secretary and would include Secretaries of concerned Departments.

84 National Biofuel Policy, 2009, page 5.

  - Cellulosic materials such as bagasse, wood waste, agricultural and forestry residues etc.;

2. Biodiesel: a methyl or ethyl ester of fatty acids produced from vegetable oils, both edible and non-edible, or animal fat of diesel quality;

3. Other biofuels: biomethanol, biosynthetic fuels etc.

4.3.6 Ministry of Petroleum and Natural Gas and its new powers

The President of India under clause (3) of the Article 77 of the Constitution of India is conferred with the power to make rules for the more convenient transaction of business of the Government of India, and for the allocation among Ministries of the said business. Under this provision, the President has formulated the Government of India (Allocation of Business) Rules, 1961. Prior to August 2017, under these rules the MNRE had the power to formulate the National Policy on biofuels and carry out the overall coordination concerning biofuels, however post 4th August 2017[85], the MoPNG has been allocated the following:

1. Overall coordination concerning biofuels;

2. National policy on biofuels;

3. Marketing, distribution and retailing of biofuels and its blended products;

4. Policy/scheme for supporting manufacturing of biofuels;

5. Blending and blending prescriptions for biofuels including laying down the standards for such blending;

6. Setting up the National Biofuel Development Board and strengthening the existing institutional mechanism;

7. Research, development and demonstration on transport, stationery and other applications of biofuels.

4.3.7 National Policy on Biofuels – 2018

Introduction

In May 2018, the Cabinet approved the new biofuel policy[86] and the policy was notified in June 2018. Therefore, currently the new biofuel policy is in place thereby supersedes the previous biofuel policy of 2009. This section summarises the new biofuel policy, focussing on its salient features. This National Policy on Biofuels – 2018 ("NPB 2018") builds on the achievements of the earlier National Policy on Biofuels and sets the new agenda consistent

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85 Cabinet Secretariat Notification, 4th August 2017, available at https://mnre.gov.in/sites/default/files/uploads/discontinuing-biofuels-programme-in-the-MNRE.pdf.

86 See http://pib.nic.in/newsite/PrintRelease.aspx?relid=179313.

with the redefined role of emerging developments in the Renewable Sector. In its preamble, the NPB 2018 stresses on the importance of reducing import dependency in Oil & Gas Sector and to does so by following the Government's five pronged strategy of:[87]

- Increasing domestic production
- Adopting biofuels and renewables
- Energy efficiency norms
- Improvement in refinery processes
- Demand substitution

The above lays down the strategic role of biofuels in India's Energy security.

The policy aims to do the following[88]:

1. Increase usage of biofuels in the energy and transportation sectors of the country

2. Utilise, develop and promote domestic feedstock and its utilisation for production of biofuels, substituting fossil fuels while contributing to National Energy Security, Climate change mitigation and creating new employment opportunities in a sustainable way.

3. Encourage application of advance technologies for biofuel generation.

The goal of the policy is to enable availability of biofuels in the Indian market and for doing so has proposed an indicative target of 20% blending of ethanol in petrol and 5% blending of biodiesel in diesel by 2030.[89] To achieve this goal, the policy recommends among other things, the setting up of Second Generation (2G) bio refineries as well as developing new technologies for conversion to biofuels.

The NBP-2018 categorises the following fuels as biofuels, which can be used as transportation fuel of in stationary application as (i) bioethanol; (ii) biodiesel; (iii) advanced biofuels; (iv) drop-in fuels; and (v) bio-CNG.[90]

To Government has adopted the following programmes/strategies for promoting the use of biofuels:[91]

- Ethanol Blending Programme ("EPB") using ethanol derived from multiple sources
- Development of 2G ethanol technologies and its commercialisation
- Biodiesel Blending Programme
- Focus on drop-in fuels produced from MSW, industrial waste, biomass etc.
- Focus on advanced biofuels including bio-CNG, bio-mathanol, DME, bio-hydrogen, bio-jet fuel etc.

87 See NPB 2018, Section 1, para. 1.3.
88 See NPB 2018, Section 2, para. 2.1.
89 See NPB 2018, Section 2, para. 2.2.
90 See NBP 2018, Section 3. Defintions are dealt with in further detail in the subsequent sections.
91 See NPB 2018, Section 4.

- The policy focuses on production of biofuels from indigenous feedstock and establishes a National Biomass Repository, which conducts an appraisal of biomass across the country.
- Thrust given to development of advanced biofuels and other new feedstocks.
- The policy encourages international cooperation via joint research and technology development, field studies, pilot scale plants etc.

Feedstock

In India biofuels are only produced from non-food feedstocks, however the present policy increases the scope of raw material for procurement of ethanol to sugarcane juice, damaged food grains like wheat, broken rice etc. which is unfit for human consumption as well as surplus food grains with approval from NBCC.[92]

Second Generation Ethanol

The policy allows procurement of ethanol produced from other non-food feedstock besides molasses, like cellulosic and lignocelluloses materials including petrochemical route. The policy recognises that globally the 2G-ethanol industry works largely on incentives as the technology is yet to be proven at commercial scale and the ethanol produced thereby is more environment friendly.[93]

Other Biofuels

The policy recognises that the waste generated in India has a huge potential of producing drop-in fuels and generate power including refused derived fuel, biogas/electricity and compost to support agriculture. Furthermore, Algae based biofuels and requisite research and development on this subject will also be promoted to attain techno-commercial viability.[94]

Financing

The policy proposes the following measures, which could be taken in order to promote biofuels:

- Government shall consider declaring the oil extraction and processing units for production of biodiesel and storage and distribution infrastructure for biofuels as a priority sector for loans by financial institutions.[95]
- Encouraging bilateral and multilateral funding including carbon-financing opportunities.[96]

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92 See NPB 2018, Section 5, paras 5.2,5.3 and 5.4.
93 See NPB 2018, Section 5, para. 5.10.3.
94 See NPB 2018, Section 5, para. 5.12.2.
95 See NPB 2018, Section 5, para. 5.13.
96 See NPB 2018, Section 5, para. 5.14.

- Promoting Joint ventures and investments in the biofuel sector and subsequently encouraging 100% foreign direct investment ("FDI") in biofuel technologies through automatic approval route provided the biofuel produced is for domestic use.[97]

Incentives to the Advanced Biofuels Industry

The policy recognises that the advanced biofuel industry is still in a nascent stage therefore it provides for fiscal incentives in the form of tax credits, advance depreciation on plant expenditure, differential pricing vis-à-vis &G Ethanol, viability gap funding etc.[98]

In addition to the fiscal and financial incentives, the policy stresses on the importance of innovation, indigenous R&D and technology development for the deployment of second generation and advanced biofuels using domestic feedstock in India.[99]

Furthermore, at present the Government determines the price of first generation biofuels and the same will be the case for advanced biofuels, however advanced biofuels will be priced differently in order to further incentivise them. This pricing mechanism will be determined by NBCC.[100]

Import and Export of Biofuels

The NPB 2018 states that imports of biofuels shall not be allowed. This has been provided in order to promote the development of domestic biofuel industry and feedstock. Furthermore, the import of feedstock for biodiesel shall be permitted depending of non-availability of domestic feedstock requirement.[101]

Similarly, since the domestic biofuel availability is much lower than the Country's requirements, the policy also states that the export of biofuels shall not be permitted.[102]

4.3.8 Key points of difference between the NBP 2009 and the NPB 2018

Definition of biofuels

The NBP 2009 defines biofuels as 'liquid or gaseous fuels produced from biomass resources'[103] whereas the NPB 2018 defines biofuels as 'fuels produced from renewable sources'. The new policy expands the scope of biofuels to include fuels made from renewable resources, as it is possible to produce biofuels made from renewable resources that are not biomass. However, it defines renewable resources as 'biodegradable fraction of products, wastes and residues from agriculture, forestry, tree based oil and other non-

97 See NPB 2018, Section 5, para. 5.15.
98 See NPB 2018, Section 5, para. 5.17.
99 See NPB 2018, Section 5, para. 5.20.
100 See NPB 2018, Section 5, para. 5.29.
101 See NPB 2018, Section 6, para. 6.2.
102 See NPB 2018, Section 6, para. 6.3.
103 See NBP 2009, Section 3.

edible oils and related industries as well as the biodegradable fraction of industrial and municipal wastes'[104], thereby limiting the scope of renewable sources.

Categories of Biofuels

The NPB 2018 categorises the following fuels as biofuels: (i) bioethanol; (ii) biodiesel; (iii) advanced biofuels; (iv) drop-in fuels; (v) bio-CNG and thereby defines them. Following are the points of difference between the old and new policy.

1. Bioethanol- the definition of bioethanol in the in the NPB 2018 has been expanded includes biomass produced from other renewable resources like industrial waste.[105]

2. Biodiesel- the definition of biodiesel in the NPB 2018 has been limited to that produced from non-edible vegetable oils as opposed to edible and non-edible vegetable oils in the NBP 2009.

3. Advanced Biofuels- The NBP 2009 includes other biofuels such as biomethanol, biosynthetic fuels etc. and makes reference to second-generation biofuels vis-à-vis research and development and fiscal incentives to promote second-generation biofuels. However, it does not define them. The NPB 2018 defines advanced biofuels as fuels which:

   - Are produced from lignocellulosic feedstocks (i.e. agricultural and forestry residues, eg. rice & wheat straw/corn cobs & stover/bagasse, woody biomass), non-food crops (i.e. grasses, algae), or industrial waste and residue streams; and
   - Have low CO2 emission or high GHG reduction and do not compete with food crops for land use.

   The following fuels are classified as advanced biofuels -Second Generation Ethanol, drop-in fuels, algae based 3G biofuels, bio-CNG, bio-methanol, Di Methyl Ether (DME) derived from bio-methanol, bio-hydrogen, drop in fuels with MSW as the source/feedstock material.[106]

4. The NPB 2018 goes on to define drop-in fuels[107] and bio-CNG[108]. These definitions were missing in the NBP 2009.

Use of non-food feedstock

The Approach of the previous policy was based on non-food feedstock raised on degraded or wastelands that are not suited to agriculture. However the present policy increases the scope of raw material for procurement of ethanol to sugarcane juice, damaged food grains

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104 See NPB 2018, Section 3.
105 See NPB 2018, Section 3, para. 3.2 (i).
106 See NPB 2018, Section 3, para. 3.2 (iii).
107 See NPB 2018, Section 3, para. 3.2 (iv).
108 See NPB 2018, Section 3, para. 3.2 (v).

like wheat, broken rice etc. which is unfit for human consumption as well as surplus food grains with approval from National Biofuel Coordination Committee.

Focus on advanced biofuels

The focus of the NBP 2009 was predominantly on first generation bioethanol and bio-diesel. However, the NPB 2018 also focuses on the development of the advanced biofuel industry via financial and fiscal incentives, promoting R&D in this sector, encouraging JVs, as well as pricing advanced biofuels differently when compared with first generation biofuels.

Import/Export of Biofuels

The NBP 2009 allowed import and export of biofuels (after meeting of domestic demands) with prior approvals from the NBCC. However, the NPB 2018 recognises the need to develop the domestic biofuel industry and therefore prohibits imports and exports of biofuels.

Institutional mechanisms

1. The NPB 2018 recommends the creation of a National Biomass Repository, which carries out an appraisal of the biomass available in the country in order to ensure availability of biofuels from indigenous feedstock.[109]

2. The NPB 2018 modifies the composition of the NBCC and Biofuel Steering Committee. The NBCC will now be headed by the Minister of Petroleum and Natural Gas and is composed of representatives of various departments/Ministries. While the Biofuel Steering Committee is chaired by the Joint Secretary (Refinery) Ministry of Petroleum and Natural Gas and is responsible for the implementation of the biofuel program.[110]

3. The NPB 2018 also enumerates the roles and responsibilities of each Ministry.[111]

4.3.9 Legislation and Policies in the Pipeline

The Draft Renewable Energy Act, 2015

Although the National Renewable Energy Act, 2015 is still in draft phase, the draft developed by the MNRE[112] proposes to promote the production of energy through the use of renewable energy sources with an aim to reduce dependence on fossil fuels, ensure security of supply and reduce emissions of CO2 and other greenhouse gases.

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109 See NPB 2018, Section 4, para. 4.2.
110 See NPB 2018, Section 9, para. 9.2.
111 See NPB 2018, Section 7, para. 7.5.
112 The Draft National Renewable Energy Act, 2015, available at https://mnre.gov.in/file-manager/UserFiles/draft-rea-2015.pdf.

If implemented, it attempts to provide a backbone institutional framework to facilitate increase in the use of renewable energy for all relevant applications including heat, electricity and transport.

The draft legislation includes biofuels as a renewable energy source and promotes the development of 'renewable energy fuels for transportation sector with due considerations for sustainability of such fuels and implications for food security of the country.'[113]

The Renewable Energy Law could help in developing a clear institutional, financial, and structural policy roadmap for India at a national level. As the situation stands today, there is a need for a holistic framework legislation, which addresses all renewable energy sources, for electricity generation as well as for other applications such as transport. Therefore the Renewable Energy Law has the potential to fill this gap and act as the central legislation for renewable energy sources.

4.4 Comparative Analysis between the RED-II and the NPB 2018

This section looks into the similarities and differences between the Indian policy on biofuels and the EUs approach on the same, providing a comparative breakdown on issues, which have emerged important for the two jurisdictions. As mentioned in the preamble for the study, this could prove to be fruitful for facilitating further cooperation between governments, technology developers and the industry. For the purpose of this section below, each key issue will be subsequently analysed and compared from the India and EU perspective.

For the purpose of the present study, the comparative analysis is made between the NPB 2018 and the RED-II. However, it is important to note that the RED will only be repealed as from 1 July 2021 and that Member States have to transpose the RED-II by 30 June 2021. The comparative analysis therefore focuses on how the situation will be in the near future. In Section 4.2.6, the key differences between the RED and the RED-II are outlined for the purpose of the present study, allowing the reader to ascertain the situation in the EU until the full transposition of the RED-II.

4.4.1 Instrument

At the outset, before further delving into the substantial issues that concern the two jurisdictions, it would be pertinent to note that the Renewable Energy Directive ("RED"), the primary source of legislation concerning biofuels in the EU, is a legislative Act. The same would apply to the RED-II. The RED-II is the result of several policies and legislative acts that have preceded it. As shown above, these concern biofuels in one-way or another. The Indian approach on biofuels however, at the moment is reflected through its current National Policy on Biofuels ("NPB 2018"), which lays down a framework under which the general biofuel program of India is implemented. The policy is yet to be transposed into

[113] The Draft National Renewable Energy Act, 2015, page 17, available at https://mnre.gov.in/file-manager/UserFiles/draft-rea-2015.pdf.

legislation. Prior to this the Indian biofuel program was advanced through ad hoc programs such as the Ethanol Blending Program or the National Biodiesel Mission undertaken by the MoPNG.

Accordingly, further comparisons between the two jurisdictions will be made on the basis of these two instruments, i.e. the NPB 2018 on the one hand and the RED-II on the other.

4.4.2 Implementation of legislation/policy

Whereas the RED-II establishes a common framework for the Member States for promoting, amongst others, the use of biofuels, it are the individual Member States that must implement the RED-II in their own legislation in order to do so. Similarly, while the RED-II sets mandatory targets that the Member States must achieve for, amongst others, the share of renewable energy in transport, it is through national legislation within the framework established by the RED-II that the Member States must achieve this. The Member States have certain room for policy choices and to decide the manner in which to achieve their targets, as long as this is done within the framework of the RED-II and not contrary to it.

For instance, as discussed in more detail below, the RED-II establishes sustainability criteria for biofuels, and the biofuels that can count towards the target of a Member State must meet these criteria. This means that a Member State must implement these sustainability criteria in one way or another in their national legislation. Whereas this allows the Member States certain flexibility to implement the RED-II in a way that is most suitable to their national situation, this can also lead to discrepancies in treatment between different Member States, leading to potential barriers in the internal market.

In India, the National Biofuel Coordination Committee ("NBCC") as set up under the Policy is responsible for providing the overall coordination, effective end-to-end implementation and monitoring of biofuel programmes as set up under the Policy.[114] The Policy also encourages state level involvement in the implementation of the biofuel programme through the setting up of State Level Biofuel Development Boards. The State Governments have the power to decide on land use for plantation of non-edible oilseed bearing plants or other feedstock for biofuels and on allotment of Government wasteland, degraded land for raising such plantations.

The MoPNG in India is the nodal ministry in charge of the overall coordination for the development of biofuels. It formulates the forthcoming biofuel policies for India and their implementation thereof, undertakes all the activities relating to marketing, retailing and distribution of biofuels as well and research and development on application of biofuels. Furthermore it is responsible for determining the blending levels of biofuels and developing pricing and procurement policies. The Policy also enumerates the roles of the

[114] The NBCC is headed by the Minister, Petroleum and Natural Gas and has representations from the various ministeries involved in the implementation of the Biofuel Programme in India.

concerned ministries and government departments in the effective implementation of the biofuel programme.

4.4.3 Aims and Objectives

The RED-II works towards the objectives of promoting reduction of greenhouse gas emissions through the use of renewable energy sources as well as security of energy supply and providing employment opportunities. It also works towards providing sustainable energy at affordable prices and establishing technological and industrial leadership.

The NPB 2018 aims to mainstream biofuels by increasing their usage in the energy and transportation sectors, which would work towards climate change mitigation, create employment opportunities, contribute to energy security for the country as well as lead to an environmentally sustainable development.

Both the instruments in the EU and in India recognize the role that biofuels could play in achieving similar goals. However, while in the EU the key aim and objective appears to be climate change mitigation and providing sustainable energy at affordable prices, in India the focus appears to be more on energy security and reducing import dependency in the oil & gas sector.

4.4.4 Definition of Biofuels

The NPB 2018 defines "biofuels" as fuels produced from renewable resources and used in place of or in blend with diesel, petrol or other fossil fuels for transport, stationary, portable and other application. It also defines "renewable sources" as being the biodegradable fraction of products, wastes and residues from agriculture, forestry tree based oil, other non-edible oils and related industries as well as the biodegradable fraction of industrial and municipal wastes.

On the other hand, the RED-II defines "biofuels" as liquid fuels for transport produced from biomass. "Biomass" is in turn defined as the biodegradable fraction of products, waste and residues from biological origin from agriculture (including vegetal and animal substances), forestry and related industries including fisheries and aquaculture, as well as the biodegradable fraction of waste, including industrial and municipal waste of biological origin.

A key difference is that the definition of biofuels in the RED-II is limited to liquid transport fuels, while the NPB 2018 does not have such a limitation and goes beyond transport. The RED-II does include a definition of bioliquids, which are used for energy purposes other than transport. Moreover, the RED-II includes definitions for biomass fuels and biogas. In the NPB 2018 these are all referred to as biofuels.

In addition, the definition of "renewable resources" in the NPB 2018 and of "biomass" in the RED-II is quite similar. However, the RED-II places a requirement that the biodegradable fraction of products, waste and residues must be from biological origin, whereas the NPB

2018 does not include such a requirement. This seems to suggest that the definition in the NPB 2018 is wider than that in the RED-II.

Finally, the NPB 2018 provides definitions for different categories of biofuels, including bioethanol, biodiesel, drop-in fuel, bio-CNG and advanced biofuels. Apart from advanced biofuels, which are discussed in further detail below, the RED-II does not provide a further categorisation of biofuels.

4.4.5 Implementation of targets

The NPB 2018 proposes an indicative blending target for biofuels by 2030. Whereas this is not expressly stated in the section on the targets, it appears that this indicative target is directed towards "oil marketing companies".[115] The RED currently adopts an approach whereby it imposes a mandatory target on EU Member States to achieve a certain share of renewable energy in the total energy used in transport. However, the RED-II follows an approach that is closer to the NPB 2018, whereby it imposes an obligation on Member States to require "fuel suppliers" to ensure that the target is reached.

Moreover, whereas the NPB 2018 imposes a target to blend a certain percentage of biofuels into petrol and diesel, the RED-II imposes a target of obtaining a certain share of EU energy consumption from renewable energy sources in transport. There is consequently a difference in approach on how the targets are set. First, the NPB 2018 targets are indicative, while the RED-II targets are mandatory. Second, the NPB 2018 targets are blending targets, while the RED-II targets are targets to obtain a certain share in consumption.

Finally, it is important to note that the targets in the NPB 2018 are specific to biofuels, whereas the targets in the RED-II concern all renewable energy sources in transport. Moreover, the NPB 2018 sets separate targets for the blending of ethanol in petrol on the one hand, and biodiesel in diesel on the other. As also mentioned below, the RED-II does set a specific target for advanced biofuels, whereas the NPB 2018 does not.

4.4.6 Sustainability and Greenhouse Gas Emission Saving Criteria

In the EU the RED-II imposes certain sustainability criteria and greenhouse gas emission saving criteria on biofuels[116] in order for them to be counted towards the target as well as for them to receive financial support. These criteria are imposed on feedstocks cultivated both within and outside the EU and this is done to ensure that biofuels consumed in the EU are sustainable.

The NPB 2018 states "renewable energy resources are indigenous, non-polluting and virtually inexhaustible."[117] It further states that biofuels are derived from renewable biomass resources and wastes, and "therefore seek to provide a higher degree of national

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[115] See NPB 2018 Section 5 G, para. 5.28.
[116] These same criteria are also imposed on bioliquids and biomass fuels.
[117] See NPB 2018, Section 1 para. 1.1.

energy security in an environmentally friendly and sustainable manner".[118] It also calls on the active participation of stakeholder in the areas of generation of feedstock in a sustainable manner on wastelands and encouraging farmers to grow varieties of feedstock on their marginal lands.[119] Whereas this does seem to indicate that biofuels should be sustainable, the NPB 2018 does not contain sustainability criteria for biofuels such as those in the RED-II.

These elements suggest that the RED currently focuses more on combatting climate change than the Indian biofuels policy.

Nevertheless, the NPB 2018 defines advanced biofuels as fuels that have "low CO2 emissions or high GHG reduction and do not compete with food crops for land use". Whereas this is not specifically stated as such, these elements could be considered to constitute sustainability criteria. The NPB 2018 does not provide any such criteria for other biofuels. Conversely, the RED-II does not limit the applicability of its sustainability and greenhouse gas emission saving criteria, imposing these on all biofuels.

4.4.7 Food and Feed Crops

The EU has gradually moved towards limitations placed on biofuels produced from food and feed crops, with a strict cap being placed on such biofuels in the RED-II.

On the other hand, whereas the NBP 2009 approach towards biofuels was solely based on non-food feedstocks, avoiding possible conflict of fuel v food security,[120] the NPB 2018 has expanded its approach towards biofuels to include biofuels produced from damaged food grains that are unfit for human consumption, as well as surplus food grains[121].

4.4.8 Advanced Biofuels

Both the NPB 2018 and the RED-II encourage the development and use of advanced biofuels. The NPB 2018 focuses on the development of the advanced biofuel industry via financial and fiscal incentives, promoting R&D in this sector, encouraging JVs, as well as pricing advanced biofuels differently when compared with first generation biofuels. The RED-II encourages the use of advanced biofuels by imposing a mandatory target and double counting their usage. The NPB 2018 does not provide for specific targets for advanced biofuels.

Importantly, the NPB 2018 and the RED-II each provide a specific definition for advanced biofuels, as outlined in the below table below:

[118] See NPB 2018, Section 1 para. 1.4.
[119] See NPB 2018, Section 7, para. 7.1.
[120] See NBP 2009, Section 1, para. 1.5.
[121] See NPB 2018, Section 5, para. 5.1.

NPB 2018	RED-II
Fuels which are: (1) produced from lignocellulosic feedstocks (i.e. agricultural and forestry residues, e.g. rice & wheat straw/corn cobs & stover/bagasse, woody biomass), non-food crops (i.e. grasses, algae), or industrial waste and residue streams, (2) having low CO2 emission or high GHG reduction and do not compete with food crops for land use. Fuels such as Second Generation (2G) Ethanol, Drop-in fuels, algae based 3G biofuels, bio-CNG, bio-methanol, Di Methyl Ether (DME) derived from bio-methanol, bio- hydrogen, drop in fuels with MSW as the source / feedstock material will qualify as "Advanced Biofuels".	'advanced biofuels' means biofuels that are produced from feedstocks listed in part A of Annex IX: Feedstocks for the production of advanced biofuels, the contribution of which towards the target referred to in the first and second subparagraph 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) Bio-waste as defined in Article 3(4) of Directive 2008/98/EC from private households subject to separate collection as defined in Article 3(11) 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, i.e. 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 as defined in point (r) of the second paragraph of Article 2. (q) Other ligno-cellulosic material as defined in point (q) of the second paragraph of Article 2 except saw logs and veneer logs.

Regarding the definitions, a first element of note is that the definition of advanced biofuels in the RED-II is more detailed than that in the NPB 2018.

With respect to specific feedstocks, in the EU, as far as municipal solid waste is concerned, only the biomass fraction thereof is taken into account for the production of advanced biofuels. In the definition of the NPB 2018, this restriction does not appear.

In addition, as far as industrial waste is concerned, in the EU this also only relates to the biomass fraction and adds the additional restriction that it may not be fit for use in the food or feed chain. Again, in the definition of the NPB 2018, these restrictions do not appear.

Finally, the RED-II also includes biofuels produced from sewage sludge, whereas it is not clear whether this is also the case under the NPB 2018.

4.4.9 Import and Export of Biofuels

To encourage the development of domestic biofuel industry and feedstock, the NPB 2018 states that the import of biofuels will not be allowed. However, depending on the availability of domestic feedstock, import of feedstock for production of biodiesel would be permitted to the extent necessary. Similarly, as the domestic biofuel availability is significantly lower than India's domestic requirements, the NPB 2018 states that the export of biofuels will not be allowed.

The RED-II does not place any such restrictions on imports and exports. In fact, in principle even biofuels that do not meet the sustainability and greenhouse gas emission saving criteria can still be imported an exported, even though they would not count towards any of the targets or be eligible for incentives.

5 EU-INDIA TRADE AND COOPERATION ON ENERGY AND SCIENCE AND TECHNOLOGY

5.1 Introduction

Having compared the policies and existing legislation in both the EU and India it is important to place into perspective the EU-India Cooperation on Energy and Science and Technology. These two joint efforts between the EU and India provide the foundations for and facilitates any cooperation between scientists, academics, technology developers and industry partners between the two parties on collaborative actions on energy issues. Specifically, the Indo-European Clean Energy and Climate Partnership identifies advanced biofuels as an area of common interest. On the basis of this EU-India co-operation the description of the various technology value chains will be described in Section 7.

The European Union and the government of India have signed cooperation agreements in several areas. Of importance to the present study there are two such agreements:

- on Energy[122], and
- on Science & Technology[123].

At the same time, there are trade opportunities between the EU and India in the field of biofuels, as well as certain trade barriers.

5.2 Cooperation on Energy

5.2.1 The EU-India Strategic Partnership

The EU-India Strategic Partnership was created in 2004, but EU-India diplomatic relations date back to 1962. The 1994 EU-India Cooperation Agreement, the legal framework for EU-India relations, boosted political, economic and sectorial cooperation. EU-India relations have evolved through regular Summits, Ministerial and expert-level meetings on a broad range of issues. In addition, regular Parliamentary exchanges have taken place. To underpin that Strategic Partnership, the 2005 Summit adopted the EU-India Joint Action Plan (the "JAP"), which was updated in 2008[124].

122 See https://ec.europa.eu/energy/sites/ener/files/documents/20120210_joint_declaration_eu_india.pdf.

123 See http://ec.europa.eu/research/iscp/pdf/policy/india_agreement.pdf#view=fit&pagemode=none.

124 See https://eeas.europa.eu/sites/eeas/files/eu_india_factsheet.pdf.

5.2.2 The 2016 Summit on Indo-European Clean Energy and Climate Partnership

India has rapidly growing energy needs due to a growing GDP and population as well as a huge energy infrastructure deficit. India is focusing on domestic production, including renewables and nuclear, and on energy efficiency. EU-India energy cooperation was considerably strengthened over the past years, which led to the launch, at the 2016 Summit, of an Indo-European Clean Energy and Climate Partnership. During the EU-India Summit an India-EU Clean Energy and Climate Partnership was announced with the aim of reinforcing cooperation on implementation of the Paris Agreement by strengthening joint activities for deployment of climate friendly energy sources. The partnership brings together, in a joined-up approach, the EU and its Member States, EU and Indian institutions, businesses and civil society. The aim is to jointly implement concrete projects, to promote access to and disseminate clean energy and climate friendly technologies and encourage research and development. The Energy Panel meets annually at senior officials' level and an energy security working group was launched in 2016. Working groups on clean coal and renewable and efficient energy are also active. Energy cooperation is thus ongoing on a broad range of energy issues, like smart grids, energy efficiency, offshore wind and solar, infrastructure and research and innovation (cooling).

At the 2016 Summit cooperation on advance biofuels was not included as an area of common interest and no Working Group was established.

5.2.3 The EU-INDIA Joint Statement on Clean Energy & Climate Change of 6 October 2017

Following discussions between the Directorate General for Energy and the Ministry of Petroleum and Natural Gas both sides agreed to include advanced biofuels as an area of common interest. This was included in the EU-INDIA Joint Statement on Clean Energy & Climate Change[125] issued on 6 October 2017 in New Delhi. The areas of mutual importance to the clean energy transition for which EU and India intend to step up cooperation are:

- The implementation of climate action commitments
- Green cooling and sustainable refrigeration technologies
- Grid integrated Solar Pumping
- Off shore wind
- Energy storage technologies
- Next generation solar cells
- Electric mobility
- Advanced biofuels

As a first action it was the agreement of the Directorate General for Energy and the Ministry of Petroleum and Natural Gas to jointly organize a conference on advanced biofuels on 6-8 March 2018 in New Delhi.

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125 See https://www.consilium.europa.eu/media/23517/eu-india-joint-declaration-climate-and-energy.pdf.

5.3 Cooperation on Science & Technology

The European Union and India have since many years had an agreement for scientific and technological cooperation and such an agreement was signed on 09/08/2002[126] and renewed in 2007. The cooperation covered all the activities of research, technological development and demonstration. The cooperation was reviewed during the 7th Framework Programme (see section 8.2.1 below)[127] by two independent experts in 2012. The review identified certain weaknesses in the agreement and put forward proposals on how to overcome them. The Agreement signed in 2001 and renewed in 2007 regulates EU-India science and technology ("S&T") cooperation by means of 12 articles defining purpose, principles and instruments.

The main purpose is presented in Article 1, which states that the EU and India 'shall encourage and facilitate cooperative research and development activities in science and technology fields of common interest….'. EU-India S&T cooperation relies on 4 principles which refer to i) mutual benefits, ii) reciprocal access to cooperative activities, iii) exchange of information between partners, and iv) the protection of property rights, as outlined in Article 3.

The forms of cooperative activities are listed in Article 5, and include: i) the participation of Indian research institutions and scholars in the projects, funded by the Framework Programme (FP)1, ii) joint projects, iii) the pooling of projects, and iv) the mobility of researchers and the exchange of information and equipment. The 'executive agents' of the Agreement are India's Ministry of Science and Technology (Department of Science and Technology) and the European Commission of the European Communities (Directorate General for Science, Research and Development). According to Article 6, the 'executive agents' establish a bilateral Steering Committee, which is in charge of the coordination and facilitation of the cooperative activities, identifying new priorities and recommending joint initiatives[128]. The recommendations for improvements were along the following three areas:

1. Improving EU-India mutual knowledge;
2. Addressing internal and context weaknesses of EU-India S&T Cooperation Agreement; and
3. Overcoming asymmetric interests.

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126 See http://ec.europa.eu/research/iscp/pdf/policy/india_agreement.pdf#view=fit&pagemode=none.

127 See http://ec.europa.eu/research/iscp/pdf/policy/india-review-brochure.pdf#view=fit&pagemode=none.

128 See http://ec.europa.eu/research/iscp/pdf/policy/india_agreement.pdf#view=fit&pagemode=none.

During the 14th Summit between the European Union and India that took place in New Delhi on 6 October 2017 both sides reconfirmed their commitment to strengthen the India-EU Strategic Partnership based on shared principles and values of democracy, freedom, rule of law and respect for human rights and territorial integrity of States. At the Summit the two sides agreed on a "Roadmap for EU-India Scientific and Technological Cooperation"[129] that prioritized areas for cooperation.

India has also announced that their Science and Technology Programme, IMPRINT[130], is also open to EU researcher participation provided they come with their own funding.

Finally, in order to facilitate cooperation and access to EU funded programmes the EU-INDIA S&T Window Cooperation[131] has been set up. This is an Initiative to help parties access the most relevant information for EU-India S&T Cooperation.

5.4 Trade issues and opportunities

With the growing importance of biofuels in the EU as well as India, there are possibilities for trade and investment opportunities. This has however been called into question with the fact that the NPB 2018 prohibits the import and export of biofuels. This prohibition is very likely to be in violation of the rules of the World Trade Organisation ("WTO"), which in principle prohibit import and export bans, except for certain specific legitimate exceptions. It remains to be seen whether a WTO Member would bring a dispute against India on this matter.

However, for the foreseeable future, it would have been unlikely that there would be a significant increase in exports from the EU to India. Indeed, most biofuels produced in the EU are for domestic consumption. At the same time, India has not been a large exporter of biofuels to the EU, but has also not been an insignificant source of biofuel imports in the recent past. Again, with the increased importance placed on biofuel consumption in India, it is possible that this would have decreased, even without the export ban as outlined in the NPB 2018.

Moreover, the bulk of trade in biofuels concerned first generation biofuels, rather than advanced biofuels. There could have been an opportunity for change in this respect. The EU is currently the second market for advanced biofuels, closely following the US. These markets have been growing and are forecast to continue to grow. Importantly, the highest growth is forecast to take place in Asia Pacific, including in India. This could have increased trade and investment opportunities in the field of advanced biofuels between the EU and

129 See http://ec.europa.eu/research/iscp/pdf/policy/in_roadmap_2017.pdf#view=fit&pagemode=none.
130 See http://imprint-india.org/.
131 See http://www.euindiacoop.org/.

India. Unfortunately, at least in the field of trade, it appears that these opportunities will not materialise in the light of the Indian import and export bans as set out in the NPB 2018.

There is also a potential for additional barriers and other issues. Currently, some of these are more likely to be faced by first generation biofuels. For instance, as described above, biofuels must meet sustainability and greenhouse gas emission saving criteria in the EU to be counted towards renewable energy targets. At the same time, there is a cap on the use of first generation biofuels in the EU. These are potential barriers to trade, which are not faced by advanced biofuels. Indeed, whereas there is a cap on the use of first generation biofuels, advanced biofuels have a target and are double counted.

With the current focus of the EU on advanced biofuels, and the growing focus on advanced biofuels in India, trade in advanced biofuels would have had a potentially brighter future ahead than trade in first generation biofuels. The prohibition on imports and exports as currently laid down in the NBP 2018 seems to have nipped these opportunities in the bud.

Nevertheless, there are clear investment opportunities between the two jurisdictions, where technology developers and investors have ever increasing opportunities to invest in both markets.

6 COST OF BIOFUELS

Producing a full report on cost of biofuels is a lengthy process with dubious results as the technology developers are reluctant to provide information on their cost structures and estimates. For the purposes of the cost of biofuels, the present study has taken into account the findings of the Sub Group on Advanced Biofuels. The approach selected by the Sub Group on Advanced Biofuels was instead to develop a base of estimated production cost ranges for most of the different pathways to the group, and then to present it to its members inviting them to comment. There were several interactions with the members of the Sub Group on Advanced biofuels and the final result presents first-hand views from the technology developers and industry stakeholders.

Figure 2[132] shows the summary of the analysis. The figure shows ranges for the cost of production of the biofuels compared to those of the fossil fuels. The red lines indicate the data found in the literature from various published work while the green lines indicate the cost of production of biofuels adjusted by the members of the Sub Group on Advanced Biofuels. The figure also shows the typical price for lignocellulosic biomass (in the range of 10-20 €/MWh). Table 3[133] below summarises data per value chain and cost of feedstock.

[132] See page 9 in: Ingvar Landälv & Lars Waldheim, "Cost of Biofuels", Sub Group on Advanced Biofuels, edited: Kyriakos Maniatis, Eric van den Heuvel & Stamatis Kalligeros, February 2017.

[133] See page 8 in: Ingvar Landälv & Lars Waldheim, "Cost of Biofuels", Sub Group on Advanced Biofuels, edited: Kyriakos Maniatis, Eric van den Heuvel & Stamatis Kalligeros, February 2017.

Figure 2: Summary of production costs

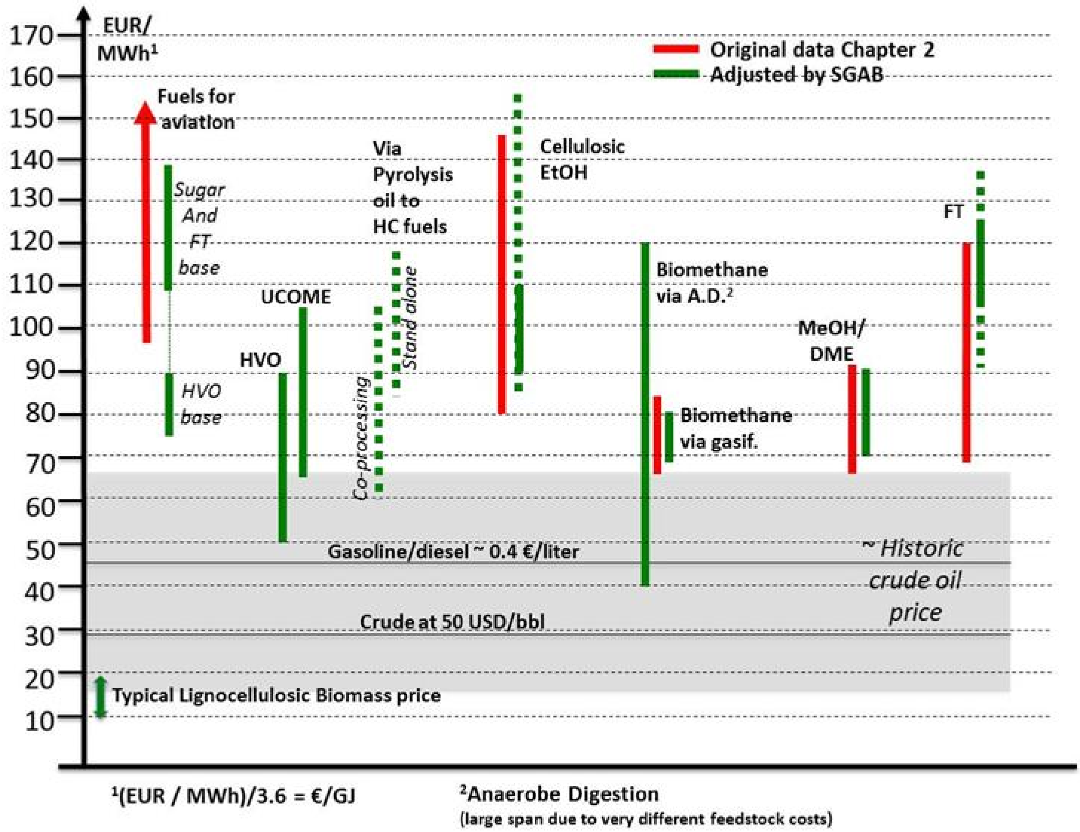

Table 3: Summary of Biofuels Production Costs

Biofuel type production costs	Feedstock price EUR/MWh	Production cost range EUR/MWh	Production cost range EUR/GJ
Aviation HEFA	40-60	80-90	22-25
Aviation sugar fermentation or FT synthesis	Sugar: 65-85 FT: 10-20	110-140	31-39
HVO liquids	40	50-70	14-19
	60	70-90	19-25
UCOME liquids	55	67-68	19
	75	93-104	26-29
Biomethane from biogas	0-80	40-120	11-34

Cellulosic ethanol	13	103	29
	10	85	24
Biomethane & ethanol from waste	(x)[134]	67-87	19-24
FT liquids from wood	20	105-139	29-35
	10-15	90-105	25-29
Biomethane, methanol or DME (Dimethyl Ether) from wood	20	71-91	20-25
	10-15	56-75	16-21
Pyrolysis bio-oil co-processing	10-20	58-104	14-27
Pyrolysis bio-oil stand alone	10-20	83-118	23-33

Key Messages on the Cost of production of biofuels:

- Biofuels are and, with rare exceptions, will remain more expensive than fossil fuels unless the cost of oil increases significantly and/or the cost of climate change mitigation is taken into account when in estimating the cost of fossil fuels.
- The cost of the biomass feedstock plays an important role in the overall production cost of the biofuels. Unless the biomass feedstock has a zero or negative cost (as in the case of municipal solid waste), at present there are no possibilities for competitive cost production.
- Biomethane produced from biogas generated via anaerobic digestion of waste streams is commercially available at present and has the lowest cost at about 40-50 EUR/MWh. In certain niche markets it can be competitive to fossil fuels.
- Hydrotreated Vegetable Oils (HVO) is commercially available at present and has a production cost in the range of 50-90 EUR/MWh subject to the cost of the feedstock. HVO used in aviation can be produced at a cost of 80-90 EUR/MWh and it is the only biofuel at present that has been produced and used for commercial flights.
- Cellulosic ethanol is at the verge of commercialisation with several industrial scale demonstration plants currently in operation or commissioning. The production cost of cellulosic ethanol is estimated in the range of 90-110 EUR/MWh subject to the feedstock cost.
- All other biofuels and value chains are still in the large scale demonstration plant stage and their production costs can vary significantly, and are estimated in the range of 80-140 EUR/MWh.

134 X: Base: Net tipping fee of 55 EUR/ton, energy content of 4.4 MWh/ton, Conversion efficiency of 50%.

7 TECHNOLOGY AVAILABILITY AND READINESS FOR ADVANCED BIOFUELS

7.1 Introduction

This section of the report aims at providing the reader with a focused description of advanced biofuels technologies, technology developers and plants at high technology readiness level ("TRL") for advanced biofuels both in the EU and India. A detailed description of the available technologies in the EU and India can be found in Annex I of this report.

There are numerous technologies, value chains and possible applications making this area an exciting one. Some of the value chains are ready to be commercialized and few are actually commercial. Others are at *first-of-a-kind* (FOAK) plant level ready to cross the valley of death and reach market deployment while there are few that still have to reach the FOAK level before deployment can be considered.

Since all use various types of biomass resources, have different production capacities and produce different types of biofuels for different applications; it is impossible to pick winners. Actually this would be a mistake since the EU and India will need all sustainable advanced biofuels that can be produced.

7.2 Thermal Processing

7.2.1 Gasification

Gasification has a long history in the EU and several technology developers have been trying to develop gasification platforms from the very small systems to the large scale commercial plants. The success has been limited in the small capacity based on downdraft gasifiers destined for power and heat applications, while better achievements have been attained in the large scale. European technology developers have gained significant experience from running large scale demonstration facilities, however the market and policy conditions have been a barrier to the further deployment of gasification technologies for advanced biofuels. Although at present there are no large scale commercial facilities operating on gasification for advanced biofuels, few projects are in the planning phase and it is expected that their construction could start soon after the RED-II has been adopted and the various Members States of the EU have enacted appropriate legislation in their national legislation.

In India there are currently no gasification plants for the production of advanced biofuels, although there is a significant degree of work in gasification for power and heat generation. This however is beyond the scope of the present study.

7.2.2 Fast Pyrolysis

Few companies have developed fast pyrolysis over several years in the EU, which has provided continuity in the development of the technology mainly in the Netherlands and Finland. Initial work focused on producing a fuel oil for power and heat applications and few commercial facilities are operational at present in the EU with good prospects for further commercialisation. The focus recently has shifted to co-processing bio-oil in existing refineries aiming at reducing downstream processing costs in upgrading the bio-oil into a transport fuel.

In India there have been few efforts to develop fast pyrolysis, however significant efforts have been made based on the process of thermochemical catalytic technology ,which has reached the large scale demonstration phase. This technology converts biomass directly into 'drop in fuels'.

7.2.3 Hydrotreated Vegetable Oils ("HVO")

HVO has been a success story in the EU with NESTE[135] being the first company world-wide to produce this drop-in fuel on a commercial basis and has built plants worldwide. Other European refineries are reconverting existing oil refineries into HVO bio refineries. The problem this market and value chain faces in the EU is the fact that large scale commercial refineries need large volumes of vegetable oils and the most common feedstock is palm oil which faces political and stakeholders' opposition in the EU.

There is no dedicated HVO plant in India however **Indian Oil Corporation**[136] Technology has been examining the co-processing of non-edible oils in petroleum refinery. In this technology it is not necessary to set up a new green field-processing unit, but only minor modifications are required in the existing petroleum processing plant.

7.3 Biological Conversion

7.3.1 Cellulosic Alcohols

Cellulosic ethanol has been successfully developed in the EU with main research and innovation emphasis on the development of enzymes and yeasts, which are the key components in converting biomass into liquid fuels. This value chain is ready for commercialisation and several demonstration plants are being built while few commercial plants are being planned for construction.

In line with India's Ethanol Blending Programme, to keep up with the blending targets, at present only final (C heavy) molasses have been used as feedstock, which has remained largely inadequate. Therefore in light of this limitation of availability of final molasses, it became essential to examine cellulosic feedstocks that can be used for producing ethanol. It is proposed to set up 12 plants based on cellulosic ethanol by public sector OMCs at

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135 See https://www.neste.com/
136 See https://www.iocl.com/.

various locations in India. This has created a significant market interest in advanced biofuels with cellulosic ethanol.

7.3.2 Biomethane

Biomethane from anaerobic digestion is a commercial technology in the EU. There are more than 17,000 biogas plants in the EU and the majority of them are decentralized CHP facilities. About 400 of them produce biomethane with the majority of such plants in Germany, Sweden and the UK. Biomethane is mainly injected into the natural gas grid and in few cases it is used in captive fleets where centralized filling stations are available. Both anaerobic digestion plants and upgrading of the biogas to biomethane are fully commercial technologies with several technology providers.

In India, many medium scale and large-scale biogas and biomethane plants were set up using effluent of distilleries, breweries and other industries. In addition, biogas & biomethane plants based on sludge of Sewage Treatment Plant, MSW, crop residues, kitchen waste etc. have also been set up. Till recently, biogas plants were used to produce electricity and steam (CHP), especially in distilleries. However, there is an increasing trend to set up bio-CNG plants in India. There is a largescale program for producing bio-CNG using crop residues such as rice straw.

7.4 Algae

Recent work on biofuels from algae indicated that at present the cost of such value chains is prohibitive and in the EU algae are cultivated for other market segments (food, feed, cosmetics, etc). However, using algae in waste water treatment facilities to purify waste water has been a successful application by AQUALIA, Spain[137].

In India **Phycolinc Technologies PVT LTD** in Ahmedabad is engaged in implementing Phycospectrum Environmental Research Centre's (PERC), algae remediation technology in industries in India. The company uses phycoremediation for the removal or biotransformation of pollutants from wastewater[138]. Microalgae are used during the tertiary treatment of wastewater in maturation ponds. Algae are known to remove or bio-convert nitrogen compounds and other contaminants including heavy metals.

7.5 Power to X

Power to X refers to technologies that convert power to liquid or gaseous fuels. There are several pilots and demonstration plants in the EU however all these are considered to be far from commercialisation. Since India is an energy deficit country, Power to X does not have any prospects in India in the short or medium term.

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137 See http://www.fcc.es/en/water-presentation

138 See http://www.phycospectrum.in/industrial-projects.

7.6 Carbon Capture and Utilisation (CCU)

Carbon Capture and Utilisation (CCU) is an interesting approach to increase the overall carbon conversion efficiency of a certain industrial processes (such as steel). Although there is significant interest in both the EU and India for market applications of CCU technologies there are no technology developers in the EU or India who have been able to build large scale demonstration facilities.

8 FINANCING MECHANISMS FOR DEMONSTRATION PLANTS IN THE TRL RANGE OF 6-9

8.1 Introduction

All technologies have to go through the valley of death to be able to reach the deployment stage. With state of the art technologies and first-of-a-kind (FOAK) plants it is necessary to provide adequate financing to assist the technology developers in covering the technical and other risks. This financing can be significant and in the range of several hundreds of million euros and therefore dedicated financing mechanisms are needed. Often the actual needs of the industry and technology developers are not well understood resulting in failure of the mechanisms.

8.2 Financing mechanisms in the EU

Financing in the EU comes from several sources such as National plans and mechanisms to promote renewable energy sources, the European Union's innovation programs and some dedicated actions managed by the European Commission to provide dedicated funding for innovative technologies and FOAKs. However the main tool is that of the Framework Programmes for Research and Innovation of the European Union. These programmes (see below FP7 & H2020) operate on annual calls in which the priorities of the Call Topics vary. Technology developers and research organisations submit proposals at certain deadlines. These proposals are then evaluated by independent experts hired by the European Commission and scored against specific criteria. The consortia of the successful proposals that get the highest score are then contracted to implement the projects. All proposals must be submitted by consortia with organisations from at least 3 Member States or 2 Member States and an Associated Country[139]. The participation of Indian organisations in the current Framework Programme is described below in b) Horizon 2020.

8.2.1 Seventh Framework Programme (FP7)

The Seventh Framework Programme of the European Community for *research, technological development and demonstration activities* was implemented over the period 2007-2013 (FP7)[140]. With a voted budget of EUR 55 billion, FP7 was one of the largest transnational competitive RTD programmes in the world[141]. The main focus of FP7 was on science, especially the promotion of collaborative research and excellence. FP7 has paved

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[139] See http://ec.europa.eu/research/participants/data/ref/h2020/grants_manual/hi/3cpart/h2020-hi-list-ac_en.pdf.

[140] Decision No 1982/2006/EC of the European Parliament and of the Council of 18 December 2006.

[141] Brussels, 19.1.2016, COM(2016) 5 final. See https://ec.europa.eu/research/evaluations/pdf/archive/fp7-ex-post_evaluation/commission_communication_1_en_act_part1.pdf#view=fit&pagemode=none.

the way towards contributing to the achievement of the priorities of the Juncker Commission, by developing a common knowledge and technology base and innovative solutions in areas addressing pan-European challenges, for instance in the areas of environment, transport energy, digital single market, health, food safety and security. FP7 was a global programme with participants from 170 countries and funded projects in all areas covered by the Sustainable Development Goals. FP7 fostered growth and jobs and, in particular during the financial and economic crisis, helped maintain research and innovation activities at national level.

The budget for energy related projects was €2 350 million. CORDIS[142] is the data basis for accessing publicly available information on completed and ongoing FP7 Contracts[143].

Numerous projects have been supported for advanced biofuels under FP7 however the large scale demonstration project based on industrial leadership were managed by the Directorate General for Energy and these are listed in Table 18 below.

Table 18: DG ENER-Funded Large-Scale Demonstration Projects under FP7

EC Biofuel Cluster	Contract Acronym	Coordinator	Technology Provider	Biofuel	EC Support € M	Biomass	Production Capacity
Synthetic	OPTFUEL	VW	Choren Industries	Fischer-Tropsch	7.8	Wood	15,000 t/y
	BIO DME	Volvo	Chemrec	Dimethyl-ether	8.2	Black Liquor	600 t/y -150 days operation)
Cellulosic Ethanol	BIOLYFE	Chemtex Italia	Chemtex Italia	Ethanol	8.6	Various	40,000 t/y
	FIBREEtOH	UPM	UPM	Ethanol	8.6	Fibre	20,000 t/y
	KACELLE	Dong Energy	Inbicon	Ethanol	9.1	Straw	20,000 t/y
	LED	Abengoa	Abengoa	Ethanol	8.6	Corn res.	50,000 t/y
	GOMETHA*	Biochemtex	Biochetemx	Ethanol	19.0	Various	80.000 t/y
	SUNLIQUID*	Clariant	Clariant	Ethanol	19.0	Various	60,000 t/y
Pyrolysis	EMPYRO	BTG	BTG	Bio-oil	5.0	Wood	17,400 t/y
Algae	ALL-GAS	Aqualia	Aqualia	Biodiesel & biomethane	7.1	Algae	90t/ha.y algae on 10 ha
	BIOFAT	A4F	Alga Fuel	Biodiesel & ethanol	7.1	Algae	90t/ha.y algae on 10 ha

142 See https://cordis.europa.eu/guidance/archive_en.

143 For a search on completed and ongoing projects see https://cordis.europa.eu/projects/result_en?q=%28contenttype%3D%27project%27%20OR%20/result/relations/categories/resultCategory/code%3D%27brief%27%2C%27report%27%29%20AND%20programme/pga%3D%27H2020-EU.3.3.%2A%27.

	INTESUSAL	CPI	CPI	Biodiesel	5.0	Algae	90t/ha.y algae on 10 ha
Bio-Jet	BFSJ	Swedish Biofuels	Swedish Biofuels	Bio-Jet & diesel	27.8	MSW, wood	5,000 t/y 5,000 t/y
	Biorefly	Chemtex Italia	Chemtex Italia	Bio-Jet	13.8	Lignin	2,000 t/y
					Total=155.4		

In addition to the above projects DG ENER provided 15 million € for a joint call with the Directorate General for Research & Innovation on Biorefineries. Thus the total ENER related funding is about 170 million €.

The above projects were the first large scale demonstration projects on advanced biofuels in the EU and in some areas (such as cellulosic ethanol) on a global scale. They were instrumental in providing the technology providers with a dedicated support for FOAKs as well as a conducive environment for investing in such technologies. Comparatively seen the EC support was relative low and on average about 15-20% of the total investment.

FP7 was a very successful programme for advanced biofuels plants and it helped the EU technology developers to be the first to construct and operate FOAKs especially in the sector of cellulosic ethanol. It is also characteristic that all cellulosic ethanol plants built in the US are based on EU technology. Abengoa built the Hugoton[144] plant (95 million litre/yr) in the US based on the results they obtained from their demonstration plant in Salamanca[145], Spain. The Salamanca plant was supported by the European Union's FP6 Programme. Abengoa Bioenergy went bankrupt and the Hugoton plant (belonging to Abengoa Bioenergy Biomass of Kansas) was sold to Synata Bio for $48.5 million[146]

The LIBERTY plant of the joint venture POET /DSM[147] is located at Emmetsburg, Iowa and produces 60,000 t/y bioethanol. It is a cooperative between these two companies. POET[148], based in Sioux Falls, South Dakota, is one of the world's largest ethanol producers, with a 25-year history as an American renewable fuel pioneer. The company, with 27 grain ethanol plants, has expertise in organizing feedstock availability, conditioning and storage. Royal DSM[149], a global science-based company active in health, nutrition and materials, has a decades-long legacy of driving environmental progress and technological advancement. DSM has a proven track record in conversion technologies (yeast and enzymes) for

144 See http://www.abengoabioenergy.com/web/en/2g_hugoton_project/.

145 See http://www.abengoabioenergy.com/web/en/prensa/noticias/historico/2005/200510_noticias.html.

146 See http://www.hpj.com/ag_news/hugoton-cellulosic-ethanol-plant-sold-out-of-bankruptcy/article_ae8fb952-c85f-11e6-87dc-0b12cf1982e3.html.

147 See http://poet-dsm.com/liberty.

148 See https://poet.com/biofuel.

149 See https://www.dsm.com/corporate/home.html.

cellulosic biomass to ethanol. DSM has the technology that can co-ferment all C6 and C5 sugars (xylose & arabinose).

DuPont[150] built the cellulosic ethanol plant in Nevada Iowa with a production capacity of about 90,000 t/y bioethanol produced from about 350,000 dry tonnes of corn stover. However DuPont didn't have in-house expertise and in order to obtain the technology related to enzymes and yeasts it bought the Danish company Danesco with its Genecor[151] division, which was a leader in this field. However in November 2017 DuPont decided to close the facility and to try and find a buyer[152].

The only technology area that failed to make any significant progress is that of synthetic biofuels and especially the Fischer-Tropsch (FT) value chain. The OPTFUEL[153] project had to be stopped and although the plant was able to produce FT fuel CHOREN[154], the technology provider, went into bankruptcy[155].

Participation of Indian Organisations in FP7

India participated in 181 FP7 projects and the European Commission's contribution received by Indian participants was about €35.8m during the FP7. The participation of India in the 7th Framework Programme increased significantly when compared to previous frameworks. The number of India's participants rose to 142 in FP6 (2002-2006) and more than doubled in FP7 (2007-2013) which counted 305 participants. The highest degree of cooperation is in the Health and Knowledge-Based Bio-Economy areas. Other active cooperation areas are Environment, Security and Social Sciences and Humanities[156].

8.2.2 Horizon 2020 (H2020)

The 8th Framework Programme of the European Community for research, technological development and demonstration activities was given the acronym Horizon 2020 and is being implemented over the period 2014-2020 (H2020)[157]. A budget of €5 931 million has been allocated to non-nuclear energy research for the period 2014-2020.

Horizon 2020 is the biggest EU Research and Innovation programme ever with nearly €80 billion of funding available over 7 years (2014 to 2020) – in addition to the private investment that this money will attract. It promises more breakthroughs, discoveries and world-firsts by taking great ideas from the lab to the market. Energy is addressed under the "Energy Challenge" and the programme is designed to support the transition to a

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150 See http://www.dupont.com/.
151 See http://biosciences.dupont.com/about-us/history/.
152 See http://www.biofuelsdigest.com/bdigest/2017/11/02/breaking-news-dowdupont-to-exit-cellulosic-ethanol-business/.
153 See https://cordis.europa.eu/project/rcn/90314_en.html.
154 See http://www.choren.com/en/company.html.
155 See http://www.energytrendsinsider.com/2011/07/08/what-happened-at-choren/.
156 See https://indigoprojects.eu/object/news/139.
157 See https://ec.europa.eu/programmes/horizon2020/.

reliable, sustainable and competitive energy system. 3 work programmes have been prepared:

- Work Programme 2014-2015[158]
- Work Programme 2016-2017[159]
- Work Programme 2018-2020[160]

In the last Work Programme the parts that relate to 2019 and 2020 are provided at this stage on an indicative basis. These will be decided during 2018 and/or 2019.

On every year there are calls related to advanced biofuels; for example for 2018 the following Call Topics can be found:

- LC-SC3-RES-21-2018: *Development of next generation biofuels and alternative renewable fuel technologies for road transport*; (page 67 in footnote 54)
- LC-SC3-RES-22-2018: *Demonstration of cost effective advanced biofuel pathways in retrofitted existing industrial installations*; (page 67 in footnote 54)

While for 2019 the following Call Topics have been planned:

- LC-SC3-RES-23-2019: *Development of next generation biofuel and alternative renewable fuel technologies for aviation and shipping*; (page 68 in footnote 54)
- LC-SC3-RES-24-2019: Boosting pre-commercial production of advanced aviation biofuels; (page 69 in footnote 54)

In addition to these Call Topics that are dedicated to innovative technologies, there are others addressing the innovative transport solution in cities under the Smart Cities area (see page 95 in footnote 54); however, these are out of scope for this study.

Finally in Section B of the Work Programme there several studies related to advanced biofuels have been proposed to be undertaken via open tender calls, for example:

- Support for policy and market development for alternative and renewable transport fuels and products (page 166 in footnote 54).

Also under Section B there are dedicated Calls for standardization work under the European Centre for Standardisation (CEN), for example:

- Standardisation request to the CEN for algae and algae-based products in support of the implementation of the RED II (page 181 in footnote 54).

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158 See http://ec.europa.eu/research/participants/data/ref/h2020/wp/2014_2015/main/h2020-wp1415-energy_en.pdf.

159 See http://ec.europa.eu/research/participants/data/ref/h2020/wp/2016_2017/main/h2020-wp1617-energy_en.pdf.

160 See http://ec.europa.eu/research/participants/data/ref/h2020/wp/2018-2020/main/h2020-wp1820-energy_en.pdf.

However, due to the structure of the Call Topics and the overall strategy of H2020 no large scale demonstration project has been proposed yet. Therefore although H2020 has contributed significantly to research and innovation for the TRL 1-7, little has been achieved for large industry scale demonstration projects in the TRL 8-9.

Bio-based Industries Joint Undertaking

The Bio-Based Industries Joint Undertaking[161] (BBI JU) is a €3.7 billion Public-Private Partnership between the EU and the Bio-based Industries Consortium. Council Regulation (EU) No 560/2014 of 6 May 2014 established it.

It operates under Horizon 2020, with a total budget of 3.7 billion € which is expected to be allocated to innovative investments in the area of the bio economy. This budget consists of 975 million € of EU funds provided by the Horizon 2020 programme and 2.7 billion € of private investments form the participating stakeholders. Furthermore the BBI JU will be leveraging capital markets aiming to attract additional private and public funds (e.g. synergies with EU Structural Funds[162]).

The BBI JU's mission is to implement, under Horizon 2020 rules, the Strategic Innovation and Research Agenda (SIRA)[163], which was developed by the industry and validated by the European Commission. BBI JU organises Calls for proposals to support research, demonstration and deployment activities enabling the collaboration between stakeholders along the entire value chains covering primary production of biomass, processing industry and final use. Numerous projects have been supported by the BBI JU[164] and these will accelerate the deployment of innovative technologies in the EU.

Participation of Indian Organisations in H2020

Indian researchers, universities, research organisations and enterprises are able to team up with any European partners to participate in projects under Horizon 2020 and make the best use of Europe's scientific excellence[165]. Through participation in Horizon 2020, Indian participants can gain great benefits from access to excellent talent, knowledge, data, infrastructures and connection to world-leading teams, networks and value chains.

As to funding, participants from India, just like the other emerging economies (BRIC) are no longer automatically eligible for funding. Indian participants have therefore to find the financial resources for their participation in Horizon 2020 collaborative projects. These could be their own funds or funds from Indian ministries, foundations and other organisations that fund international research and innovation activities. Contributions can

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161 See https://www.bbi-europe.eu/.

162 See https://ec.europa.eu/info/funding-tenders/funding-opportunities/funding-programmes/overview-funding-programmes/european-structural-and-investment-funds_en.

163 See https://www.bbi-europe.eu/sites/default/files/sira-2017.pdf.

164 See https://www.bbi-europe.eu/projects.

165 See http://ec.europa.eu/research/participants/data/ref/h2020/other/hi/h2020_localsupp_india_en.pdf.

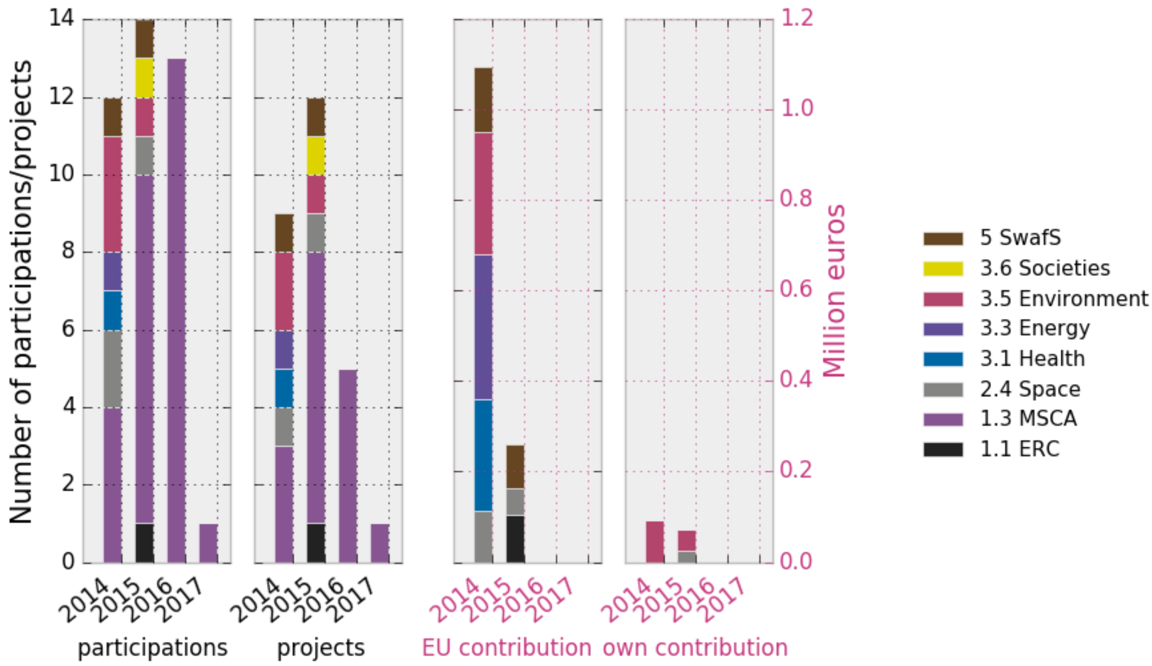
also be made in kind. In exceptional circumstances, funding can be received by H2020 directly if the participation of an Indian organisation is essential for the execution of the project.

For this purpose, the Indian Department of Science (DST), the Indian Department of Biotechnology (DBT) and the Ministry of Earth Sciences (MoES) have established a Co-Funding Mechanism (CFM) to fund the successful Indian participants in a number of pre-identified calls of proposals. The detailed information on the co-funding modalities for Indian researchers can be found on DBT website: http://www.dbtindia.nic.in/dbt-ec_h2020_call_2017-18/.

A dedicated guide for Indian users[166] has been developed and interested organisations are advised to read it carefully.

Figure 43 shows the participation of Indian organisations in Horizon 2020 up to 17/10/2017.

Figure 43: Participation of Indian organisations in H2020 up to 17/10/2017



Note: Participations of beneficiaries, third-parties and partner-organisations.
Source: DG Research and Innovation - International Cooperation
Data: CORDA (JRC, EIT and art.185 not included); extraction date: 17/10/2017

8.2.3 NER 300[167]

The funds for the NER300 grants were obtained by selling up to 300 million carbon allowances (rights to emit 1 ton of CO_2) from the set-aside for the New Entrants' Reserve (NER i.e. new industries established after the ETS system was implemented). The sales of

[166] See http://eeas.europa.eu/archives/delegations/india/documents/h2020_brochure-india-aug_2014.pdf.

[167] See page 89 in: "Building up the future", Sub Group on Advanced Biofuels, edited: Kyriakos Maniatis, Lars Waldheim, Eric van den Heuvel & Stamatis Kalligeros, February 2017.

the European Union Allowances ("EUAs") was EUR 1.65 billion from the first tranche sales (200 million EUAs) in 2011-2012 and EUR 0.55 billion from the sales of the remaining 100 million EUAs in the second tranche in 2013-2014. The funding from the NER300 program can be obtained for installations of different innovative energy projects including renewable energy, smart grids and CCS.

The selection of projects was based on call for proposals. Each of the EU Member States could be granted at least one project and no Member State would be granted more than three projects in total.

However, the grant is not received directly in the beginning of a project or in proportion to the project spending (unless a MS provides a corresponding capital guarantee). Instead, the grant funding to a project is only receivable once the plant has been constructed and has come into operation. The grant will then be paid during the initial five years of operation based on a pro rata basis of the actual production achieved relative to the nameplate production capacity, but with a margin for reduced capacity factor for the use of new technologies. This margin required that in order to obtain 100% of the grant funding allocated to a project, the actual capacity over the first five years of operation must reach 75% of the nominal output.

In the calls of NER 300 several advanced biofuel projects were proposed and approved, amongst which were 3 commercial scale projects to produce Fischer-Tropsch biofuels from biomass. However all three were cancelled when it became apparent that all the technical risks had to be undertaken by the technology developers and investors.

In conclusion the NER 300 was ill conceived for FOAK plants and projects on advanced biofuels.

Only the VERBIO biomethane plant was supported by the NER 300 as well as a relative small section of the Cresentino cellulosic ethanol plant of Biochemtex. However, the VERBIO biomethane plat it is not an actual FOAK since the basic technology had already been developed while the Cresentino plant had already been supported by FP7.

8.2.4 INNOFIN EU Finance for Innovators

Under the Horizon 2020 programme the European Commission is developing the New Financial Instrument[168] to provide easier access, via financial instruments, to loans, guarantees, counter-guarantees and hybrid, mezzanine and equity finance for innovative projects.

InnovFin – EU Finance for Innovators is the financial instrument under which the EU promotes a range of debt and equity products and advisory services in order to effectively boosts the availability of finance for research and innovation activities in Europe. It is basically a range of tailored products – from guarantees for intermediaries that lend to

168 See https://ec.europa.eu/programmes/horizon2020/en/h2020-section/access-risk-finance.

SMEs to direct loans to enterprises - helping support the smallest to the largest R&I projects in the EU and countries associated to Horizon 2020.

The European Investment Bank ("EIB")[169] and the European Investment Fund ("EIF")[170] are the two main financial institutions assisting in implementing each financial instrument facility on behalf of and in partnership with the European Commission. The European Investment Bank provides loans to medium to larger companies, or guarantees to banks lending to them. It also provides a range of technical assistance and advisory services, in order to help project promoters to make research, development and innovation bankable.

The European Commission launched a Public Consultation for an Innovation Fund on 15/01/2018 and the deadline of comments was on 10/04/2018[171]. The EU plans to invest a part of the revenues from the EU Emissions Trading System (EU ETS) into low-carbon technology demonstration projects, through a new Innovation Fund. This will follow the same approach as with the NER300. The European Commission is welcoming contributions from:

- Stakeholders directly affected by Commission Regulation and highly interested (most likely to benefit from the funding): industries, in particular steel, iron, aluminium, copper, oil refining, chemicals & bio-based industries and pulp & paper, cement, lime, glass & ceramics, renewable energy generation and storage, and industries/power plants utilising CCS/CCU.
- Stakeholders indirectly affected by Commission Regulation and highly interested (are not likely to benefit from the funding, but have stated an interest in the initiative): EU/National Industry associations, Environmental NGOs, National/Regional authorities and EU institutions; European Investment Bank/ EU/national financial institutions; Member States.
- General Public.

The results of the Consultation are expected within 2 months after the deadline. After the Consultation the European Commission will set up the final details of this new instrument by the end of 2018. The EU biofuels industry has been recommended to contribute to this Public Consultation to ensure that the shortcomings of the NER300 will be avoided.

8.3 Financing mechanisms in India

Funding and financial support by the Government is essential for setting up of capital intensive advanced biofuel projects in India. In 2009 Government of India formulated a policy on biofuels which proposed an indicative target of 20% blending of bio-fuels in petrol and diesel by 2017. However, this target was not realized. It also proposed to give a major thrust to research, development and demonstration with focus on second generation

169 See http://www.eib.org/.
170 See http://www.eif.org/.
171 See https://ec.europa.eu/clima/consultations/public-consultation-establishment-innovation-fund_en.

biofuels and sought International cooperation in this sector. Government of India has announced a new biofuel policy, NPB 2018, which includes funding of advanced biofuels. The policy proposes an indicative target of 20% blending of ethanol in petrol and 5% of biodiesel in diesel by 2030. The policy gives permission to use sugarcane juice or 'B heavy' molasses, whenever sugar production is likely to be surplus, and also damaged grain for ethanol production. It also proposes that 1-G and 2-G Ethanol, Biodiesel, MSW to Fuel and Bio-CNG together with Methanol (DME) be promoted, which will contribute to the advancement of rural economy. The policy classifies second generation (2G) Ethanol, drop-in-fuels, bio-CNG, algae based 3G biofuels, bio-methanol, DME, bio-hydrogen etc. as advanced biofuels and proposes a National Biofuel Fund for providing financial incentives.[172] It plans a minimum of production capacity of 1 billion litres per year of advanced biofuels with an investment of Rs 50 billion. The Government of India has already asked state owned oil companies to set up 12 ethanol plants at various locations. Financial support is envisaged for integrated bioethanol projects using lignocellulosic biomass and other renewable feedstocks. In addition, to support new project, the OMCs are likely to show willingness to a 15 year purchase agreements with 2G ethanol producers. The scheme also proposes for financial support to promote investment in the initial few commercial scale 2G ethanol bio-refineries by means of Viability Gap Funding (VGF) of 20 per cent of the project cost with a maximum of Rs. 1500 million. Furthermore, the policy also proposes that 2G Bio-ethanol project developers can also obtain grant from state government or PSEs or other agencies up to 20 per cent of the total project cost. For the proposed funding scheme, the government plans to allocate Rs. 49.5 billion for commercial and demonstration projects and Rs. 500 million as administrative charges to Centre for High Technology for coordinating the scheme.

Furthermore the policy also proposes exploring generating carbon credits for savings on CO2 emissions on the account of biofuel feedstock generation and use of biofuels.[173] Finally it encourages the National Bank for Agriculture and Rural Development ("NABARD") and other public sector banks to provide funding and financial assistance through soft loans etc.[174]

It is understood from discussions held during the EU-India Conference on Advance Biofuels, 6-8 March, 2018, New Delhi, that five of the 12 biorefineries are in advanced state of negotiations between the oil companies, the technology developers and the Ministry of Petroleum and Natural Gas.

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172 See NPB 2018 Section 5 D, paras 5.16, 5.17.
173 See NPB 2018 Section 5 D, para 5.18.
174 See NPB 2018 Section 5 D, para 5.19.

9 CONCLUSIONS

The analysis on the overview and comparison of the existing legislation and policies in the EU and India revealed the following elements:

- In both the EU and India the current instruments have recently undergone a review. In India the New National Policy on Biofuels was adopted in May 2018. In the EU, the RED-II is in the process of adoption, and is likely to be adopted in the near future. These developments will bring the two systems closer in their approach, in particular with the increased focus on advanced biofuels.

- Whereas biofuels have had a relatively long history in both jurisdictions, there has been a more established framework for biofuels in the EU than in India, even though India is starting to catch up.

- The key difference is that the EU has a legislative framework for the promotion of biofuels, whereas India merely has a policy. While there are other differences in approach, the analysis has shown that there are several similarities and that there appears to be an increasing convergence between the two systems.

- Both the instruments recognise the role of biofuels in achieving similar goals of climate change mitigation, energy security as well as creating employment opportunities. However, in the EU the key goal is climate change mitigation, while in India they focus is primarily on energy security.

- The NPB 2018 recognises biofuels as environmentally friendly fuels and therefore does not specifically provide for sustainability criteria or a greenhouse gas emission saving criteria for biofuels. It does however provide that advanced biofuels should have low CO_2 emission or high GHG reduction and do not compete with food crops for land use. This significantly differs from the EU approach, which has set sustainability and greenhouse gas emission saving criteria in the RED-II. Such criteria are currently missing from the Indian biofuel policy as it stands today.

- Overall, both instruments aim to progress in a similar direction. The key difference is the degree to which this is done. For instance, whereas both instruments encourage the development of advanced or second-generation biofuels, the RED-II goes further than the NPB 2018. The NPB 2018 merely places a focus on financial incentives and R&D for advanced biofuels, whereas the RED-II goes a step further and double counts the use thereof and sets a specific 3,5% mandatory target for advanced biofuels by 2030.

- In addition, whereas both instruments provide for a framework, in the case of the EU the Member States must implement this in their national legislation, whereas the Indian states do not have to implement anything in their state legislation.

Regarding the analysis on the technology status and development of advanced alternative and renewable fuels in India and the EU, the following conclusions can be drawn:

- From all advanced biofuels biomethane (upgraded from biogas) and Hydrotreated Vegetable Oils (HVO) are commercial and several technology providers exist. HVO is economically interesting in large-scale refinery type facilities; however further extensive market deployment of HVO may face shortages of supply of the raw material (sustainable vegetable oils, used cooking oils, oil industry process waste streams etc.). Biomethane can be produced from a variety of biomass residues and waste streams, however it is mostly based on relatively small installations, which may be a barrier for upgrading the biogas to biomethane.

- Cellulosic ethanol has achieved significant progress and it can be claimed that the commercialization has started with the first licenses being given. The first plants built in the EU, India and USA still have to undergo optimization and improvements to increase reliability and reduce the costs; however this is believed to be a matter of time. There have been some closures of plants but it must be noted that this was not due to technical failures but to other external problems.

- From the thermochemical processes pyrolysis has matured but mainly for producing bio-oil for power and heat applications. Upgrading the bio-oil to a biofuel is still a long way to go but the industry now looks into co-processing the bio-oil into existing oil refineries thus avoiding the cost of a green field facility. On the other hand gasification followed by synthesis gas still has to be demonstrated at FOAK level with the exception of the GoBiGas plant in Sweden. This is an area that needs more attention by the funding bodies since due to economies of scale it is necessary to build relatively large scale FOAKs.

- Gas fermentation technologies for CCU applications have developed relatively fast and are promising in delivering liquid fuels at large quantities in the short term. However, a point of discussion is that such fuels are not considered either as bio or renewable fuels under EU legislation.

- Algae from waste water treatment plants converted to biomethane also offer some advantages in warm climates since they offer double benefits, purifying the waste waters while producing an energy vector.

- Power to X at present and for the foreseeable future offer little prospects in India.

From the Section on EU-India trade and cooperation on energy and science and technology we can observe the following:

- The EU and the Government of India have signed cooperation agreements in the areas of energy and science and technology, which have set a solid basis for current and future partnerships.

- The cooperation on energy has culminated in the EU-India Strategic Partnership, which led to the adoption of the EU-India Joint Action Plan, the 2016 Summit on Indo-European Clean Energy and Climate Partnership, and finally the EU-India Joint Statement on Clean Energy and Climate Change of 2017, which specifically recognises advanced biofuels as an area of mutual importance.

- In addition, the cooperation on science and technology has culminated in several initiatives, such as the Roadmap for EU-India Scientific and Technological Cooperation, the opening of India's Science and Technology Programme (IMPRINT) to EU researcher participation, and the setting up of the EU-INDIA S&T Window Cooperation.

- These developments have created increasing investments opportunities between the EU and India. However, trade opportunities have been called into question as a result of the import and export ban as outlined in the NPB 2018.

Regarding the financing mechanisms for demonstration plants in the TRL range of 6-9, the analysis led to the following conclusions:

- The European Union has a long history for supporting innovation via the Framework Programmes (FP) for Research and Innovation which provide for continuity to the research community, the academic world and the industry in developing new concepts, improve existing ones and bring into the market innovative technologies. At present the 8th FP, called Horizon 2020, is under implementation until 2020 while the preparation of the 9th FP for the period 2021-2027 has already started. Under FP7 several advanced biofuel value chains were demonstrated at industrial scale and this helped the EU industry to maintain its leading role in this area.

- The Bio-based Industries Joint Undertaking has been an interesting initiative in promoting innovation in the area of the bioeconomy in general, which encompasses advanced biofuels. However, other initiatives such as the NER300 were not as successful and contributed very little in further deploying advanced biofuels in the market. The new financial instrument under preparation in the EU, INNOFIN, could be instrumental in facilitating investments in first-of-a-kind plants if properly designed and effectively applied.

- India also has a relatively long history in supporting research and innovation in the area of biofuels and India has developed its own technologies in several value chains of advanced biofuels. In addition the new strategy to be implemented by the Ministry of Petroleum and Natural Gas is considered to be very effective. This is due to the fact that the Ministry is in direct dialogue with the Indian oil companies, which will have to implement the strategy, and at the same time it will facilitate the process with financial support and other policy coordination at government level. Because of this it is expected that India has the potential to become one of the leading countries in producing advanced biofuels in the future.

1 ANNEX I: TECHNOLOGY STATUS AND DEVELOPMENT OF ADVANCED ALTERNATIVE AND RENEWABLE FUELS IN INDIA AND THE EU

1.1 Introduction

This Annex aims to identify the technologies and value chains of advanced alternative and renewable fuels that have reached the large-scale industrial demonstration phase and are close to market deployment. Recent progress of advanced biofuels that have already reached the deployment and commercialisation phase are also to be covered. The objective is to discuss the various value chains that are expected to be commercial in the near future or by 2025. Technologies, value chains and processes that are still in the early research or pilot phase and are not expected to be in the market by 2025 are excluded.

The Annex on the technology status doesn't aim to provide a detailed analysis of the value chains and technology description but instead an authoritative presentation of the progress achieved by the technology developers and the industry and the readiness of the technologies for market deployment.

For the European technologies the authors based their analysis on the "Technology Status and Reliability of the value chains" report of the Sub Group on Advanced Biofuels that was published in March 2017[175] and presents the most recent description of the status of the various technologies. For the Indian technologies the authors assembled the information and data via personal contacts and visits to the technology developers.

The cost of advanced fuels is of critical importance as it compares the development cost to that of the commercial fossil fuels (petrol, diesel and kerosene). Detailed cost estimates are impossible to obtain as these are regarded as commercial secrets by the technology developers. The Sub Group on Advanced Biofuels carried out a comparative analysis of the costs of advanced fuels to that of fossil fuels, which is considered state of the art, and as the most reliable information on this topic at present. Since it is not practical to derive any better data or information on advanced fuel costs; the key conclusions of the "Cost of Biofuel"[176] report of the Sub Group on Advanced Biofuels will be used in this report and wherever possible they will be updated from Indian data.

175 Ingvar Landälv, "Technology Status and Reliability of the value chains", Sub Group on Advanced Biofuels, edited: Kyriakos Maniatis, Lars Waldheim, Eric van den Heuvel & Stamatis Kalligeros, February 2017.

176 Ingvar Landälv & Lars Waldheim, "Cost of Biofuels", Sub Group on Advanced Biofuels, edited: Kyriakos Maniatis, Eric van den Heuvel & Stamatis Kalligeros, February 2017.

Definitions

To facilitate the reader, the following definitions are used through this Annex. They are the same as those used by the Sub Group on Advanced Biofuels in its final report "Building up the future"[177].

- *Technology Readiness Level* (TRL)[178] according to NASA are a type of measurement system used to assess the maturity level of a particular technology. In the EU the TRL are defined[179] in the Horizon 2020 programme[180].
- *Advanced Biofuels* are those produced from biomass (a) other than food/feed crops while meeting the EU/Indian sustainability regime (b) under the legislation in force (c).
  - a) *Biomass* as defined under RED or any amendment to it and or Indian legislation.
  - b) *Sustainability regime* as defined under EU Legislation and or Indian legislation.
  - c) Existing legislation in force at the time of consideration.
- *Advanced Renewable Fuels* are advanced biofuels, and, liquid and gaseous fuels produced from renewable intermediates or renewable process by-products (H_2, CO, CO_2 etc.).
- *e-Fuels* are Advanced Renewable Fuels produced from renewable electricity via electrolysis.
- *Low Carbon Fossil Fuels* are liquid and gaseous fuels produced by the conversion of exhaust or waste streams of fossil fuel industrial applications via catalytic, chemical, biological or biochemical processes.

Structure of the Annex

The Annex will start with a summary of the cost of biofuels to be followed by the description of the various value chains and their corresponding technology readiness.

The structure followed in this Annex is to start with the description of the technologies and value chains at the highest TRL 9 (*actual system proven in operational environment (competitive manufacturing in the case of key enabling technologies; or in space*), then with those at TRL 8 (*system complete and qualified*) to be followed by those at TRL 7 (*system prototype demonstration in operational environment*) and finally those at TRL 6 (*technology demonstrated in relevant environment (industrially relevant environment in the case of key enabling technologies)*). Each technology and value chain first discusses the European examples and is then followed by the Indian examples.

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177 "Building up the future", Sub Group on Advanced Biofuels, edited: Kyriakos Maniatis, Lars Waldheim, Eric van den Heuvel & Stamatis Kalligeros, February 2017.

178 See https://www.nasa.gov/directorates/heo/scan/engineering/technology/txt_accordion1.html.

179 For definitions per TRL 1-9 under the H2020 programme, see: https://ec.europa.eu/research/participants/data/ref/h2020/wp/2014_2015/annexes/h2020-wp1415-annex-g-trl_en.pdf.

180 See http://ec.europa.eu/research/participants/portal/desktop/en/home.html.

1.2 Different processes to convert biomass to energy

Biomass resources can be converted to energy via thermochemical and biological processing. The key difference between thermochemical and biological conversion is that biological conversion gives single or specific products such as ethanol or biogas and is a relatively slow process, typically taking hours, days, weeks (e.g. anaerobic fermentation and farm digestion) or years (e.g. landfill gas by digestion) for reactions to be completed. Thermochemical conversion gives multiple and often complex products, with catalysts often used to improve the product quality or spectrum, and takes place in very short reaction times of typically seconds or minutes. Another distinction is that thermochemical processing take place at high temperature, typically above 500°C, while biological processing take place at temperatures below 60°C. In the former catalysts are being used to maximize the yield of the desirable product while in the later living organisms such as bacteria, enzymes and yeasts are used. A final distinction is that thermochemical processing can take place under elevated pressure conditions while biological processing takes place under atmospheric conditions.

1.3 Thermochemical Processing

1.3.1 Introduction

Thermochemical processing has been attracting significant interest, and gasification has received the most RD&D support as it offers high efficiencies and the potential to produce biofuels via the synthesis gas ($CO+H_2$) route over dedicated catalysts. Fast pyrolysis has also progressed well and offers the benefits of a liquid fuel with concomitant advantages of easy storage and transport as well as comparable power generation efficiencies at the smaller scales of operation that are likely to be realized from bio-energy systems as compared with fossil fuelled systems. However, the upgrading of pyrolysis oils to biofuels is considered very expensive (due to the removal of oxygen) and at present the technology developers are moving towards co-processing pyrolysis oils in petroleum refineries. The higher efficiency of gasification systems arises from high efficiency in converting to a gas (up to 98% hot gas efficiency is realizable), and higher efficiencies in utilizing heat from combustion of gas.

In all cases, a commercial process comprises four main stages from feed reception to delivery of one or more useful products[181]:

1. Feed reception, storage, handling and pre-treatment;
2. Conversion of solid biomass to a more usable form of energy by means such as gasification or pyrolysis;

[181] Tony Bridgwater & Kyriakos Maniatis, Ch. 10, "The production of biofuels by the thermochemical processing of biomass", Molecular to Global Photosynthesis, Ed. Archer Mary D., Ed. Barber James, Imperial College Press, 2004, 521-612.

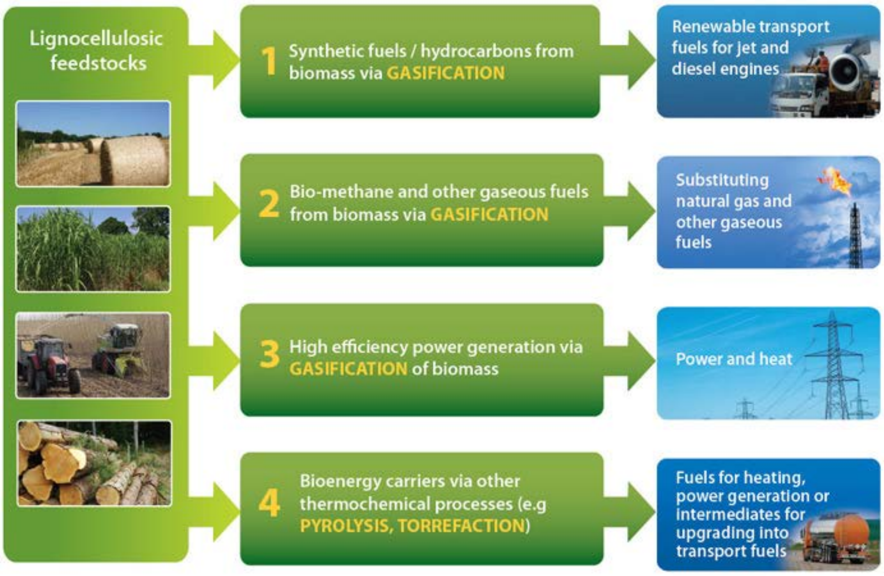
3. Primary product refining or clean-up;

4. Conversion of the primary product to a marketable end-product such as electricity, heat, liquid biofuels or chemicals.

The presentation of the value chains will be done on the basis of those at the highest TRL and will proceed to those with lower TRL up to a TRL 6. A short process description will be provided for each value chain to be followed by a table listing the technology developers, their plants or projects and finally the status of their technology development. This will be followed by a short description of the various plants or projects.

There are mainly two thermochemical processes, gasification and pyrolysis and Figure 3 below shows their respective applications[182]. For interest to this study the first, second and fourth value chains are of interest while the third one, for power and heat, is out of scope. This is because the power and heat value chain does not produce biofuels. Although the hydrotreated vegetable oils value chain is not shown per se in Figure 3, it will be addressed under this section.

Figure 3: Thermochemical value chains



Synthesis gas can be produced from biomass and related waste streams either by partial oxidation to give a mixture of carbon monoxide, carbon dioxide, hydrogen and methane with nitrogen if air is used as the oxidant, or by steam or pyrolytic gasification. The process of gasification occurs in a number of sequential steps:

- drying to evaporate moisture;
- pyrolysis to give gas, vaporised tars or oils and a solid char residue;

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[182] See Annex 1, ETIP Bioenergy Strategic Research and Innovation Agenda, 2016, available at http://www.etipbioenergy.eu/images/EBTP-SRIA-2016.pdf.

- gasification or partial oxidation of the solid char, pyrolysis tars and pyrolysis gases.

The first step, drying, is a relatively fast process. The second step, pyrolysis, is also relatively fast but it is a complex process that gives rise to the tars that cause so many problems in gasification processes. When a solid fuel is heated to 300–500 C in the absence of an oxidising agent, it pyrolyses to solid char, condensable hydrocarbons or tar and gases. The relative yields of gas, liquid and char mainly depend on the rate of heating and the final temperature, and this is discussed later in the section on fast pyrolysis. In gasification by partial oxidation, the gas, liquid and solid products of pyrolysis then react with the oxidising agent—usually air—to give the permanent gases CO, CO_2, H_2, and lesser quantities of hydrocarbon gases.

However, for the processes to produce advanced biofuels only steam or oxygen gasification can provide a gas quality that after treatment can yield a synthesis gas while that or air gasification is mainly used for CHP applications.

Generally, in gasification processes, pyrolysis proceeds much faster than char gasification, which involves relatively slow gas–solid reactions between oxygen and char and is the rate-controlling step. Char gasification is the interactive combination of several gas–solid and gas–gas reactions in which solid carbon is oxidised to carbon monoxide and carbon dioxide, and hydrogen is generated through the water-gas shift reaction. The gas–solid reactions of char oxidation are the slowest and limit the overall rate of the gasification process. Many of these are catalysed by the alkali metals present in wood ash, but still do not reach equilibrium. The composition of the gas from char gasification and partial oxidation of the other pyrolysis products is influenced by many factors, including feed composition, water content, reaction temperature and the extent of oxidation of the pyrolysis products. However, the overall composition is essentially the equilibrium composition of the C–H–O system at the temperature of gasification. Table 4 shows the basic modes of gasification[183].

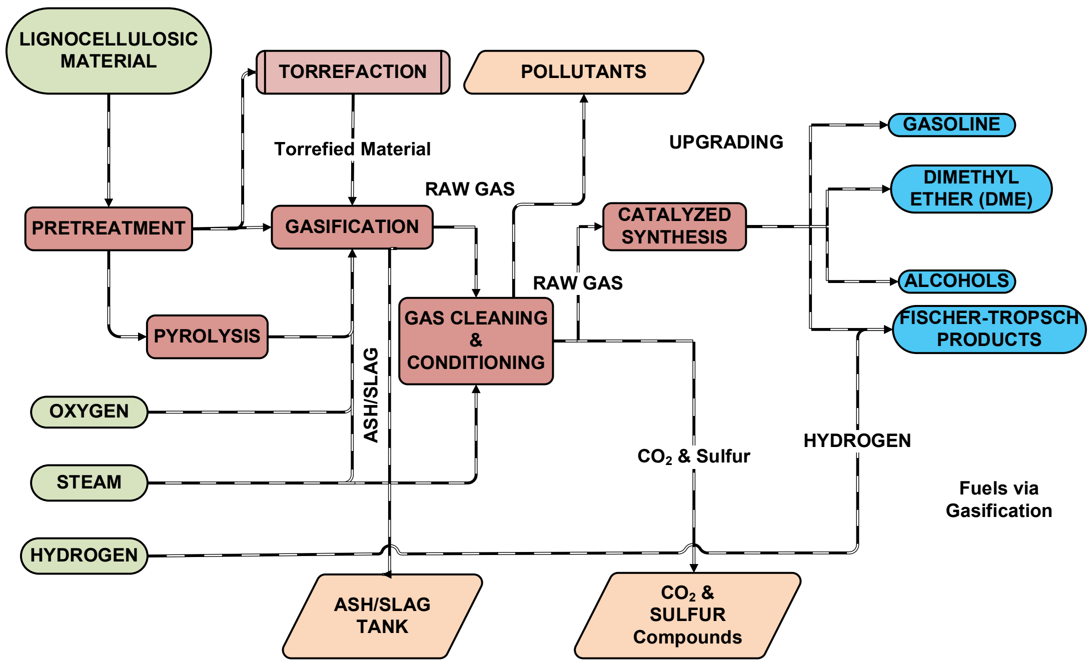
[183] Tony Bridgwater & Kyriakos Maniatis, Ch. 10, “The production of biofuels by the thermochemical processing of biomass”, Molecular to Global Photosynthesis, Ed. Archer Mary D., Ed. Barber James, Imperial College Press, 2004, 521-612.

Table 4: Modes of thermal gasification

Gasification mode	Characteristics
Partial oxidation with air	The main products are CO, CO_2, H_2, CH_4, N_2 and tar, giving a low heating value gas of ~5MJ/m³. Utilisation problems can arise in combustion, particularly in gas turbines.
Partial oxidation with oxygen	The main products are CO, CO_2, H_2, CH_4 and tar (no N_2), giving a medium heating value gas of ~10–12 MJ/m³. The cost of providing and using oxygen is compensated by a better quality fuel gas. The trade-off is finely balanced.
Steam (pyrolytic) gasification	The main products are CO, CO_2, H_2, CH_4 and tar giving a medium heating value gas of ~15–20 MJ/m³. There are several reactor configurations that can yield a synthesis gas with steam gasification.

1.3.2 Gasification

Figure 4: Gasification simplified diagram, example for synthetic biofuels such as Fischer-Tropsh, DME etc.). Process flowsheet also shows pyrolysis and torrefaction as biomass fuel pre-treatment options.



The main type of reactor is bubbling and circulating fluidized bed gasifiers, which are versatile type of reactor and can tolerate the feedstock a certain size range. Usually fluidized bed systems can operate with chips or pellets and under certain conditions with fluffy feedstock such as solid recovered fuels. They operate normally in the range of 700-900°C. However, the operating temperature is limited by the ash melting temperature of the biomass feedstock, which is caused by low alkali metal eutectics and can have severe adverse effects of the fluidized bed (bed agglomeration). Lower operating temperatures results in higher concentration of tars, an undesirable by-product of gasification, and higher concentrations of methane and hydrocarbons.

Entrained-flow gasifiers operate with fine biomass (size <1mm) at temperatures in the range of 1000-1500°C which is normally above the melting point of the ash of the feedstock and thus low alkali metal eutectics and tars are avoided. Entrained bed gasifiers can easily operate with liquids.

Following the gasification step the gas has to be conditioned and remove any impurities such as ash and dust and following this the gas has to be shifted to desired synthesis gas; ratio of CO to H2. Before the synthesis gas is fed to the catalytic reactor it is necessary to also remove any catalyst poisons that may deactivate the catalyst and reduced its life. The gas conditioning is generally speaking an expensive process that involved several unit operations.

Table 5 shows the various advanced biofuels that can be produced by gasification.

Table 5: Advanced Biofuels by gasification

Advanced Biofuel	Characteristics
Fischer-Tropsch (FT)	The Fischer–Tropsch synthesis produces a broad spectrum of hydrocarbons from but after separation the FT can be drop-in fuels either in diesel or kerosene. This process is commercially operated by Sasol in South Africa, where over a million tons per year of coal are processed into a full range of marketable hydrocarbon products. At present there is no full large scale demonstration plant in the EU.
Methanol	Methanol synthesis is commercially available and the major processes are available from various technology providers. The synthesis is followed by a distillation section where the water by-product is separated and the pure methanol is obtained.
Dimethyl Ether (DME)	DME is formed by methanol dehydration in the presence of a different catalyst (e.g. silica-alumina). The reaction is slightly exothermic. DME is stored in the liquid state at 0.5MPa pressure and ambient temperature, like Liquefied Petroleum Gas (LPG)[184]. DME can also be produced through direct synthesis using a dual-catalyst system which permits both methanol synthesis and dehydration in the same process unit, with no intermediate methanol separation.
Biomethane	In the methanation step carbon monoxide reacts with hydrogen forming methane and water. The biomethane can either be injected in a natural gas pipeline or used directly to fuel captive fleets.

184 See page 9 in: Ingvar Landälv, "Technology Status and Reliability of the value chains", Sub Group on Advanced Biofuels, edited: Kyriakos Maniatis, Lars Waldheim, Eric van den Heuvel & Stamatis Kalligeros, February 2017.

1.3.3 Gasification in the EU

Gasification has a long history in the EU and several technology developers have been trying to develop gasification platforms from the very small systems to the large scale commercial plants. The success has been limited in the small capacity based on downdraft gasifiers destined for power and heat applications while better achievements have been attained in the large scale. European technology developers have gained significant experience from running large scale demonstration facilities however the market and policy conditions have been a barrier to the further deployment of gasification technologies for advanced biofuels. Although at present there are no large scale commercial facilities operating on gasification for advanced biofuels few projects are in the planning phase and it is expected that their construction could start soon after the RED II has been adopted and the various Members States of the EU have enacted appropriate legislation in their national legislation.

Table 6 shows the technology developers for advanced biofuels via gasification in the EU.

Table 6: Gasification plants in the EU

N°	Technology Developer/Plant	Plant/Location	Production Capacity tones/yr	In operation since	TRL
1	GoBiGas plant	Gothenburg, Sweden	20MW	2013	9
2	BioTfueL pilot plant	France	N/A	2018?	8
3	Gogreengas	Swindon, UK	0.050MW	2018?	7
4	The Chemrec plant	Pitea, Sweden	4 tones DME/d	2014	7
5	The Bioliq pilot plant	Karlsruhe Institute of Technology, Germany	0.2 tones/h	2014	6

Note: 2018?: Expected to start operation in 2018

The GoBiGas plant[185] is a four times scale up from the original plant in Güssing[186], Austria which was a Combined Heat and Power gasification plant. The construction was done by Valmet[187] under a license from Repotec (the owner of the license of the Güssing plant

[185] See https://gobigas.goteborgenergi.se/English_version/Start; GoBiGas was built by Göteborg Energi's and it is a biomass gasification demonstration plant to produce bio-syngas (bio-SNG). The Gothenburg Biomass Gasification Project (GoBiGas) is the world's largest woody biomass gasification demonstration project. However, the plant has been put for sale by Göteborg Energi.

[186] See http://www.repotec.at/index.php/95.html.

[187] See http://www.valmet.com/; Valmet, a Finnish company, is a leading developer and supplier of technologies and services to the pulp, paper and energy industries.

technology). The GoBiGas plant furthermore includes tar removal via scrubbing and active carbon filters. Water gas shift and methanation units have been provided by Haldor Topsöe. The plant also includes acid gas removal technology. The plant has been operating both with pellets and forest biomass generating biomethane.

Figure 5: The GoBiGas plant in Gothenburg, Sweden

The BioTfuel[188] plant in Dunkirk will be using torrefied wood (partially pyrolysed to produce a feedstock of better and more consistent quality that biomass) in a ThyssenKrupp[189] PRENFLO gasifier. The gasifier operates with Pressurized Direct Quench. The conversion process for the synthesis gas is provided by AXENS[190]. The project aims to produce bio-kerosene and diesel fuels. The aim is to use biomass as well as biomass/petroleum coke and biomass/coal mixtures to be fully independent of potential seasonal feedstock restrictions and/or customer economical feedstock needs. However, the plant will depend on the supply of torrefied wood from another plant under construction in another location (Venette). The plant is undergoing testing.

188 See https://www.total.com/en/energy-expertise/projects/bioenergies/biotfuel-converting-plant-wastes-into-fuel.

189 See https://www.thyssenkrupp-industrial-solutions.com/en/products-and-services/chemical-plants-and-processes/gasification/; The Thyssenkrupp Industrial Solutions business area is a leading partner for the engineering, construction and service of several industrial plants and systems.

190 See https://www.axens.net; Axens SA provides advanced technologies, catalysts, adsorbents, and services. The company focuses on the conversion of oil, coal, natural gas, and biomass to clean fuels, as well as the production and purification of petrochemical intermediates.

Figure 6: BioTfueL pilot plant (main unit) in Dunkirk

The Gogreengas[191] pilot plant is a development facility for proving and optimizing the process for manufacturing biomethane from Refuse Derived Fuel (RDF) and biomass feedstocks. The project is a partnership between National Grid Gas Distribution[192], Advanced Plasma Power[193], Progressive Energy[194] and Carbotech[195]. The aim is to ensure that the gas grid could be supplied with biomethane gas from biomass resources.

Dried RDF and other feedstocks are converted to syngas in a two stage gasification process using a gas plasma technology (fluidized bed gasifier at atmospheric pressure designed by close-coupled with a plasma converter). The BioSNG pilot and commercial plants in Swindon use oxy-steam fluidised bed gasification and a plasma converter to remove tars and vitrify ash and heavy metals. Wet scrubbing systems are used for bulk removal of acid and alkaline contaminants and a series of guard beds are used for final polishing. A sweet water gas shift is followed by a series of methanation reactors. In the pilot plant a pressure swing adsorption system is used to remove carbon dioxide, but in the commercial facility a chemical scrubbing system will be used.

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191 See http://gogreengas.com/.

192 See https://www.nationalgrid.com/uk/ga.

193 See http://advancedplasmapower.com/about-us/our-company/; The Gasplasma® process is an innovative combination of two well-established technologies – gasification and plasma treatment.

194 See http://www.progressive-energy.com/; Progressive Energy is an established independent UK clean energy company focusing on project development and implementation. The company was formed in 1998 to commercialise key energy conversion technologies including coal gasification (alongside carbon capture and storage), novel waste to energy, and biomass conversion.

195 See http://www.carbotech.info/en/.

Figure 7: The "Gogreengas" demonstration plant, Swindon, UK

The CHEMREC gasification plant [196] was developed with the black liquor as feedstock for DME synthesis. The synthesis gas conversion to methanol and DME is carried out by HaldorTopsoe[197], a major catalyst technology provider. Today the plant is owned and operation by Lulea Technical University[198]. The gasification plant was started in September 2005 and the Bio-DME unit in November 2011. The feedstock is sulphate (Kraft) black liquor (a by-product of the paper industry) from the neighbouring sulphate mill but also sulphite liquor has also been successfully tested. This plant is also operated in periods of 2-3 weeks. The CHEMREC plant was supported by the European Union's FP7 program for innovation under the project BIO DME, see Table 18 in Section 8.2.1.

196 See http://biofuel.org.uk/Chemrec.html; Chemrec was founded in 1989 in Stockholm holding patents on the gasification of black liquor.

197 See https://www.topsoe.com; HardorTopsoe is a leading company in catalysis and process technology driving optimal performance within chemical processing, hydroprocessing and emissions management. It develops, manufactures, and sells catalysts, equipment, spare parts, and consumables.

198 See https://www.ltu.se/?l=en; Lulea University of Technology is an institution located in Lulea, Sweden and is experiencing a strong growth with world-leading competence in several areas of research. The university's research is conducted in close cooperation with several companies and industries.

Figure 8: The Chemrec/Lulea Technical University BioDME plant in Pitea

The Karlsruhe Institute of Technology[199] (KIT) built **the Bioliq[200] plant** and it has been in full operation since 2014. The plant consists of a Lurgi/Ruhrgas[201], fast pyrolysis reactor for the production of slurry from lignocellulosic biomass. The pyrolysis char and bio-oil produced from biomass are mixed to produce a slurry "Biosyncrude". The Biosyncrude is then gasified in an entrained bed flow gasifier to produce synthesis gas. The synthesis gas is converted to gasoline via a direct DME synthesis route. Since this is a small scale demonstration plant the plant is operated in 2 to 3 week periods.

Figure 9: The Karlsruhe Institute of Technology Bioliq plant

199 See https://www.kit.edu/english; The Karlsruhe Institute of Technology, was established by the merger of the Forschungszentrum Karlsruhe GmbH and the Universität Karlsruhe (TH) on October 01, 2009. KIT combines the tasks of a university of the state of Baden-Württemberg with those of a research centre of the Helmholtz Association in the areas of research, teaching, and innovation.

200 See https://www.bioliq.de/english/index.php.

201 See https://www.engineering-airliquide.com; the Lurgi gasification technology has been acquired by Air Liquide.

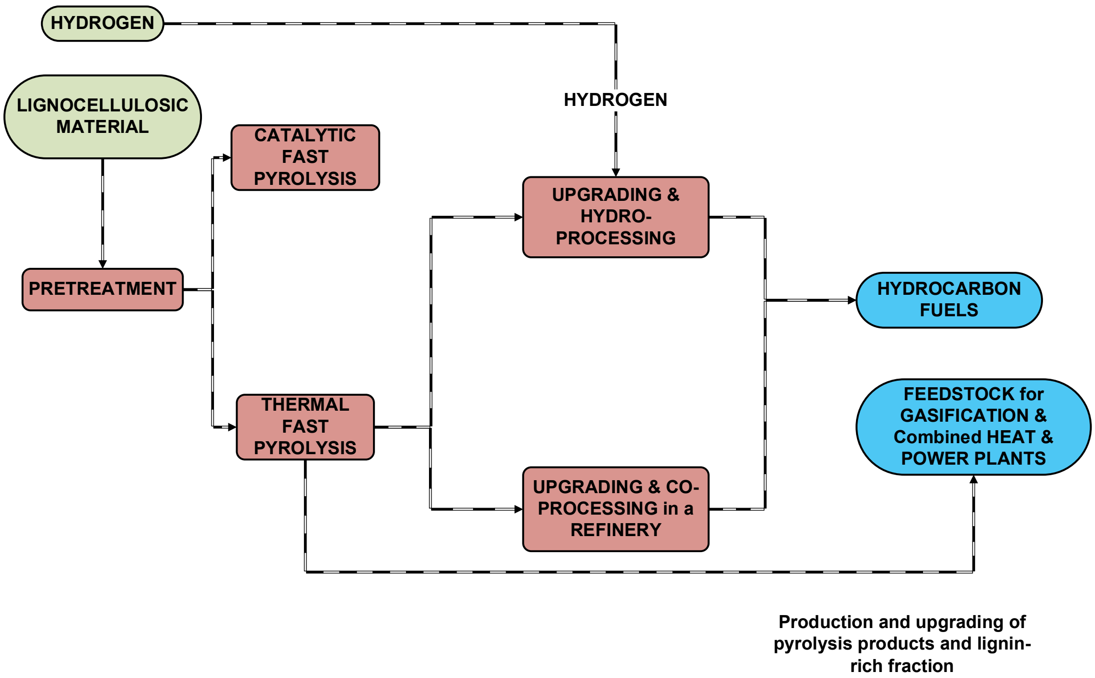
1.3.4 Gasification in India

While there are no gasification plants in India for the production of advanced biofuels, there is a significant degree of work on gasification for power and heat generation in India. This is, however, beyond the scope of the present study.

1.3.5 Fast pyrolysis

Fast pyrolysis has also progressed well and offers the benefits of a liquid fuel with concomitant advantages of easy storage and transport as well as comparable power generation efficiencies at the smaller scales of operation that are likely to be realised from bio-energy systems as compared with fossil fuelled systems. However, the upgrading of pyrolysis oils to biofuels is considered very expensive (due to the removal of oxygen) and at present the technology developers are moving towards co-processing pyrolysis oils in petroleum refineries. Figure 10 shows a generalised process flow diagram for biomass pyrolysis.

Figure 10: Simplified process flow diagram for pyrolysis. Process flowsheet also shows upgrading to hydrocarbon fuels or co-processing in a refinery.



Pyrolysis is thermal decomposition occurring in the absence of oxygen. It is always also the first step in combustion and gasification, but in these processes it is followed by total or partial oxidation of the primary products. Lower process temperatures and longer vapour residence times favour the production of charcoal. High temperatures and longer residence times increase biomass conversion to gas, and moderate temperatures and short vapour residence time are optimum for producing liquids. Fast pyrolysis for liquids production is currently of particular interest[202].

Fast pyrolysis occurs in a time of few seconds or less. Therefore, heat and mass transfer processes and phase transition phenomena, as well as chemical reaction kinetics, play important roles. The critical issue is to bring the reacting biomass particles to the optimum process temperature and minimise their exposure to the intermediate (lower) temperatures that favour formation of charcoal. One way this objective can be achieved is by using small particles, for example in the fluidised bed processes that are described later. Another possibility is to transfer heat very fast only to the particle surface that contacts the heat source (this second method is applied in ablative processes).

The essential features of a fast pyrolysis process for producing liquids are:

- very high heating and heat transfer rates at the reaction interface, which usually requires a finely ground biomass feed;
- carefully controlled pyrolysis reaction temperature of around 500°C and vapour phase temperature of 400–450°C;
- short vapour residence times of typically less than 2 seconds;
- rapid cooling of the pyrolysis vapours to give the bio-oil product.

The main product, bio-oil, is obtained in yields of up to 75% wt on a dry-feed basis, together with by-product char and gas, which are used within the process to provide the process heat requirements so there are no waste streams other than flue gas and ash.

1.3.6 Fast Pyrolysis in the EU

Fast pyrolysis has been developed over several years in the EU by few companies which have provided for continuity in the development of the technology mainly in the Netherlands and Finland. Initial work focused on producing a fuel oil for power and heat applications and few commercial facilities are operational at present in the EU with good prospects for further commercialisation. The focus recently has turned in co-processing bio-oil in existing refineries aiming in reducing downstream processing costs in upgrading the bio-oil into a transport fuel.

Table 7 shows the technology developers for advanced biofuels via fast pyrolysis in the EU. Both plants have been operating with the purpose to supply the bio-oil for CHP applications in commercial facilities; however, they are looking into upgrading the bio-oil into advanced biofuels.

[202] Tony Bridgwater & Kyriakos Maniatis, Ch. 10, "The production of biofuels by the thermochemical processing of biomass", Molecular to Global Photosynthesis, Ed. Archer Mary D., Ed. Barber James, Imperial College Press, 2004, 521-612.

Table 7: Fast pyrolysis projects in the EU

N°	Technology Developer/Plant	Plant/Location	Production Capacity MW	In operation since	TRL
1	Fortum	Joensuu, Finland	30MW	2013	9
2	Biomass Technology Group, (BTG)	EMPYRO Hengelo, The Netherlands	8 MW	2015	9

Fortum[203] integrated a fast pyrolysis unit in the **Joensuu CHP plant**. Bio-oil is produced from forest residues, wood from first thinnings and other wood biomass, such as forest industry by-products, sourced locally from the Joensuu region. The Joensuu bio-oil plant's annual production of 50,000 tonnes corresponds to the heating needs of more than 10,000 households.

Figure 11: Fortum's Joensuu power plant

BTG's EMPYRO plant[204] converts up to 70 wt.% of the biomass feedstock into bio-oil and the remaining part into char and gas. BTG's unique and patented pyrolysis technology is characterised by an intense mixing without the need for an inert carrier gas. BTG-BTL's has

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203 See https://www3.fortum.com/about-us/our-company/our-energy-production/our-power-plants/joensuu-chp-plant; Fortum's first bio-oil plant was integrated to Joensuu CHP in 2013. This fast pyrolysis technology-based bio-oil plant is first of its kind in the world on an industrial scale. Fortum Otso bio-oil is produced from wood-based raw materials like forest residues, wood chips and sawdust. Bio-oil can replace heavy or light fuel oil at heat plants or steam production.

204 See https://www.btg-btl.com/en/company/projects/empyro; In January 2014 Empyro BV started the construction of its pyrolysis oil production facility in Hengelo, the Netherlands. Start-up of the installation has commenced early 2015.

taken BTG's patented RCR (Rotating Cone Reactor) fast pyrolysis technology and engineered it into a commercial industrial installation. The improved RCR design results in a remarkably small reactor; reduced system complexity and minimum downstream equipment size compared to competing pyrolysis technologies. BTG-BTL's parent company is involved in the Biocoup project. Research in this project has demonstrated on laboratory scale that up to 20% of upgraded pyrolysis oil can be mixed in a standard refinery. Furthermore Petrobras has managed to demonstrate at scale that it is feasible to co-process crude pyrolysis oil in existing oil refineries into gasoline and diesel. Recently BTG has driven over 100 km on a blend of upgraded pyrolysis oil and diesel to demonstrate that pyrolysis oil can be blended in a high proportion with fossil diesel[205]. The EMPYRO project was supported by the European Union's FP7 program for innovation, see Table 18 in Section 8.2.1.

Figure 12: BTG's EMPYRO plant

1.3.7 Fast pyrolysis in India

There have been few efforts to develop fast pyrolysis in India however, significant efforts have been made based on the process of thermochemical catalytic technology which has reached the large scale demonstration phase. This technology converts biomass directly into 'drop in fuels'.

[205] See http://www.btgworld.com/en/news/article?id=105.

Table 8: Thermochemical catalytic technology projects in India

N°	Technology Developer/Plant	Plant/Location	Production Capacity MW	In operation since	TRL
1	CRI/SHELL	Bangalore, India	5 ton per day input	2017	8

The **CRI/SHELL/ IH² plant** technology involves four primary processes. At first the biomass is conditioned by sizing and drying up to 10 – 30 wt.% moisture. The second process step comprises of hydrodeoxygenation of the volatilized biomass using hydrogen with proprietary catalysts to produce a raw stable hydrocarbon product. The third step employs a fixed–bed hydrotreater, which uses other proprietary catalysts to polish the first–stage product and transform it into a finished hydrocarbon fuel or blend stock. Another primary element of this technology is a hydrogen production from biomass in the hydrogen manufacturing unit (HMU) that converts light gases generated in the first–stage to renewable hydrogen, in sufficient quantity for process needs. The individual process/ elements have been commercialized. This technology can produce gasoline (petrol), civil jet fuel grade and diesel. While the IH2 technology concept was developed by the Chicago-based Gas Technology Institute (GTI) for conversion of municipal and agriculture waste into liquid transport fuel, the worldwide license rights for the new technology were acquired by CRI Catalyst Company[206], a subsidiary of Royal Dutch Shell[207]. The minimum commercially viable scale of this technology is expected to be from 500 to 1000 TPD of biomass. A 500 TPD plant will produce about 200 TPD of renewable 'drop in advanced biofuel'[208].

206 See https://www.cricatalyst.com/.

207 CRI Brochure on IH2 technology – Renew, Refine & Refuel.

208 Laxmi Narasimhan, IH2 Advocacy Lead, "Drop in fuels", EU-India conference on Advanced Biofuels, New Delhi, 6-8 March 2018.

Figure 13: Photo of the CRI/SHELL demonstration plant in Bangalore, India

The Department of Biotechnology of the Institute of Chemical Technology, Mumbai (DBT-ICT) has developed a biomass liquefaction technology to produce Biogas/Biomethane. It is a hybrid patented technology based on Catalytic Thermo-Liquefaction (CTL) of biomass or MSW. The technology uses a new catalyst which operates at benign conditions of low temperature of 1500°C and 15 bar pressure and claims to give an oil yield of 90% and nearly 100% of carbon recovery efficient. The calorific value of the CTL-Oil is 22 to 25 MJ/kg. The oil can be used directly as a fuel in shipping or in the boiler. Another conventional way to use the CTL-oil is to upgrading this oil to petroleum products such as gasoline and diesel by catalytic dehydration/hydrotreatment followed by cracking and distillation. DBT-ICT has also proposed a third novel process route to produce biogas from the CTL-oil followed by purification to obtain compressed biomethane (bio-CNG). The anaerobic digestion in this process is very efficient and it is claimed that the total residence time for digestion is less than 24 hours and produces 90% methane yields and is a zero solid waste technology. However, this process to producing biomethane from biomass or MSW seems relative complex compared to other available value chains. It is proposed to set up two plants of bioCNG based on MSW and one based on biomass of capacity 100 TPD each in 2019. One of the plant proposes to produce methanol.

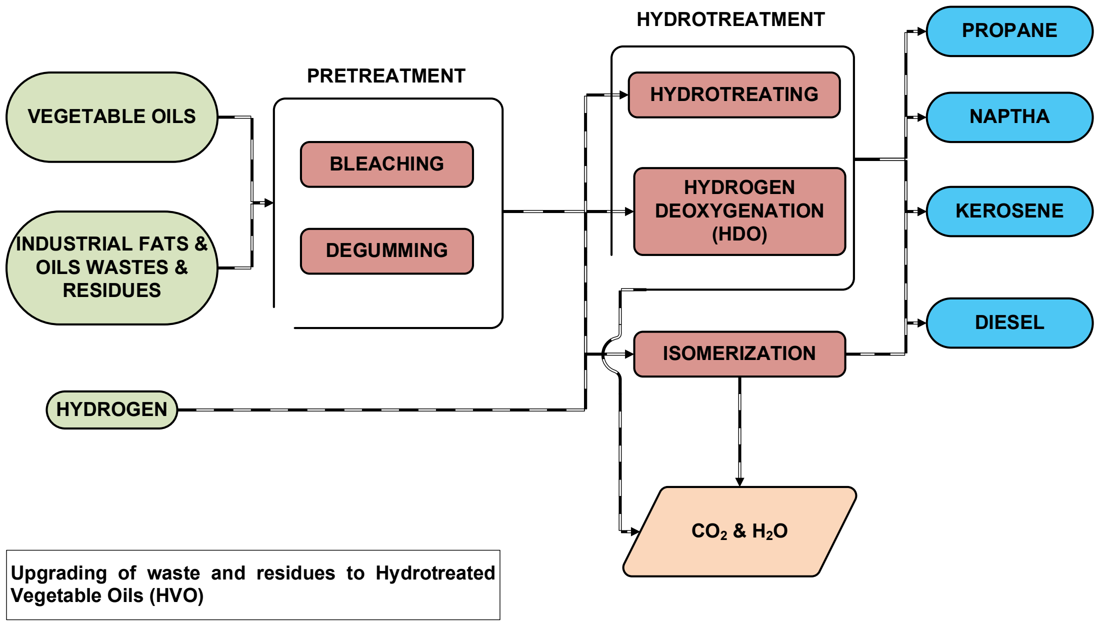
1.3.8 Hydrotreated Vegetable Oils (HVO)

HVO can be produced from a variety of resources such as vegetable oils, used cooking oils, process residues from oil industry (e.g. palm oil industry), animal fats and waste streams, or any resource containing lipids, triglycerides and fatty acids. The process is very flexible allowing the use of waste streams with relative low cost. HVO is easily blended into regular diesel in any proportion, with no adverse impact on fuel quality or engines and it is therefore the preferred biofuels for existing diesel engines either for trucks or passenger cars. The best quality of HVO can be used in aviation as bio-kerosene.

Figure 14 shows the simplified process flow diagram for HVO production. A key element in the process is the supply of hydrogen, which is needed for the hydrotreating process. HVO plants can be either standalone green-field or they can be integrated in existing refineries.

Integration in existing refineries has the advantages that several services such as utilities, ancillaries are readily available while in general the permitting and licensing procedures are greatly simplifies resulting in relative fast revamping compared to a green field. In the EU there is tendency to retrofit existing refineries in HVO refineries as has been the case with ENI and TOTAL, see Table 9.

Figure 14: HVO Simplified process flow diagram showing the variety of hydrocarbon fuels that can be produced



1.3.9 Hydrotreated Vegetable Oils (HVO) in the EU

HVO has been a success story in the EU with NESTE[209] being the first company world-wide to produce this drop-in fuel on a commercial basis and has built plants worldwide. Other European refineries are reconverting existing oil refineries into HVO biorefineries. The problem this market and value chain faces in the EU is the fact that large scale commercial refineries need large volumes of vegetable oils and the most common feedstock is palm oil which faces political and stakeholders' opposition in the EU.

209 See https://www.neste.com/

Table 9: Technology Providers for HVO in the EU

N°	Technology Developer	Plant/Location	Production Capacity tones/yr	In operation since	TRL
1	NESTE	Porvoo 1, Finland	200,000	2007	9
		Porvoo 2, Finland	200,000	2009	9
		Singapore	1,000,000	2010	9
		Rotterdam, Netherlands	1,000,000	2011	9
2	ENI	Venice, Italy	300,000	2014	9
3	UPM	Lappeenranta, Finland	100,000	2015	9
4	TOTAL	La Mede, France	500,000	2018?	9

The Finnish company **NESTE**[210] was the first worldwide to invest in this conversion technology and started in 2007 by building a relative small facility at their main refinery in Porvoo marketing the HVO as NEXBTL fuel. This has been followed in relative fast investment decisions by 3 more plants, the latter two built at a large commercial capacity of 1,000,000 t/y in Singapore and Rotterdam. Currently NESTE has a global annual production capacity of 2.4 million tones. All NESTE refineries are green field stand alone.

Figure 15: Neste's HVO plant, Rotterdam, The Netherlands

[210] See https://www.neste.com/en/companies/products/renewable-fuels.

ENI[211], the Italian Oil company uses the Ecofining™ process from UOP[212] to convert various lipid and fats feedstocks into HVO via deoxygenation, isomerization and product separation. The **Green Refinery Project** of ENI located at Porto Marghera in Venice, is the world's first plant where a section of an existing oil refinery was retrofitted into a biorefinery by revamping two existing hydrotreating units. Hydrogen is provided by the existing catalytic reforming unit. The plant produces green diesel, green naphtha, LPG and potentially also jet fuel. It is currently fed by palm oil, but the plan is also to use biomass.

Figure 16: The ENI integrated biorefinery in an existing refinery, Venice, Italy

The most recent EU investment in stand-alone HVO facility is the **UPM Lappeenranta**[213] biorefinery converting crude tall oil (a by-product of the pulp and paper industry) into HVO. The biorefinery, located on the same site as the UPM Kaukas pulp and paper mill where it took advantage of integrating the biorefinery into the mill. The key hydro-treatment technology is provided by Haldor Topsoe. As part of the project, Haldor Topsoe[214] has supplied the process design and license for the renewable fuel hydrotreating process (HydroFlex™), design of the amine regeneration unit, all the hydroprocessing reactor internals and catalysts as well as supervision and training services.

211 See https://www.eni.com/en_IT/innovation/technological-platforms/green-refinery.page.
212 See https://www.uop.com/processing-solutions/renewables/green-diesel/.
213 See http://www.upmbiofuels.com/upm-biofuels/biorefinery/Pages/Default.aspx.
214 See https://blog.topsoe.com/2015/03/wood-based-renewable-diesel-bio-refinery-goes-stream-finland.

Figure 17: UPM's Biorefinery, Lappeenranta, Finland

TOTAL is revamping its **Le Mede refinery** with an investment of €200 million to produce 500,000-ton-per-year HVO[215]. The HVO process selected by Total is a French technology developed by Axens[216] that produces high-quality fuel. The integration allows TOTAL to operate certain existing refining units (naphtha reformer) to produce the hydrogen needed for the HVO process.

1.3.10 Hydrotreated Vegetable Oils (HVO) in India

There is no dedicated HVO plant in India however **Indian Oil Corporation**[217] Technology has been examining the co-processing of non-edible oils in petroleum refinery. In this technology it is not necessary to set up a new green field processing unit but requires only minor modification in the existing petroleum processing plant. Indian Oil Corporation Ltd (R&D Centre) has developed a technology for co-processing of non-edible oils in Diesel Hydrodesulfurization/ Diesel Hydrotreating (DHDS/DHDT) units of the refinery. In this process de-gummed and de-metalled non-edible oil is mixed with diesel feed and fed into the DHDS/DHDT reactor along with recycled hydrogen. In the reactor, vegetable oil is converted to paraffins/ isoparaffins, water, CO, CO_2 and trace quantity of light gases. The diesel product with co-processing has advantages mainly in terms of better quality product with higher cetane, good oxidation stability and lower density. Indian Oil R&D has developed a demetallation process for the same and filed patent in India, USA and Europe. The salient features of this technology include utilization of existing refinery infrastructure with minor modifications. The trial run of the technology was successfully carried out on a

215 See https://www.total.com/sites/default/files/atoms/files/annexes-plan-raffinage-mede-en.pdf.

216 See https://www.axens.net/our-offer/by-market/oil-refining/top-of-the-barrel/33/diesel-hydrotreating.html.

217 See https://www.iocl.com/.

commercial scale in April, 2013 at the DHDT unit of Manali Refinery[218] of Chennai Petroleum Corporation Ltd[219] with 6.5% of Jatropha oil with diesel feed.

Table 10: Co-processing of oils in a petroleum refinery

N°	Technology Developer/Plant	Plant/Location	Production Capacity MW	In operation since	TRL
1	Indian Oil Coorporation	Manali Refinery, India	6.5% Jatropha oil with diesel feed	2013	8

Figure 18: The Manali Refinery

1.4 Biological conversion

1.4.1 Introduction

The key biological conversion process routes for advanced biofuels is the production of cellulosic ethanol and biomethane via upgrading biogas produced from anaerobic digestion. A recent development is fermentation of synthesis gas produced from thermal gasification. In this process the synthesis gas is cooled and then is fed to bacteria which convert it to ethanol. However, since there is no major technology developer on this value chain in the EU this technology will not be described any further.

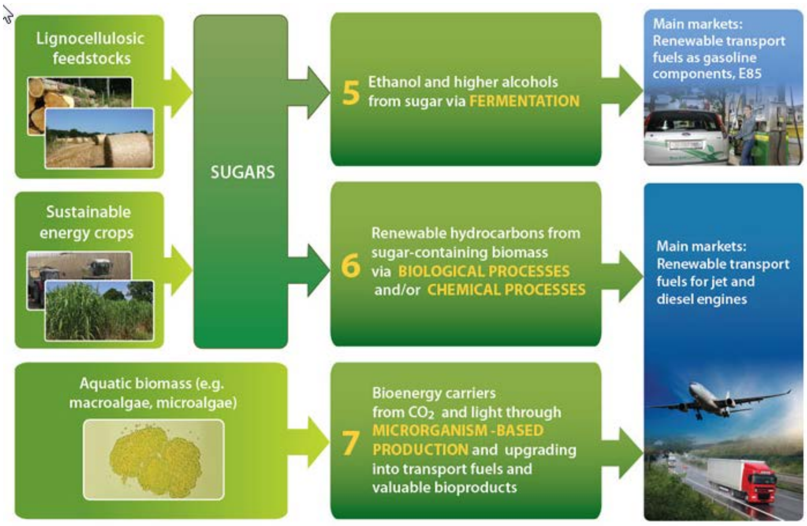
In order to produce ethanol from biomass it is necessary to first extract the sugars with enzymes (saccharification) and then ferment them with yeasts to ethanol. However, the

218 See https://www.cpcl.co.in/ManaliRefinery; The Manali Refinery has a capacity of 10.5 MMTPA and is one of the most complex refineries in India with Fuel, Lube, Wax and Petrochemical feedstock production facilities. The main products of the Refinery are LPG, Motor Spirit, Superior Kerosene, Aviation Turbine Fuel, High Speed Diesel, Naphtha, etc.

219 See https://www.cpcl.co.in/.

first step is always a severe pre-treatment step to open the structure of biomass so that the enzymes can reach the cellulose and hemicellulose components of biomass so that these can be hydrolysed to sugars before the fermentation step can proceed. Carbohydrates such as starch also require hydrolysis. The saccharification step and the fermentation step can be performed separately, Separate Hydrolysis and Fermentation (SHF) or combined into one step, Simultaneous Saccharification and Fermentation (SSF). Integrated processes like the SSF since they take place simultaneously in one step reduce costs and improve overall efficiency. Fermentation is particularly suitable for materials with high moisture content, as drying is not required. Ethanol can be readily converted to ETBE (ethyl tertiary butyl ether), which can be directly used as a gasoline additive. The fermentation technology is already commercial. Figure 19[220] shows the main biological process value chains.

Figure 19: Biological Conversion pathways



The composition of biomass differs from one species to another; however, the main constituents are very similar. Biomass consists for about 50–60% carbohydrates in the form of cellulose and hemicellulose and about 20–35% lignin. The lignin cannot be converted into valuable products by microorganisms and it is either burned for process heat, particularly for ethanol concentration, for power applications where the feed-in tariffs are high or used in lignin chemistry to produce chemicals.

Several pre-treatment methods have been developed and major research efforts have been spent to find efficient and fast pre-treatment methods, which render a structure that is easy to hydrolyze by using various enzymes. Common for all of them is the requirement to yield a material, which can be processed further downstream to yield ethanol in high yield.

Significant innovation has taken place the last decades in developing bioengineered, including genetically modified, microorganisms for the fermentation of the C6 sugars.

220 See Annex 1, ETIP Bioenergy Strategic Research and Innovation Agenda, 2016, http://www.etipbioenergy.eu/images/EBTP-SRIA-2016.pdf.

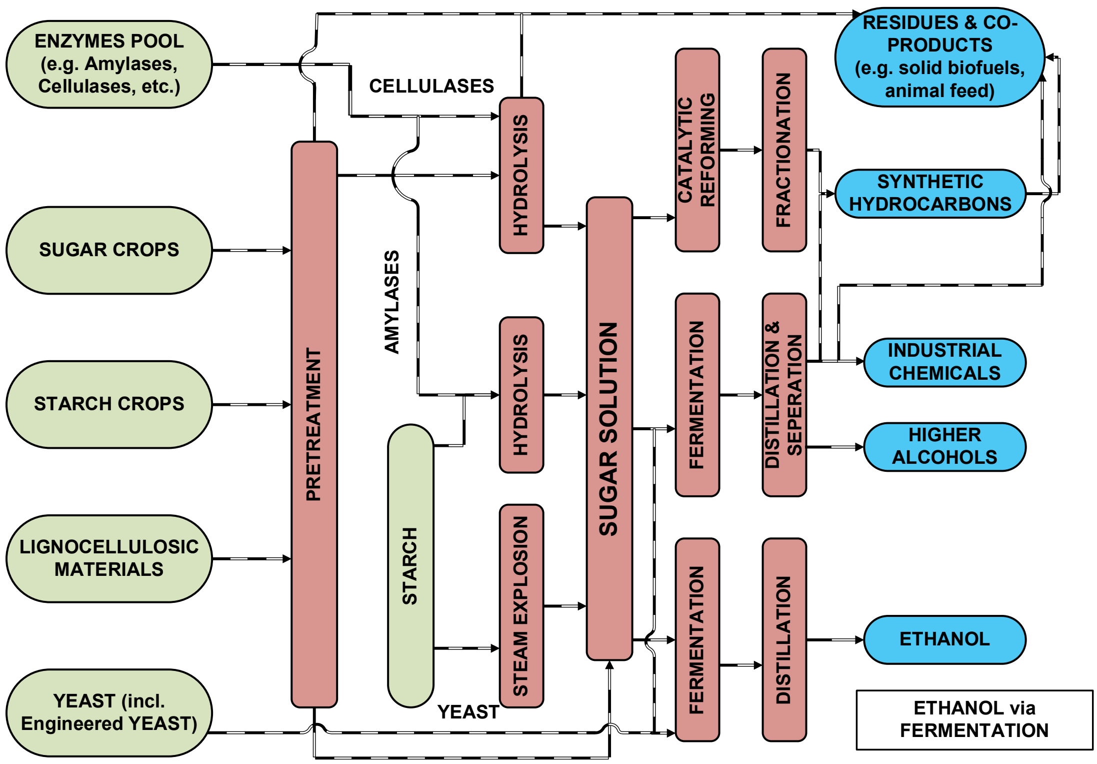
Most commonly traditional yeasts are bioengineered to derive the desired microorganism that can be active for the particular sugars from biomass. Also for the fermentation of C5 sugars significant progress has been achieved the last years with genetically modified.

1.4.2 Cellulosic alcohols in the EU

Cellulosic ethanol has been successfully developed in the EU with main research and innovation emphasis on the development of enzymes and yeasts which are the key components in converting biomass into liquid fuels. This value chain is ready for commercialisation and several demonstration plants being built while few commercial plants are being planned for construction.

The technology of cellulosic ethanol and especially the developments of enzymes and yeast has progressed significantly in the EU and the main enzyme and yeasts providers are EU based. However, some of the investments have taken place in the USA from EU technology providers due to the more stable legislation and attractive financial packages in the USA than those of the EU. Therefore, the discussion will also cover the plants built in the USA by EU technology providers. Figure 20 shows the main pathway to produce ethanol and higher alcohols via sugar extraction from biomass and fermentation.

Figure 20: Ethanol, higher alcohols, industrial chemicals & hydrocarbons via sugar extraction from biomass and fermentation



The technology providers and the corresponding plants they have built are shown in Table 11.

Table 11: Technology Providers for Cellulosic Alcohols in the EU

N°	Technology Developer	Plant/Location	Production Capacity t/yr	In operation since	TRL
1	BIOCHEMTEX	Crescentino, Italy	40,000	2013	9
		Undecided	60,000	2020?	9
2	Abengoa	Salamanca, Spain	5,000	2010	8
		Hugoton, USA	95,000	2014	9
3	DSM/POET	LIBETRY,	60,000	2015	9
4	CLARIANT	Straubing, Germany	900	2012	8
		Romania	50,000	2019?	9
		Slovakia	50,000	2019?	9
5	BORREGAARD	Sarpsborg, Norway	80,000	2018	9
6	INBICON	Kalundborg, Denmark	20,000	2010	8
7	ST1, Cellunolix®	Kajaani, Finland	7,200	2016	8
		Undecided, Finland	36,000	2020?	9
8	IFP Futurol	Pomacle, France	75	2011	5
		Bucy-le-Long, France	7,500	2016	8

BetaRenewables[221] (a company in the Italian Mossi & Ghisolfi Group[222]) was the first company to build a commercial plant at **Crescentino**, Italy. BetaRenewables has developed the PROESA technology[223] which utilizes heat treatment followed by enzymatic hydrolysis for pre-treatment of the feedstocks. The project was initially supported under the FP7

221 See http://www.betarenewables.com/en.
222 See http://www.gruppomg.com/en.
223 See http://www.betarenewables.com/en/proesa/what-is-it.

programme of the EU and later also got funding under the NER 300 programme of the EU. The plant produces 40,000 t/y of cellulosic ethanol and it has been in operation since 2013. In 2017 M&G faced financial difficulties[224] and the Crescentino plant has been put for sale. The plant is managed by a dedicated company, Biochemtex. Biochemtex has two other contracts under FP7 one COMETHA[225] to build a 60,000 t/a plant cellulosic ethanol and the other BIOREFLY[226] to build a large scale demonstration plant producing biokerosene from the lignin residue of the cellulosic ethanol process. At Crescentino the lignin is burned in a CHP facility to produce process heat and power for the plant while excess power is sold to the grid.

Figure 21: The BetaRenewables plant in Crescentino, Italy

Abengoa[227] was one of the first companies to build a large scale demonstration plant in **Babilafuente**, Salamanca, Spain to produce ethanol from cellulosic agricultural residues and later to modify the plant to operate with onsite shorted municipal waste[228]. Both projects were supported under FP6 and FP7. The demonstration plant, uses waste-to-biofuels technology developed by Abengoa to produce second-generation biofuels from MSW using a fermentation and enzymatic hydrolysis treatment.

Abengoa also constructed a commercial cellulosic ethanol plant[229] at **Hugoton, Kansas**, USA. The Hugoton plant was designed to produce about 95 million l/y from about 350,000 tons of biomass annually. The process residue (lignin) will be combusted along with 300 tons/day of fry, raw biomass material (feedstock) to produce 18 megawatts of electricity. The key technologies are based on a sulphuric acid-catalysed steam explosion pre-treatment, in situ enzyme production, enzymatic hydrolysis and co-production of C5 and C6 sugars to ethanol.

224 See http://www.betarenewables.com/en/media-relations/news-detail/32.
225 See http://www.cometha.eu/.
226 See http://www.biorefly.eu/.
227 See http://www.abengoabioenergy.com/web/en/acerca_de/.
228 See http://www.biofuelsdigest.com/bdigest/2013/07/01/abengoa-completes-waste-to-biofuels-demo-plant-in-spain/.
229 See http://www.abengoabioenergy.com/web/en/2g_hugoton_project/.

However, in 2017 the Abengoa Group faced financial difficulties and the ethanol business was sold. Abengoa Bioenergy Biomass of Kansas[230] sold its Hugoton cellulosic ethanol plant to Synata Bio for $48.5 million, according to a brief release from its agreement adviser, Ocean Park, a boutique investment bank in Los Angeles, California[231].

Figure 22: Abengoa's demonstration plant at Babilafuente Salamanca, Spain

Figure 23: Abengoa's commercial plant at Hugoton, Kansas, USA

POET/DSM is a 50/50 consortium between the USA based POET LLC and the Dutch DSM that built the **LIBERTY[232] plant in Emmetsburg, Iowa**, USA. DSM developed new enzymes that are also expected to improve effectiveness of the enzyme mix, further reducing costs for the process while POET constructed the rest of the plant. The cellulosic ethanol plant is co-located with a grain-based ethanol plant, and uses a proprietary biomass pre-treatment technology based on a two-stage acid-catalysed steam explosion, followed by

230 See http://www.biofuelsdigest.com/bdigest/2016/07/18/abengoas-hugoton-cellulosic-ethanol-project-goes-on-the-block/.

231 See http://www.hpj.com/ag_news/hugoton-cellulosic-ethanol-plant-sold-out-of-bankruptcy/article_ae8fb952-c85f-11e6-87dc-0b12cf1982e3.html.

232 See http://poet-dsm.com/liberty.

enzymatic hydrolysis with DSM-tailored enzymes. The fermentation of C5 and C6 sugars is based on DSM engineered yeast. The lignin streams as well the waste organic streams from the plant are mixed and undergoes anaerobic digestion to produce biogas for power supply.

Figure 24: The POET/DSM plant in Emmetsburg, Iowa, USA

CLARIANT has built its technology on the basis of a demonstration plant at **Straubing**, Germany. The plant can produce 900 t/y, however, since it is a demonstration plant it is not operated continuously but for testing and optimization purposes. It is a well-integrated plant consisting of chemical-free steam pre-treatment, integrated on-site enzyme production, hydrolysis, solid-liquid separation, fermentation of C5/C6 sugars to ethanol, and ethanol purification. The company has been awarded a FP7 contract to build a 50,000 t/y facility under project SUNLIQUID[233]. CLARIANT also obtained additional financial support from the Bio-Based Industries Joint Undertaking under the European Union's Horizon 2020 research and innovation program under grant agreement programme of the EU. The new plant will be built in the south-western part of Romania where the availability of the biomass has been confirmed. At full capacity, the new plant will process approximately 250.000 tons of wheat straw and other cereal straw annually, which will be sourced from local farmers. Co-products from the process will be used for the generation of renewable energy with the goal of making the plant independent from fossil energy sources.

Furthermore CLARIANT already announced a successful step towards increasing the commercial attractiveness of its sunliquid® technology by signing the first technology license agreement with Enviral, a member of the Envien Group[234]. The plant will be built in Slovakia and I will also have a capacity of 50,000 t/y. Envien Group is one of the largest and most significant groups of companies in the CEE region active in the production of biofuels, used in blends with conventional diesel and gasoline. The group consists of ten member

233 See https://www.clariant.com/sunliquid.
234 See https://www.enviengroup.eu/en/.

companies in 4 European countries - Slovakia, Czech Republic, Hungary and Croatia. These companies are interconnected and create an entity managed as a single unit through divisional organization system.

Figure 25: Clariant's development plant at Straubing, Germany

BORREGAARD[235] has one of the oldest but innovative biorefineries in Europe at **Sarpsborg, Østfold** county, Norway. It was established in 1889 and its main products were traditionally pulp and paper. The company later started producing chemicals based on timber as a raw material and recently developed the BALI technology for the production of chemicals and ethanol. The BALI process is based on a sulphite-based cooking pre-treatment followed by enzymatic hydrolysis of the pre-treated biomass, fermentation of the sugars to ethanol and processing of the lignin to value added performance chemicals.

Figure 26: The BORREGAARD demonstration plant at Sarpsborg, Østfold county, Norway

Inbicon[236]**/Dong**[237] built a demonstration plant at **Kalundborg**, Denmark that has gone through optimization stages. The plant has an annual input capacity of 30,000 t of straw. The key technologies used in the demonstration plant are a three-stage continuous process based on biomass mechanical conditioning, hydrothermal pre-treatment followed

235 See https://www.borregaard.com.
236 See http://www.inbicon.com/en/global-solutions/danish-projects.
237 As of 6 November 2017, Dong Energy (the Danish Utility) changed its name to Ørsted, after Danish scientist Hans Christian Ørsted. See https://orsted.com/en/About-us.

by a pre-enzymatic hydrolysis at high dry matter consistency (up to 30% d.m.) which provides a continuous liquefaction. The plant has operated efficiently with technology using C5/C6 mixed sugar fermentation which resulted in improvements in the ethanol yield. Due to the lack of stable policies in the EU Inbicon now concentrates to biochemical and biomaterials.

Figure 27: The Inbicon/Dong demonstration plant at Kalundborg, Denmark

ST1[238] built the world's first softwood sawdust to ethanol plant in **Kajaani**, Finland based on its Cellunolix® technology. The bioethanol plant is located on the Renforsin Ranta industrial estate in Kajaani. The raw material for the plant will be sawdust from a nearby factory. The production capacity of the plant, 10 million litres of bioethanol per year, and the ethanol will be leased to North European Oil Trade Oy[239] (NEOT), which engages in oil and bio-products wholesale trade. The process is based on acid catalyst based pre-treatment, hydrolysis, fermentation, lignin separation, evaporation, distillation, turpentine and furfural recovery units and utility stations. Lignin and evaporation residues are converted, fed in to the boiler plant in the vicinity. Fermentation organism utilize mainly C6 sugars while majority of C5 sugars remain as future potential.

Acting on behalf of NEOT St1 has begun the analysis and signed letters of intent with Alholmens Kraft and UPM on a sawdust-based ethanol plant[240] in the Alholma industrial area in Pietarsaari. The project is estimated to be in the investment decision stage in 2018 and the plant could start up in 2020. The intention is to build a 50-million-litre Cellunolix® bioethanol plant. At the same time considerations on expanding the Kajaani plant are under way.

238 See http://www.st1.eu/.

239 See http://www.neot.fi/.

240 See http://www.st1biofuels.com/company/news/st1s-and-soks-joint-venture-neb-plans-50-million-litre-cellunolix-bioethanol-pla.

Figure 28: The ST1 plant in Kajaani, Finland

IFP Energies nouvelles[241] (IFPEN) is one of the founders of the **Futurol**[242] project. First a pilot plant was built at **Pomacle**, France. In 2016, a final step was taken with the completion of the construction and commissioning of the industrial biomass pre-treatment prototype, installed at the Tereos[243] sugar plant in Bucy le Long, in the Aisne area of northern France. Unit reception tests will continue in 2017, prior to a phase dedicated to the acquisition of the parameters required to validate the industrial scale-up of the technology. Axens[244] will market the process from 2017.

Figure 29: The FUTUROL pilot plant at Pomacle, France

The Futurol technology includes hydrothermal pre-treatment technology followed by SSF (hexoses and pentoses) to produce bioethanol for biofuels and sustainable chemistry. The plant comprises the following process steps: grinding, pre-treatment, hydrolysis &

241 See http://www.ifpenergiesnouvelles.com/Research-themes/New-energies/Biofuel-production.

242 See https://www.projetfuturol.com/.

243 See https://tereos.com/en.

244 See https://www.axens.net/.

fermentation, enzyme production, yeast propagation, distillation, lignin separation, stillage recycling, soluble sugars recovery.

1.4.3 Cellulosic alcohols in India

The government of India is promoting biofuels for mainly for energy security. The Indian mandatory Ethanol Program commenced on January 1, 2003. The production of bioethanol as well as total volume of ethanol used for blending with petrol has increased significantly since its inception. The blend percentage in petrol has been in the range of 2 to 3.5% in the last few years. At present only final (C heavy) molasses have been used as feedstock which is inadequate. In view of this limitation of availability of final molasses, it became essential to examine cellulosic feedstocks which can be used for producing Ethanol.

It is proposed to set up 12 plants based on cellulosic ethanol by public sector OMCs in various locations in India. In addition, some private companies may also set up such plants. Table 12 gives a list of cellulosic bio-ethanol projects proposed to be set up in India. These will be based on Indian technologies and eventually EU technologies. Table 13 presents the Indian technology providers and plants.

Table 12: Cellulosic Bio-ethanol Projects Proposed to be established in India

S No.	Location	Name of State	Name of Company	Technology Supplier	Capacity (KLPD)	Expected date of commissioning
1	Bhatinda	Punjab	Hindustan Petroleum Corporation Limited	Institute of Chemical Technology	100	2019
2	Panipat	Haryana	Indian Oil Corporation Limited	Praj Industries	100	2019
3	Bina	Madhya Pradesh	Bharat Petroleum Corporation Limited	Institute of Chemical Technology	100	2019
4	Numaligarh	Assam	Numaligarh Refineries Ltd	Chempolis, Finland	100	2019

5	Bargarh	Odisha	Bharat Petroleum Corporation Limited	Praj Industries	100	2019
6	Dahej	Gujarat	Indian Oil Corporation	Praj Industries	100	2019
7	Aurangabad	Maharashtra	Bharat Petroleum Corporation Ltd.	?	100	2020 -2022
8	Hardoi	Uttar Pradesh	Hindustan Petroleum Corporation Limited	?	100	2020 -2022
9	?	Bihar	Hindustan Petroleum Corporation Limited	?	100	2020 -2022
10	West Godwari	Andhra Pradesh	Hindustan Petroleum Corporation Limited	?	100	2020 -2022
11	?	Uttar Pradesh	Indian Oil Corporation Limited	?	100	2020 -2022
12	Harihar	Karnataka	Mangalore Refinery & Petrochemical Ltd.	?	100	2019
13	Gorakhpur	Utttar Pradesh	Indian Oil Corporation Limited	Indian Oil Corporation	100	2022
14	Location	Gujarat	CVC Ltd	Beta Renewable	100	?

15	Locations	Gujarat	CVC Ltd	Beta Renewabl e	100	?
16	Location	Punjab	CVC Ltd	Beta Renewabl e	100	?
16	Locations	Punjab	CVC Ltd	Beta Renewabl e	100	?
18	Fatehgarh Saheb	Punjab	JAP Innogy	Not decided	200	Q1 2020
19	Patiala	Punjab	JAP Innogy	Not decided	200	Q3 2020
20	Sangrur	Punjab	JAP Innogy	Not decided	200	Q2 2021

Table 13: Indian Technology providers and plants

N°	Technology Developer	Plant/Location	Production Capacity t/yr	In operation since	TRL
1	Praj Industries	Daund, Pune, India	1000	2017	8
2	DBT-ICT/ India Glycol	Kashipur, India	3	2010	7

Praj Industries[245], a large company with global sales of first generation bioethanol plants has developed its propriety technology for cellulosic ethanol. The demonstration plant is a continuous one with a capacity of 3 KLPD of Ethanol based on 12 TPD of feedstock in **Daund, in Pune** district. The plant started commissioning in May 2017 and it became fully operational before the end of 2017. Based on successful trials and due diligence of this technology by IOCL & BPCL, it has entered into MOU to set up 3 cellulosic ethanol plants at Panipat in state of Haryana and Dahej in Gujarat for Indian Oil Corporation, and at

245 See https://www.praj.net.

Bargarh in Odisha for Bharat Petroleum Corporation Limited. All these plants will be of 100 KLPD of bio-ethanol capacity each with a biomass requirement of around 400 TPD each.

Figure 30: Views of the Praj Industries demonstration plant in Daund, in Pune district

Based on funding from Department of Biotechnology (DBT), Government of India, the **Institute of Chemical Technology** (ICT) has developed commercial technology which has been demonstrated at India Glycol Ltd (IGL), **Kashipur**[246] on continuous processing pilot plant. The process is based on a novel two step continuous enzyme process with rapid reaction rates and reduction in enzyme dosage and reaction time resulting in more than 90 % yield of sugars from biomass. The ethanol yield is > 300 L/Ton biomass.

Figure 31: View of the demonstration plant at India Glycol Ltd (IGL), Kashipur[247]

1.4.4 Biomethane

Anaerobic digestion is microbial conversion of organic materials to methane and carbon dioxide in the absence of oxygen. The product gas from farm digesters is typically around 60% methane, although higher levels have been reported. The typical methane content from landfill sites is lower at 50–55%. Digestion is particularly suitable for residues with high moisture content, as drying is not required. The biogas can be used for heat with minimal

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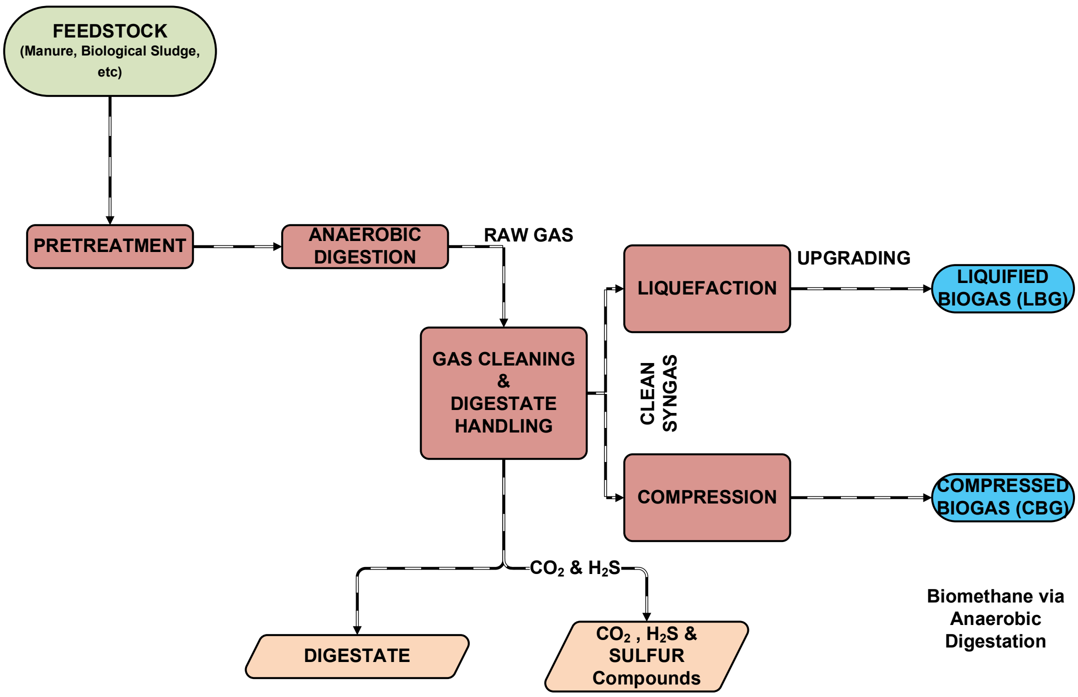
246 See http://www.indiaglycols.com/.
247 See http://www.fipi.org.in/attachments/11_May_16/Session%20IV/2_SR%20SONI.pdf.

processing, or for power generation in engines and (after upgrading to methane quality by removal of carbon dioxide and other components) in fuel cells, injecting it to the natural gas grid or as gaseous fuel for transport applications. This requires increasingly stringent quality specifications. Landfill gas produced from landfill sites may contain high concentrations of various contaminants (such as acid components) that need to be removed before upgrading to biomethane quality. Landfill sites have typically long operational times (20-25 years) and the landfill gas is collected through a system of wells, which collect and pipe the gas to the user. However as pressure grows to reduce land filling by legislation in the European Union, this resource is expected to reduce in the long term. On-farm or industrial digesters using farm wastes, industrial food wastes and household wastes are becoming more widely used for smaller scale applications. The wastewater industry in particular has successfully and effectively used digestion for in-plant power generation for many years. In the EU the last years several anaerobic digesters operate with energy crops. The solid residues and process waters after digestion contain dissolved organics and inorganics as well as non-digested solids. Depending of the feed, these residues can have a value as e.g. fertilizers or may require further treatments if they are to be disposed. Figure 32 shows the generalized pathways to produce biomethane from anaerobic digestion.

Figure 32: Biomethane production from anaerobic digestion



1.4.5 Biomethane in the EU

Biomethane from anaerobic digestion is a commercial technology in the EU. There are more than 17,000 biogas plants in the EU and the majority of them are decentralized CHP facilities. About 400 of them produce biomethane with the majority of such plants in

Germany, Sweden and the UK. The biomethane is mainly injected into the natural gas grid and in few cases it is used in captive fleets where centralized filling stations are available.

Both anaerobic digestion plants and upgrading of the biogas to biomethane are fully commercial technologies with several technology providers; therefore only 3 recent examples of large scale plants will be provided in Table 14.

Table 14: Recent plants producing biomethane from anaerobic digestion

N°	Technology Developer	Plant/Location	Production Capacity	In operation since	TRL
1	Malmberg/Västblekinge Miljö AB	Mörrum, Sweden	400 Nm³/h	2015	9
2	Biogest Biogas/Greener for Life Ltd	Somerset, UK	380 Nm³/h	2015	9
3	VERBIO	Schwedt, Germany	12 t/d compressed Bio-CH4	2015	9

Malmberg's upgrading plant in **Mörrum**[248], Sweden, upgrades biogas to 99% pure bio-methane. The gas is sold to the international power company EON, which provides it to their vehicle gas stations. Three municipalities are filling up their local busses with the resulting bio-methane. The feedstock is organic waste collected from around 250,000 people resulting in 18,000 tonnes of pure organic waste which is then dry digested producing 3,000 tonnes of biogas. The waste also generates 7,500 tonnes for composting and 7,500 tonnes recycles to fertilization. The digestion method used is solid state fermentation, meaning that food waste is digested in from the way it is generated, i.e. with no additional water mixed in. This provides a stable and energy efficient operation where the food waste is digested.

248 See https://vimeo.com/144843151.

Figure 33: The biomethane plant of Malmberg/Västblekinge Miljö AB in Mörrum, Sweden

The Biogest Biogas[249]/Greener for Life Ltd in Somerset plant produces at least 4,000 MWh electricity and 7.2 million m3 of biogas/4.3 million m3 of biomethane (40GWh) yearly using optimized feedstock mix of cattle slurry and manure, sugar beet, grass silage and maize silage. The plant provides a good symbiosis with the farming community in the area since the farm wastes are delivered to the plant allowing the farmer to manage the manure and crop rotations more efficiently. The design is based on an external main digester and an internal post-digester. The main digester is a ring canal, thereby allowing a controlled plug flow.

Figure 34: The biomethane plant of Biogest Biogas/Greener for Life Ltd in Somerset, the UK

VERBIO's[250] bio-methane plant in Schwedt/Germany is operated with 100% straw as raw material. The biogas is purified and conditioned to natural gas quality and fed into the natural gas grid. This so called bio-methane is sold as bio-component into the CNG fuel market. All main types of straw are tested in use and theses ones have already been

249 See http://www.biogest.at/.
250 See http://verbio.com/verbio/?lang=en.

approved to be suitable for the plant: wheat straw, barley straw, rye straw, corn straw, rape straw and triticale straw. The fermentation residues are brought back to the fields as a high-quality bio-fertilizer. The straw-bio-methane plant has been designed as an extension to the already existing bioethanol-bio-methane plant of VERBIO Ethanol Schwedt GmbH.

Figure 35: The VERBIO biomethane gas plant in Schwedt, Germany (yellow outline)

1.4.6 Biomethane in India

Many medium scale and large-scale biogas and biomethane plants were set up using effluent of distilleries, breweries and other industries. In addition, biogas & biomethane plants based on sludge of Sewage Treatment Plant, MSW, crop residues, kitchen waste etc. have also been set up. Till recently, biogas plants were used to produce electricity and steam (CHP), especially in distilleries. However, there is an increasing trend to set up bio-CNG plants in India. There is a largescale program to use crop residues such as rice straw for producing bio-CNG in which IOCL proposes to set up 2000 plant in India. An MOU for setting up of 42 plants by 2018 in Punjab has been signed between IOCL and the State Government. It proposed to scale the project to set up 400 plants consuming 10 million tonnes per year of biomass over the next 3 to 4 years. These plants are projected to produce about 1,400 million kg per annum CNG and 6,000 million kg per annum manure. The plants, to be based on a new concept and technology, will be set up at a total investment of Rs 50 billion[251]. From those plants below only one will be described since the technology is commercial.

[251] Press Release, Directorate of Information & Public Relations, Government of Punjab, Chandigarh, January 15, 2018. See http://diprpunjab.gov.in/?q=content/punjab-govt-signs-mou-ioc-setting-bio-gas-bio-cng-plants.

Table 15: Biomethane plants in India

Name of Company	Plant Location	Feedstock	Production Capacity of Biogas (M³/day)	Production Capacity of BioCNG (Kg/day)
Green Elephant India Pvt. Ltd	Bhuinj, Satara, Maharashtra	Distillery Effluent	28,000	11,000
M/s Spectrum Renewable Energy Pvt. Ltd.,	Warana nagar, Maharashtra	Sugar press mud	20,000	8,000
Noble Exchange	Talegaon Industrial Zone, Pune, Maharashtra	350 TPD of organic MSW	?	Biomethane 5657 TPA

Green Elephant has set up its first large scale biogas plant in India's sugar belt at **Satara District** in Maharashtra in November 2010. It consumes approximately 200,000 m³ of press mud (organic sugarcane waste) per annum and generates approximately 8 million m³ of gas per annum.

Figure 36: The Green Elephant plant at Satara District in Maharashtra, View of the Purification System of Compressed Biomethane Plant

Spectrum Renewable Energy Ltd, in partnership with **Warana Sugarcane Cooperative**, has one of the oldest large-scale biogas commercial plant in operation in the country in the state of Maharashtra. It produces biogas and compressed biomethane/Bio-CNG from 100 tonnes per day of press mud (filter cake of sugar mill) since November, 2012. The production of Bio-CNG varies from 4,000 to 7,500 kg/day. The compressed biomethane in high pressure cylinders is being sold to industrial customers, and the nutrient-rich organic manure/soil conditioner is being sold to the cooperatives' sugarcane farmers and in the local agricultural markets.

Figure 37: Compressed Biomethane Filling Section of Plant in Warna, Maharashtra

Noble Exchange Environment Solutions Pvt Ltd (NEX) is funded by Adar Poonawala's Clean City Movement, which is supported by the promoters of the Serum Institute, along with Pune Municipal Corporation. It has implemented a biomethanation project with a capacity of 358 TPD of MSW food waste at a cost of Rs 650 million at **Talegaon'**s industrial zone 35 kms from Pune. This plant has zero discharge and zero fresh water requirement. The company has also set up a plant at **Bengaluru** with capacity of 388 TPD of MSW food waste processing plant. With a combined annual capacity of 240,000 tonnes of food waste every year, the plants will produce 11,788 t/y of compressed Biogas and 43,000 t/y of Organic Manure[252].

Figure 38: View of Digesters at Compressed Biomethane Plant in Talegaon, Maharashtra

252 Pune Municipal Corporation. See https://pmc.gov.in/en/noble-exchange.

1.5 Algae

1.5.1 Introduction

There are numerous types of algae and their taxonomy is a science of its own however in general there are photosynthetic algae (including macro- and micro-algae) and photosynthetic cyanobacteria. Such aquatic biomass can be cultivated on non- arable land or even off-shore, using sea or brackish water, industrial carbon dioxide as carbon source and wastewater as nutrient input (nitrogen and phosphorus). Aquatic biomass are energy crops that do not compete with food crops for land or other resources.

In general macro algae are grown in the sea in off-shore farms and their main application is in food and proteins while microalgae are grown in open ponds and photo-bioreactors. Heterotrophic and mixotrophic algae are cultivated in stirred tank bioreactors or fermenters[253].

In general algae by themselves cannot produce biofuels, however, it is an interesting way of producing biomass with high productivity per hectare per year that can be subsequently used in energy production from biomass. Algae can grow relative rapidly compared to other biomass and may contain valuable components such as of carbohydrates, proteins, lipids, pigments and vitamins that can be used in various applications including energy. Some species of algae can have a high lipid content (in the range of 20-25 dry wt%) while other species are known to produce directly H2, ethanol or alkanes under certain cultivation conditions[254].

The initial considerable interest for algal biofuels originated on the premises that[255]:

- the lipids could be extracted relative easily and converted into biodiesel (fatty acid methyl ester),
- algal farms can be established on non-arable land or in the sea, thus avoiding completion of land use,
- algae can grow almost in almost any kind of water (fresh, sea, brackish or waste water),
- they can exhibit high productivity in the range of 50-70 tonnes/ha/year

Efforts have been undertaken by the industry and research community to increase the lipid contend of oleaginous strains either by genetic modifications or by severe stress conditions of nitrogen starvation. Although the results have been promising it soon became apparent that the overall process economics are very high compared to the cost of fossil fuels due to the high processing cost of harvesting and drying. The industry has

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253 See http://www.ieabioenergy.com/wp-content/uploads/2017/02/IEA-Bioenergy-Algae-report-update-Final-template-20170131.pdf.

254 See http://publications.jrc.ec.europa.eu/repository/bitstream/JRC98760/algae_biofuels_report_21122015.pdf.

255 See http://www.enalgae.eu/public-deliverables.htm.

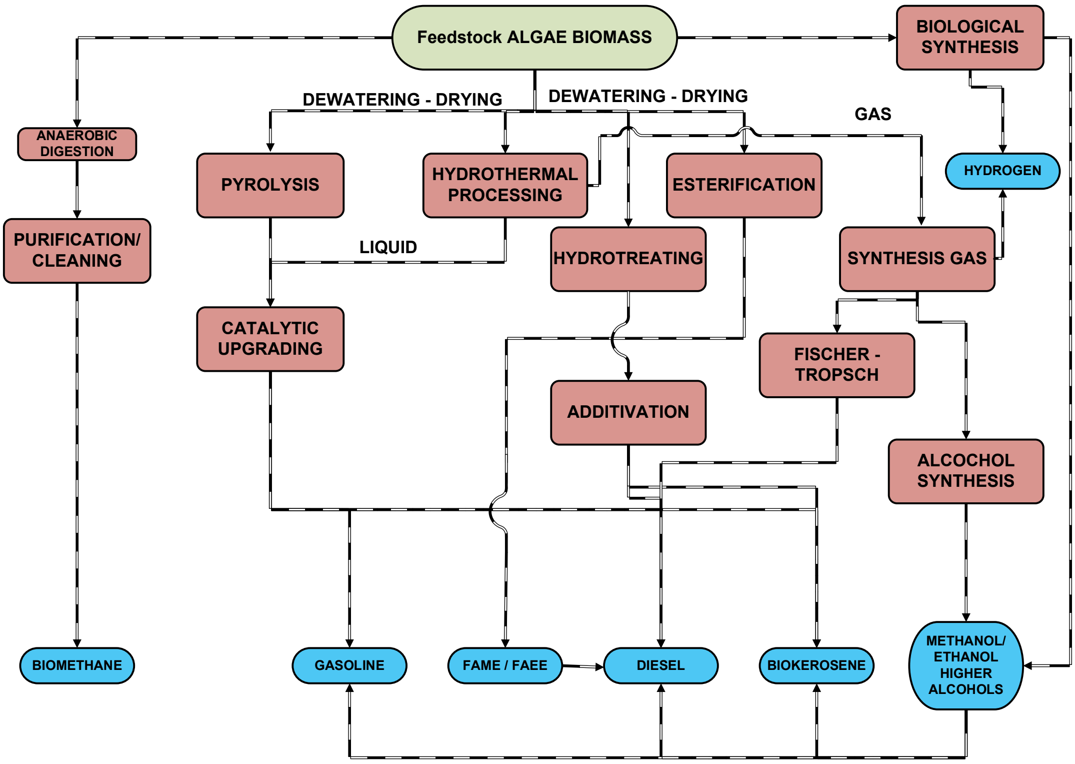
therefore turned its attention to small volumes high price products such as components for pharmaceuticals, cosmetics, nutraceuticals and fish fodder while interest in the high volume low price biofuels approach has for the moment been significantly reduced.

Furthermore the siting of algae farms is critical in view of appropriate climatic conditions, access to industrial parks, good logistics and type of land used[256].

The only exception remains that of using algae as a purification method in waste water treatment facilities since the algae produced under such conditions and applications are not considered suitable for application other than energy.

Figure 39 shows a generalized process flow diagram for algal biomass production of advanced biofuels.

Figure 39: Generalised flowsheet for algal biomass treatment to advanced biofuels; the most simplified process is that of biomethane production via anaerobic digestion



1.5.2 Waste water treatment plants in the EU using algae

Recent work on biofuels from algae indicated that at present the cost of such value chains is prohibitive and in the EU algae are cultivated for other market segments (food, feed, cosmetics, etc). However, using algae in waste water treatment facilities to purify waste water has been a successful application by AQUALIA of Spain[257].

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256 See https://ec.europa.eu/energy/sites/ener/files/documents/ENER_C2_2012_421_1.pdf.
257 See http://www.fcc.es/en/water-presentation

There are numerous contracts supported under FP7 and Horizon 2020 in the EU, however, only one of them, the ALL GAS[258] project is particularly looking into advanced biofuels and has reached the TRL 8-9.

Table 16: EU projects on algae for biofuels

N°	Technology Developer	Plant/Location	Production Capacity	In operation since	TRL
1	Aqualia/ALL GAS	Chiclana, Cadiz, Spain	150 kg/d (as CH_4)	2017	8

The ALL GAS project aims to build an algae plant over 4 ha based on open ponds. The algae are co-digested together with about 5000 m3/d of wastewater, as well as other extraction by-products, to produce biogas (CH_4 and CO_2). The biogas is upgraded to biomethane which is used as vehicle fuel to power up to 200 cars. An external biomass combustion (sludge from a wastewater treatment plant located in the area), together with internal biomass combustion (digestate from residual algae and wastewater solids), are used to supply the necessary CO_2 to the algae farm aiming to enhance the algal yield.

Figure 40: The ALL GAS project in Chiclana, Cadiz, Spain

[258] See http://www.all-gas.eu/en/.

1.5.3 Waste water treatment plants in India using algae

Phycolinc Technologies PVT LTD located in Ahmedabad is engaged in implementing Phycospectrum Environmental Research Centre's (PERC), algae remediation technology in industries in India. The algal biomass /sludge has high nutrient value and may be suitable as a feed for aquaculture as well as a bio-fertilizer/manure. The company uses phycoremediation for the removal or biotransformation of pollutants from wastewater[259]. Microalgae are used during the tertiary treatment of wastewater in maturation ponds. Algae are known to remove or bio-convert nitrogen compounds and other contaminants including heavy metals.

Table 17: Indian projects on algae for biofuels

N°	Technology Developer	Plant/Location	Production Capacity	In operation since	TRL
1	Phycolinc Technologies	Ranipet, Tamil Nadu	?	2006	9

Several commercial ETPs based on phycoremediation have been set up including that of **Snap Natural & Alginate Products Pvt. Ltd.**, Ranipet, Tamil Nadu, which reduces the high total dry solids and highly acidic to normal pH. The plant has been in operation since 2006. The company has manufacturing activity spread over 12.00 acres site. It manufactures salts of Alginic Acid, Carrageenan and Seaweed extract as an Organic Agricultural Input.

259 See http://www.phycospectrum.in/industrial-projects.

Figure 41: The phycoremediation plant at Ranipet, Tamil Nadu India

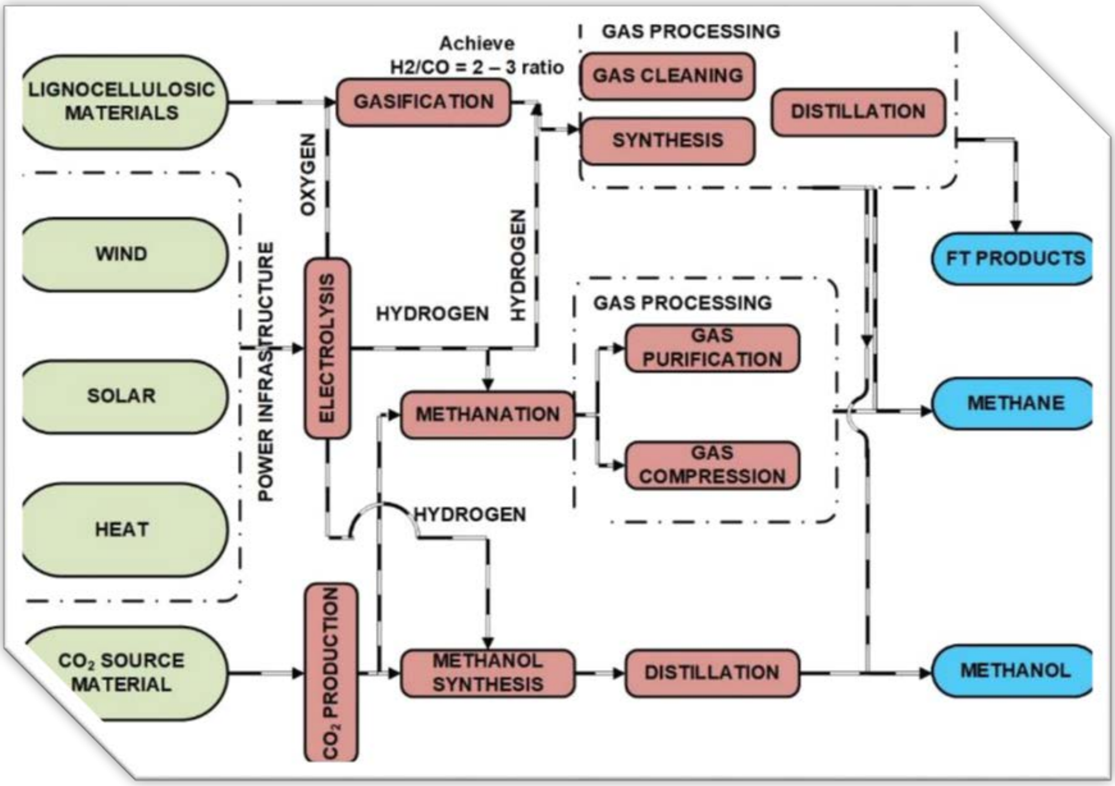
1.6 Power to X

1.6.1 Introduction

In general *Power to X* refers to technologies that convert power to liquid or gaseous fuels. Producing gaseous and liquid fuels from excess renewable electricity via electrolysis followed by the synthesis of the resulting hydrogen with carbon dioxide over catalysts is an attractive storage technology; however several issues need to be still resolved before such processes can be considered ready for market deployment. Some of these issues relate to the intermittent character of wind and PV electricity while the chemical conversion plant has to operate on continuous basis to provide economic viability. Using power from the grid is questionable at least from the point of view of fighting climate change since in Europe a significant part of it is coal based.

Although no detailed description will be given for Power to X plants in the EU, Figure 42 shows a generalized process flow diagram for producing renewable fuels via electrolysis.

Figure 42: Generalised process flow diagram for Power to X renewable fuels



1.6.2 Power to X in the EU

Under EU legislation if the renewable power originates from biomass (biomass combustion or combustions of bio-liquids[260] in gas turbines) then the resulting fuel is a biofuel while if the renewable power originates from wind or photovoltaics then the resulting fuel is called *renewable fuel of non-biological origin*.

There are several pilots and demonstration plants in the EU however all of these are considered to be far from commercialization.

1.6.3 Power to X in India

As on December 31, 2017 the large total installed electricity generation capacity of India was 330.9 GW out of which 60.2 GW was from renewable power[261]. However, India is an energy deficit country. With about 18% of the world's population India consumes only 6% of the world's primary energy[262]. Both in terms of prime energy and electricity India has one of the lowest per capita consumption. The per capita energy and electricity

260 Under the Renewable Energy Directive "bioliquids" are those liquid fuels of biomass origin that are used in applications other than transport, for example when biodiesel is used in a boiler.

261 Power Sector at a Glance, Ministry of Power, Government of India. See http://powermin.nic.in/en/content/power-sector-glance-all-india.

262 India Energy Outlook, World Energy Outlook Special Report, 2015.

consumption of India in financial year 2015-16 was 670 kgoe and at 1075 KWh/year respectively which was one-third of the world average[263]. Nearly 25% of Indian population today is without access to electricity. There has been a chronic shortage of electricity in India for decades although it has eased in the last few years. The average deficit and peak deficit of 10.1% and 12.7% respectively in 2009-10 while in 2016-17 the shortage has reduced to 0.6% and 1.7%. The demand is likely to grow at a rapid pace.

In conclusion Power to X doesn't have any prospects in India in the short to medium term future and therefore describing such EU technologies and projects are of little value to this report.

1.7 Carbon Capture and Utilisation (CCU)

1.7.1 Introduction

Various industries such as steel produce process gas streams that contain relative high concentrations of carbon monoxide and hydrogen. However the relative ratios of H2/Co are not adequate to use synthesis over catalysts unless additional hydrogen would be added to the process which can be very expensive. Gas fermentation uses bacteria to convert such gases to various chemicals such as ethanol. Furthermore the gas fermenting bacteria are claimed to be more tolerant to high levels of toxicity than synthesis catalyst, thereby avoiding expensive conditioning resulting in relative high yields.

1.7.2 Carbon Capture and Utilisation (CCU) in the EU and India

Lanzatech[264] has been successful in developing its technology and has achieved long term operation in pilot and demonstration plants. In 2018 Lanzatech commissioned a commercial plant in Shougang China. Lanzatech plans to commission two other plants in 2019; at the facilities of the steel mill of ArcelorMittal[265], Belgium and the other at the facilities of Indian Oil Co., India. Further expansion is foreseen in the USA and South Africa in 2020.

However since Lanzatech is neither a European or Indian company and it is active and well known in both the EU and India any further description is considered unnecessary.

[263] Draft National Energy Policy NITI Aayog, Government of India Version as on 27.06.2017.
[264] See http://www.lanzatech.com/.
[265] See https://belgium.arcelormittal.com.