IEA Bioenergy

IEA Bioenergy Task 42 on Biorefineries:
Co-production of fuels, chemicals, power and materials from biomass

IEA Bioenergy Task 42 – Countries Report

Final

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Abstract:

This report has been developed by the members of IEA Bioenergy Task 42 on Biorefinery: Co-production of Fuels, Chemicals, Power and Materials from Biomass (www.biorefinery.nl/ieabioenergy-task42). IEA Bioenergy is a collaborative network under the auspices of the International Energy Agency (IEA) to improve international co-operation and information exchange between national bioenergy RD&D programs. IEA Bioenergy Task 42 on Biorefinery covers a new and very broad biomass-related field, with a very large application potential, and deals with a variety of market sectors with many interested stakeholders, a large number of biomass conversion technologies, and integrated concepts of both biochemical and thermochemical processes.

This report contains an overview of the biomass, bioenergy and biorefinery situation, and activities, in the Task 42 member countries: Austria, Canada, Denmark, France, Germany, Ireland, and the Netherlands. The overview includes: national bioenergy production, non-energetic biomass use, bioenergy related policy goals, national oil refineries, biofuels capacity for transport purposes, existing biorefinery industries, pilot and demo plants, and other activities of research and development (such as main national projects and stakeholders). Data are provided by National Task Leaders (NTLs), whose contact details are listed at the end of the report.

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1. Background

A large fraction of worldwide energy carriers and material products (especially high value chemicals) come from fossil fuels, mainly from oil refinery. Due to the on-going price increase of fossil resources, the uncertain availability, their environmental concerns, and the fact that they are not a renewable resource, the feasibility of their use is predicted to decrease in the near future. Therefore, alternative solutions able to reduce fossil fuel consumption and subsequent pollution should be promoted. Electricity and heat can be provided by a variety of renewable alternatives (wind, sun, water, biomass, and geothermal), whereas the fossil resource alternative for the production of fuels and chemicals depends mainly on biomass, the only renewable C-containing material source available on the Earth.

As a consequence, the term of "biorefinery" is raising importance in the scientific community and the concept embraces a wide range of technologies able to separate biomass resources (wood, grasses, corn…) into their building blocks (carbohydrates, proteins, fats…), which can be converted to value-added products (chemicals/materials) and energy (biofuels, power, heat). In the near future, new biomass feedstocks are predicted to breed other desired compounds that could be easily extracted or separated.

A biorefinery can be defined as a facility that optimizes the integrated production of heat, power, transportation fuels, materials, chemicals, feed and food from biomass. By producing multiple products, a biorefinery can maximize the value derived from biomass feedstocks.

A biorefinery definition has been recently formulated by the IEA Bioenergy Task 42 on Biorefineries:

"Biorefining: the sustainable processing of biomass into a spectrum of marketable products and energy".

Biorefinery: concepts, facilities, plants, processes, clusters of industries.

Sustainable: maximising economics, - social aspects, minimising environmental impacts, fossil fuel replacement, closed cycles.

Processing: upstream processing, transformation, fractionation, thermo-chemical and biochemical conversion, catalytic processes, extraction, separation, downstream processing.
Biomass: wood & agricultural crops, wood, straw, organic residues, forest residues, aquatic biomass.
Spectrum: multiple energetic and non-energetic outlets.
Marketable: a current market exists or a future market is expected to become available, taking into consideration both market volumes and prices.
Products: both intermediates and final products, i.e. food, feed, materials and chemicals.
Energy: fuels, power and heat.

IEA Bioenergy Task 42 on Biorefineries covers a new and very broad biomass-related field with a very large application potential. To open up the biorefinery-related potential, international research and technology development together with industry is a necessity.
In contrast to most of the other IEA Bioenergy Tasks, Task 42 on Biorefineries covers a variety of market sectors (e.g. transport sector, chemical sector, power sector, agricultural and forestry sector) with a variety of different stakeholders, a large number of biomass conversion technologies, and integrated biorefinery concepts of both biochemical and thermochemical conversion technologies.

2. Aim of the report

The aim of this report is to provide an overview of the currently existing situation concerning biomass use in the 7 countries – Austria, Canada, Denmark, France, Germany, Ireland, The Netherlands – participating in IEA Bioenergy Task 42. This information is the starting point/framework for all the activities performed within this Task 42.

This report deals with an overview of biomass and bioenergy related infrastructures, and provides information concerning other biorefinery-related aspects in IEA Bioenergy Task 42 countries.

Each National Task Leader (NTL) provided data for the respective country and can be directly contacted in order to get more detailed information or data sources (a full list of NTLs with their contact details is reported at the end of this report).

The report starts in chapter 3. with a presentation of IEA Bioenergy Task 42 participating countries by means of some generic information about: total area, population, agricultural and forest land. In chapter 4. the national biomass energy use is illustrated in terms of Mtoe and % of TPES (Total Primary Energy Supply). The non-energetic biomass use, i.e. biomass which is not used for energy purposes, is reported in chapter 5.; particular attention is paid here to those biomass resources which may play a major role in the future development of biorefinery concepts (such as forest products, starch and sugar industries). Chapter 6. presents the biomass-related national policy goals, with information concerning the expected production in the near future of bioenergy, biofuel and bioelectricity; targets are provided for all IEA Bioenergy Task 42 countries. In chapter 7. the national oil refineries (places/capacities) are depicted (total production of oil and derivates), as well as national consumption of gasoline and diesel, are shown. The national production capacity of bioethanol, biodiesel and biogas, and the already existing biorefinery industries, are presented in chapters 8., 9., and 10. In chapter 11., the national activities of research and development are shown, reporting: the pilot and demo plants, the national projects, and the main national stakeholders in the biorefinery area. This overview includes the most important companies, projects and stakeholders.

3. IEA Bioenergy Task 42: Participating Parties and Countries

The 8 participating parties (7 countries and the European Commission) to IEA Bioenergy Task 42 (full task name: Biorefineries: Co-production of Fuels, Chemicals, Power and Materials from Biomass; website: www.biorefinery.nl/ieabioenergy-task42) are: Austria, Canada, Denmark, France, Germany, Ireland and the Netherlands, plus the European Commission.

Table 1. reports basic information about the involved countries, such as: total area, population, utilized agricultural area and forest land.

Table 1. Characteristics of the participating countries.

	Total area	**Population**	**Utilized Agricultural area**	**Forest land**
	[10^3 km^2]	[10^6]	[10^3 km^2]	[10^3 km^2]
Austria	83.9	8.27	33.7	32.0
Canada	9985	31.6	675	4021
Denmark	43.1	5.43	26.4	5.35
France	544	61.9	294	155
Germany	357	82.4	170	111
Ireland	70.3	4.21	43.7	7
The Netherlands	41.5	16.3	19.2	3.49

Since plants are the origin of biomass, the available land for agriculture and forestry is an important parameter for drawing the potential supply of feedstock for biorefineries. However, it should be taken into account that this land primarily has to provide vital ecosystem services and meet the food and feed demand, and secondly can be used for the production of raw materials for bio-based products related biorefineries and bioenergy industries. For instance, Canada has 4,021•10^3 km^2 of forest land but the area considered to be potentially available for commercial forest activities is about 2,948• 10^3 km^2. Besides the use of biomass crops, also industrial process residues can be used as raw materials for biorefinery purposes. The supply of raw materials for biorefineries potentially can be further increased by import of densified biomass and/or biomass-derived intermediates to countries with a lack of national available raw materials, but with a very good logistical (harbours) and (petro)chemical infrastucture. An example of such a country is The Netherlands, which potentially makes this country the potential Bio-HUB for Europe. Care should be taken that the total biomass-to-products value chain remains sustainable.

4. National biomass use for energy

A wide range of biomass sources can be used to produce bioenergy in a variety of forms. For instance, process residues from food, fiber, animal feed and wood industries; energy crops, and agricultural residues and wastes from the agricultural sector; forest residues from forest management; municipal solid waste, and organic industrial residues, can be utilized to generate power, heat, CHP, and gaseous/solid/liquid biofuels.

Bioenergy provides today about 10% of the world's total primary energy supply (47.2 EJ of bioenergy in 2005) and most of this is used in the residential sector for heating and cooking purposes (IEA database). Traditional bioenergy use (fuelwood and charcoal, often used with low efficiency) dominates in developing countries where up to 95% of national energy consumption relies on biomass. Contrarily, in developed countries, such as the Task 42 members, an efficient biomass use is becoming more important, as a low carbon, distributed, renewable component of national energy systems. In fact, utilization of modern bioenergy applications is growing in OECD countries; especially co-firing of biomass with coal, the use of gasification technologies, and biofuel production for transport (mainly bioethanol and biodiesel).

The national biomass energy use of the investigated countries is shown in Figure 1. It is expressed both as a percentage of the Total Primary Energy Supply (TPES) and in terms of Mega Tonnes of Oil Equivalent (Mtoe). Even if Germany, Canada and France produce the largest quantities of bioenergy (15.6, 12.98 and 11.91 Mtoe respectively), their shares to the national TPES is in the range of 4-5%; while countries such as Austria and Denmark, despite a lower bioenergy production (3.91 and 1.97 Mtoe respectively), meet higher shares of their TPES (11% and 9.4%). For the specific Dutch situation, the total amount of biomass use for energy purposes was only 2.4% avoided fossil fuel use in 2007. This was even less than the 2005 data given in figure 1., mainly caused by a 50% decrease in biomass cofiring in coal-fired power stations, caused by i) a declining green power subsidy by the Dutch government and ii) required maintenance stops of some of the power plants.

Figure 2. reports two examples of national bioenergy breakdowns per source: Austria and Denmark. In both countries, wood logs, wastes and wood industry residues play the biggest role, while upgraded wood solid fuels (such as wood chips, briquettes and pellets) and transportation biofuels (bioethanol, biodiesel and biogas) cover lower percentages. In Austria, the high concentration of pulp and paper industries makes the production of a wide fraction of bioenergy from black liquor and sludges possible; while Denmark benefits of strategies devoted to energy recovery from straw.

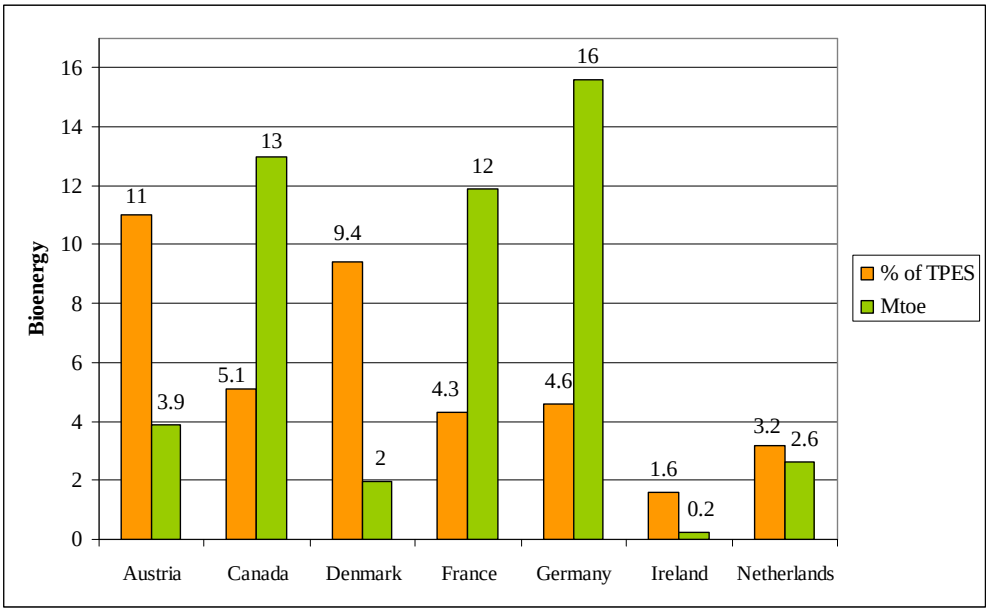

Figure 1. Bioenergy production in Task 42 countries (2005).

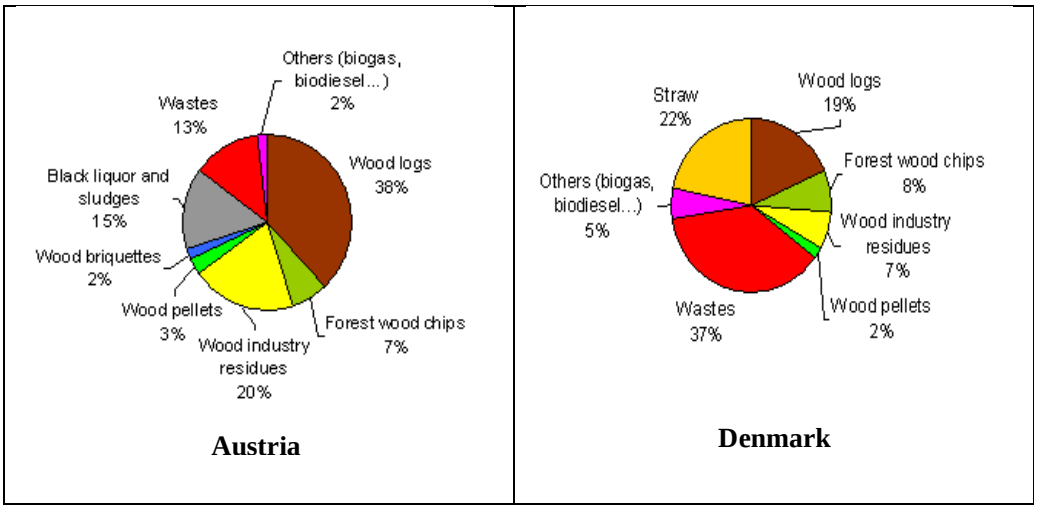

Figure 2. Origin of the bioenergy production in Austria and Denmark.

The Dutch use of biomass for energy purposes, in 2007, and the policy goals for 2010, are shown in Figure 3.

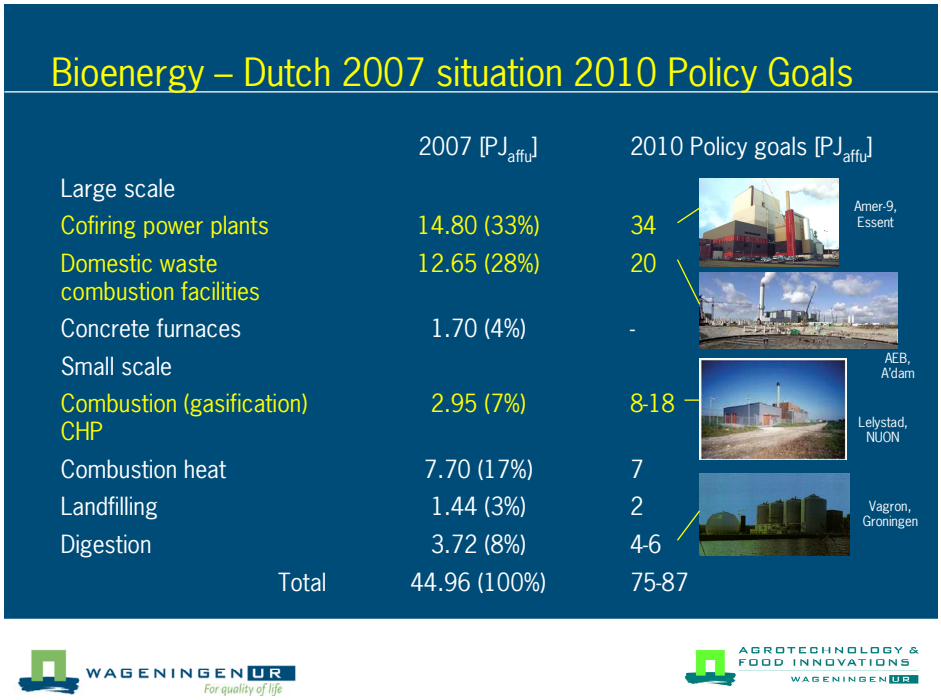

Figure 3. Bioenergy production in The Netherlands (2007).

As can be seen from the data given in Figure 3., a lot of effort is necessary to meet the 2010 policy goals, especially within the fields of direct/indirect cofiring, domestic waste combustion, and small-scale combustion/gasification for CHP production.

Concerning biofuels for transport, in 2006 67 million litres (2000 TJ) were sold in The Netherlands (38 Ml ethanol/ETBE, 29 Ml biodiesel), corresponding to about 0.4% (energy basis) of the total gasoline and diesel sold on the Dutch market (2005: 0.02%).

In 2007 the total biofuel for transport contribution was 13 $PJ_{th,\ affu}$, corresponding to about 13.6% of the total Dutch renewable energy production capacity (95.9 $PJ_{th,\ affu}$).

European policy goals are: 2% in 2005, 5.75% in 2010, and 10% in 2020. To meet these EU policy goals a lot of effort is necessary in the Netherlands.

The main national focus to meet these goals will be on the implementation of advanced (2nd and 3rd generation) biofuel production facilities, viz. sustainable production facilities that i) do not compete with food/feed concerning their raw material use (a.o. ligno-cellulosic biomass) and ii) have a large overall greenhouse gas emission reduction potential over the full biomass-to-products chain. These plants likely will be some kind of biorefinery facilities, co-producing added-value bio-based products with the biofuels for transport (a.o. by upgrading process residues), to maximise overall process economics and to minimise the environmental impact.

5. Non energy national biomass use

This section provides an overview of the most important non-energetic national biomass uses in the member countries. Table 2. focuses on those biomass feedstocks which are currently used for production of forest products, food and animal feed, and can be of relevance for the future deployment of biorefinery industries and infrastructures. One of the targets of IEA Bioenergy Task 42 is to promote the integration of the biorefinery concept within existing biomass production chains and facilities. Table 2. provides information concerning: national wood resources destined to particle board production, and to pulp and paper industries (together with their waste streams); national agricultural production of cereals (wheat, corn, barley, oats and rye); sugar from sugar beet; starch from crops; and oilseeds from rapeseed, sunflower, soybeans, canola and flax seed.

Table 2. National main production of biomass for non-energetic purposes.

Country	Unit/a	Austria	Canada	Denmark	France	Germany	Ireland	Netherlands*
Wood for particle boards	10^6m^3	4.1	12.4	n.a	5.8	17.4	0.91	0.015
Wood for pulp & paper	10^6m^3	7.3	111	n.a	8.4	9.8	n.a	n.a..
Wastes from pulp and paper	10^3ton	1.35	n.a.	n.a	n.a	n.a	n.a.	n.a
Cereal production	10^6ton	4.46	47.8	8.22	59.3	42.3	2.0	1.3
Sugar production	10^6ton	0.46	0.87	2.26	4.14	3.9	n.a	0.76
Starch production	10^6ton	n.a.	n.a.	1.70	2.91	1.51	0.40	0.4
Oilseed production	10^6ton	0.29	12.1	0.59	6.1	5.6	0.02	0.0078

*Specific production data 2007. NL Wood for particle boards – production: 0.015, import: 1.24, export: 0.343, use: 0.912. Raw materials paper industry – recycled paper: 2.73, use: 2.31. Production paper and cardboard – production: 3.219, import: 3.535, export: 3.649, use: 3.105. Oil seeds production (2002): 7.8 ktonnes; total processing capacity, mainly from imported oil seeds and for feed production: 4942 ktonnes (2002).

Besides existing biomass production chains, also residues from existing facilities are interesting raw materials to be upgraded by the biorefinery approach. For example, Rabou et al. (2006) calculated the 2000 Gross Dutch biomass production ((import-export) + production): 42.3 Mt or about 742 PJ_{th}. The 2030 projected Dutch biomass availability for non-food applications is: 6 Mt d.b. primary byproducts (100 PJ_{th}), 12 Mt d.b. secondary byproducts (200 PJ_{th}), and about 0-9 Mt d.b. energy crops (0-150 PJ_{th}).
Totally: 18-27 Mt d.b. or about 300-450 PJ_{th}. It was concluded that 60-80% of the biomass needed to meet the 2030 policy goals will have to be imported from outside The Netherlands. In case the aquatic biomass (algae, seaweeds) potential is also taken into account, the import requirement is reduced to about 50%.

6. Biomass related national policy goals

In each country, there are different national guidelines and targets concerning national future production of bioelectricity, bioenergy and transportation biofuels. Biomass, together with other renewable sources, is expected to meet increasing share of the future electricity demand, while it plays a fundamental role for achieving the targets related to the transportation sector and for renewable heat production, since they can just rely on biomass. The European Union aims to use 5.75% in 2010, and 10% in 2020 biofuel in road transport (calculated on energetic basis). Many member states promoted plans to implement these European targets.

The national targets for IEA Bioenergy Task 42 countries are the following:

- **Austria**: Concerning bioenergy, 250 PJ is expected to be produced in 2010, while, for 2020, 45% of the total primary energy supply should come from renewable sources (hydropower, biomass, wind…). Austria has been able to meet and anticipate the European goals for biofuels: the target of producing 2.5% of the total transportation fuel from biomass (mainly biodiesel) was completely achieved in 2005 and outperformed. In fact, in 2008, Austria also met the 2010 EU-target of 5.75% of biofuels in the transportation sector.

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Further, Austria estimates targets of 10% in 2010, and 20% in 2020. Similarly, in 2005 the target of 2% of "new renewable" electricity production (renewable electricity to be added to large hydropower) has been successfully met. The next targets are 4% in 2008 and 10% in 2010. In addition, 78.1% of the total electrical consumption in 1997 (202 PJ) must be covered from renewables (including large hydropower). Currently, around 144 PJ of electricity come from renewable, and the total electricity generation from renewable sources should be equal to 80% in 2010 and to 85% in 2020 (of the total national electricity demand).

- **Canada**: There are no renewable energy targets at a national level, although several provinces have renewable energy strategy plans with targets and goals. Regarding transportation biofuels, national strategies aim at a target of 5% of renewable fuels in transport sector to be achieved by blending gasoline with bioethanol in 2010. In 2012, 2% of the energy content of conventional diesel and heating oil is expected to be produced from renewable sources (e.g. biodiesel).
- **Denmark**: The Danish bioenergy targets forecast to meet, by means of renewable energy sources, the 20% of the total primary energy supply in 2011 and the 30% in 2025. In the transportation sector, the country follows the European targets of 5.75% in 2010 and 10% in 2020.
- **France**: Renewable energy targets estimates in 2020 to produce 37 Mtoe (1549 PJ) of energy from renewable energy sources (20% of the total), of which 20/25 Mtoe (850-1050 PJ) from biomass. France also made a prediction concerning the future bioenergy markets in 2020: 19 Mtoe (795 PJ) of biomass solid fuel (it was 9.5 Mtoe (398 PJ) in 2006), 4 Mtoe (167 PJ) of biofuels (0.7 Mtoe (29 PJ) in 2006) and 0.7 Mtoe (29 PJ) of biogas are expected to be produced. Concerning national targets for biomaterials and biochemicals, France expects a production of 1 Mtoe (42 PJ) of bioproducts in 2020 (the production in 2006 was 0.08 Mtoe (3 PJ).
- **Germany**: Several targets have been established. Targets for bioenergy are 4.2% in 2010 and 18% in 2020 of the TPES. The renewable energy fraction in the total primary energy supply is expected to be of 20% in 2020 (6% electricity and 14% for heat supply).

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The target for electricity predicts that 12.5% in 2010 and up to 30% in 2020 of the total electricity production will be produced from renewable sources (hydro, biomass, wind, solar…). Considering the transportation sector, the biofuel share was 7.3 % in 2007. Targets are 6.25% in 2014 and 12 – 14 % in 2020 (change to a GHG reduction target in transport fuels).

- **Ireland**: An amount of 28 PJ in 2010 and 60 PJ in 2020 of bioenergy are estimated to be produced. A fraction of 16% of the total primary energy supply will be covered by renewable sources in 2020, with a production of electricity from biomass equal to 800 MW_e (CHP).

  Targets for biofuel shares in transport sector follow the European guidelines of 5.75% (of which 6.9 PJ diesel and 4.7 PJ gasoline) in 2010 and 10% (of which 14 PJ diesel and 8.2 PJ gasoline) in 2020.
- **The Netherlands**: In the Netherlands there exists for some years a general policy goal of 10% renewable energy in 2020 (5% in 2010). Further, 9% of the electricity use in the NL should be provided by renewables in 2010. In 2007 new very ambitious policy goals were defined within the programme "Schoon en Zuinig", viz.: 20% renewable energy in 2020, 2% energy saving a year till 2020, and 30% CO_2-reduction in 2020. Concerning biofuels The Netherlands will try to comply to the the European policy goals mentioned. Further, in the NL a long-term Vision has been developed that in 2030 30% (energy basis) of the raw materials and fuels used for both industrial and energy purposes should be bio-based. To meet this long-term Vision, all available domestic biomass resources should be made available, incl. the full use of the aquatic biomass potential. Even then, about 50% of the biomass requirements should be covered by import of densified raw materials and/or biomass-derived intermediates. This huge import of biomass is no problem for the NL with the available Rotterdam, Amsterdam, Delfzijl and Terneuzen harbours; it even offers the NL the opportunity to become the Bio-HUB for Europe; i.e. importing huge amounts of biomass, giving added-value to these streams in available industrial infrastructures, and exporting these intermediate/final products to other EU-27 countries.

7. National oil refinery

This section provides an overview of the oil refinery situation in the seven IEA Bioenergy Task 42 countries. The crude oil is a mixture of many different organic hydrocarbon compounds, and the first step of oil refinery is to remove water and impurities, then distill the crude oil into its various fractions as: gasoline, diesel fuel, kerosene, lubricating oils and asphalts. Then, these fractions can be chemically changed further into various industrial chemicals and final products. Unlike petroleum, biomass composition is not homogeneous, because the biomass feedstocks might be made of grains, wood, grasses, biological wastes, and so on, and the elemental composition is a mixture of C, H and O (plus other minor components, such as N, P and other mineral compounds). This compositional variety constitutes the major constraint for the integration of bio-based intermediates into the already existing oil refinery facilities. The shift to a bio-based chemical and material industry will alter the technological basis of the industry.

Table 3. shows the oil refinery capacity of the countries, the shares of the products of the national oil refineries, and the number of refineries. National consumption of gasoline and diesel is reported in Figure 4.

Table 3 Characteristics of oil refinery.

Oil product (Mtoe/a)	Austria	Canada	Denmark	France	Germany	Ireland	Netherlands
Diesel	3.5	25	3.36	20.7	29.0	1.10	14.4
Gasoline	1.7	33	2.08	15.8	21.3	0.68	10.7
Heavy oil	1.0	9	1.43	7.6	6.1	0.95	13.6
Jet Kerosene	0.5	15	-	5.9	8.8	-	6.7
Other (mainly light oil)	0.1	-	0.63	28.6	36.6	0.24	45.4
Total	6.8	83	7.50	78.5	101.8	2.97	88.9
Reference year	2005	2007	2006	2006	2007	2005	2007
Number of refineries	2	18	2	13	14	1	5*

*NL: Pernis Shell Refinery: 416000 bbl/day, Botlek Exxon/Mobile Refinery: 195000 bbl/day, Vlissingen Total/DOW Refinery: 160000 bbl/day, Europoort BP Refinery: 400000 bbl/day, Rozenburg Q8 Refinery: 80000 bbl/day.

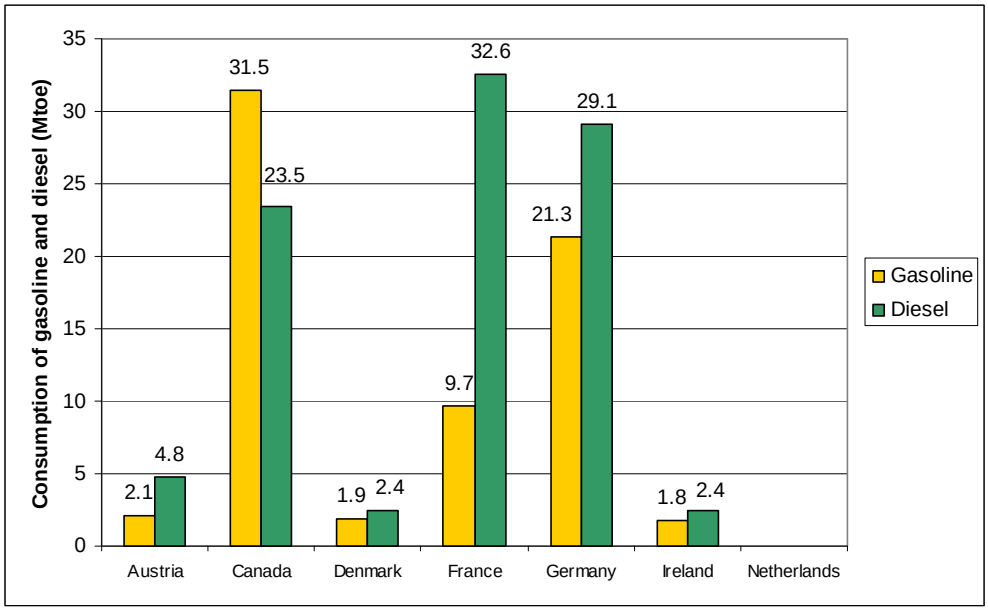

Figure 4. Consumption of gasoline and diesel.

NL (2003): 7016 Ml diesel; 5431 Ml gasoline

8. Bioethanol, biodiesel and biogas: production and capacity

One of the main driving factors for the future development of biorefinery is the production of liquid transportation biofuels able to increase the biofuel shares in the transportation sectors, in order to meet the previously reported targets. The transportation sector is growing steadily and in the same way grows the demand for fuels.

As already mentioned above, Europe aims at a share of 10% biofuel in 2020, and IEA and IPCC expect a significant contribution of biofuels on the transportation market in 2030 (10 – 20%). As a consequence, the main driver for the development of biorefinery is seen by IEA Bioenergy Task 42 – from an energy point-of-view – in the efficient and cost effective production of transportation biofuels, whereas for the coproduced biomaterials and biochemicals additional economic, environmental and social benefits might be gained. Table 4. reports data and information concerning production of the 1st generation biofuels bioethanol, biodiesel and biogas. For each of them, effective production, estimated capacity, feedstocks and number of installation plants are specified.

Biodiesel is the main biofuel in European countries, while bioethanol dominates the biofuel market in Canada (and the US). The production of biogas is diffused in all the countries, and in the last few years it has been strongly implemented in countries with high feed in tariffs for electricity generation from biogas (especially European countries). In Germany and Austria, biogas is also used as transportation biofuel, after upgrading to biomethane. Straight vegetable oil is mainly used in Germany, with an annual production of 800 ktonnes. Another type of biofuel, Ethyl Tert-Butyl Ether (ETBE, derived from ethanol), is produced in France (4 production plants, 250 ktonnes capacity), Germany (500 ktonnes capacity), and The Netherlands (2 production plants, 755 ktonnes capacity). ETBE is commonly used as an oxygenate gasoline additive.

Table 4. Characteristics of biofuel production in IES Bioenergy Task 42 countries.

Country	Year	Production	Estimated capacity	Feedstock	Number of plants	Application
Austria						
Biodiesel (10^3t/y)	2007	442	1,248	Waste, animal fat and plant oil	18	Transportation fuel
Bioethanol (10^3t/y)	2007	15.0	15.0	Wheat, corn, sugar beet	1	Transportation fuel
Biogas (10^3toe/y)	2007	118	n.a.	Manure, corn	332	Electricity/heat, Tr. Fuel
Canada						
Biodiesel (10^3t/y)	2007	n/a	92.4	Tallow, Canola, Yellow Grease	8	Transportation fuel
Bioethanol (10^3t/y)	2007	646	684	Corn and wheat	10	Transportation fuel
Biogas (10^3toe/y)	2007	488	n.a.	Landfill gas, sewage, manure	110	Electricity/heat
Denmark						
Biodiesel (10^3t/y)	2007	98.0	130	Rapeseed, animal waste	2	Exported
Biogas (10^3toe/y)	2007	93.5	n.a.	Manure, slaughterhouse	51	Electricity/heat
France						
Biodiesel (10^3t/y)	2007	1,300	n.a.	Rapeseed and sunflower	18	Transportation fuel
Bioethanol (10^3t/y)	2007	426	n.a.	Sugar beet, wheat	18	Transportation fuel
Biogas (10^3toe/y)	2007	55	n.a.	Landfill, sewage	200	Electricity/heat, Tr. Fuel
Germany						
Biodiesel (10^3t/y)	2007	2,900	5,010	Rapeseed, soya and palm oil	n.a.	Transportation fuel
Bioethanol (10^3t/y)	2007	357	766	Sugar beet, wheat, molasses	7	Transportation fuel
Biogas (10^3toe/y)	2006	1,923	1300$Mw_{e,h}$	Landfill, sewage, starch	3500	Tr. fuel, Electricity/heat
Ireland						
Biodiesel (10^3t/y)	2006	4.00	n.a.	RVO, Rapeseed Soya	7	Transportation fuel
Biogas (10^3toe/y)	2006	34.7	n.a.	Landfill, sewage, starch	n.a.	Electricity/heat
Netherlands*						
Biodiesel (10^3t/y)	2007	0.253	1.5-4.5	Waste fats/oils, rapeseed	10**	Transportation fuel
Bioethanol (10^3t/y)	2007	0.132	0.5	Sugar beet, molasses	3**	Transportation fuel
Biogas (10^3toe/y)	2008	-	100 Mm^3	Landfill, sewage, starch	>	CHP, transport

* In the NL the current (2008) known biodiesel production capacity is about 750 - 1500 ktonnes/year. Additional production capacity of about 1500 ktonnes per year is in the start-up phase; whereas another 1500 ktonnes/year initiatives is in the idea phase [info SenterNovem GAVE website, December 2008]. For the time being there is only little production capacity available to produce bioethanol for transport purposes; however, there exists a production capacity of about 755 ktonnes ETBE. There is a bioethanol production capacity in the start-up and idea phase of about 750 Ml. Besides biodiesel, bioethanol and biogas, there are some small-scale PPO production facilities, and an 800 ktonnes/year biomethanol production facility. ** Only running plants, and start-up initiatives, being taken into account.

9. Existing biorefinery industries

This section presents a list of the most important existing biorefinery and non conventional biomass industries which are running in IEA Bioenergy Task 42 countries (Table 5). Note that the conventional biomass uses (i.e. agricultural production, wood industry, pulp and paper industry and CHP applications) and 1st generation transportation biofuel production (i.e. biodiesel and bioethanol) are not included. These existing biorefineries are already competitive in the market.

Table 5 Existing biorefinery and non conventional biomass industries.

Country	Feedstock	Pruducts	Description
Austria			
Lenzing AG	Fibre and pulp	Furfural, acetic acid, sodium sulfate, potassium-lignin-sulfate	Separation of chemicals as a co-product of fibre and pulp processes. CHP from lignin
Danisco	Wastewater of pulp and paper industry	Xylose	Separation of xylose out of wastewater
Canada			
Ensyn	Agricultural and wood residues	Bio-oil, charcoal, food flavors, adhesive resins, green gasoline, diesel and jet fuels.	Rapid pyrolysis produces bio-oil that can be used for power generation, renewable transportation fuels and a range of chemicals.
Tembec	Pulp mill biomass	Ethanol,acetic acid, phenol-formaldehyde resins and lignosulfonates	Conversion of cellulose wastes to ethanol and fine chemicals
Dynamotive	Waste sawdust / recyled lumber	Bio-oil, char	Rapid pyrolysis to produce bio oil and char
Nexterra/Tolko	Wood residue	Heat energy	Gasification to syngas
Denmark			
Agroferm	Green juices	Lysin for animal feed	Production of lysin for animal feed by fermentation of green juices from green pellet production
Dangront	Grasses	Green pellets and green juices	Production of green pellets and juices from grasses
France			
Novance	Vegetable oil	Oleochemistry for non-food markets	Production of solvents, lubricants, biodiesel, resins
DRT	Terpen, resins	chemicals from paper and pulp industry by-products	Resin, gum rosin, resin, fine chemicals, tall oil derivatives, surfactants
Roquette	Wheat, potato, maize, pea	Starch, food, feed, bulk and fine chemicals, succinic acid, ethanol…	Physical, chemical and fermentation processes
ARD, Cristal Union, Chamtor	Wheat, sugar beet,	Food, feed, ethanol, succinic acid, cosmetics, electricity	Physical, chemical and fermentation processes
Tembec, Smurfit…	Wood	Cellulose, paper, tall oil, lignosulfonates, electricity, steam	Production of products and energy

Germany			
Südzucker	Sugar, grain	Sugar, palatinose, food additives, feed, ethanol biogas, electricity	Logistics, sugar/starch-refinery, palatinose plant, CropEnergy for Ethanol and Byproducts
Zellstoff Stendal	Wood	Cellulose, paper, tall oil, MeOH, turpentine, electricity, steam	Production of products and energy from wood by cooking, bleeching, drying, power plant waste water treatment
Biowert	Grass	Biogas, insulation material, biocomposites	Production of fibres and juice from grasses
CropEnergies	Sugar, grain	Ethanol, DGGS, electricity	See Südzucker
Ireland	none operational		
Netherlands			
Bio MCN	Glycerin	Methanol	Upgrading of the biodiesel byproduct glycerin to biomethanol for transport
BioValue			
Vierhouten Vet	Waste oils/fats	Biodiesel	Waste plant oils and animal fats used in the food industry are upgraded to biodiesel
Ecoson/Vion	Waste meat industry	Biogas, CHP, Biodiesel	Integrated production of biogas, fats and biodiesel from meat waste
BioValue	Waste oils/fasts	Biodiesel, fuel additives	Integrated production of biodiesel, and fuel additives from glycerin fraction
Ten Kate Vetten	Raw animal fats	Consumable fats, aromas & flavours, gelatine, CHP	Integrated production of food and CHP
Food industry	Various	various	Various

10. Pilot and demonstration plants

Bioethanol, biodiesel and biogas represent the so called biofuels of 1st generation, while the 2nd generation is still under development in different research activities and pilot/demo plants but are not yet on the market. The term 2nd generation biofuels refers to those biofuels which are produced from lignocellulosic materials (such as wood and straw) or other feedstocks which do not compete with the food and feed industries. Table 6 and 7 report a list of the biorefinery pilot plants, while the demo plants are reported in Table 8.

Table 6 Biorefinery pilot plants in Austria, Canada, Denmark and France.

Country	Feedstock	Products	Description	Status
Austria				
Güssing	Lignocellulose	SNG and FT-fuels	Gasification of forest wood chips and conversion to FT-fuels	Pilot plant
Utzenaich	Grass silage	Amino acids, lactic acid, biogas	Green biorefinery: production of amino acids, lactic acid and biogas from grasses	Pilot plant

Hartberg	Grass silage	Amino acids, lactic acid, biogas, fiber boards	Green biorefinery: production of amino acids, lactic acid, biogas and fiber boards from grasses	Pilot plant
Canada				
IMUS, Vegreville, AB	Manure for biogas; wheat for ethanol and DDGS	Biogas, electricity, fertilizers, ethanol and DDGS	Hydrolysis & fermentation of wheat into ethanol & DDGS fed to cattle producing manure; anaerobic digestion of manure	Pilot plant
Iogen, Ottawa, ON and Saskatchewan	Straw	Cellulosic ethanol, byproducts: lignin, power	Fractionation, enzymatic hydrolysis & ethanol fermentation; ON: 40kt→2.5ML SK: 750kt→90ML	Pilot plant
Enerkem and Greenfield Ethanol	Selected Municipal Solid Waste	Alcohols	Gasification & catalytic synthesis of alcohols; 36 ML ethanol from 100 kt MSW	Pilot plant
Enerkem and industry partners	Utility poles, forest residues, selected MSW	Alcohols	Gasification & catalytic synthesis of alcohol fuels; 50 ML/a, 8.2 M$	Under development
Enerkem, Kruger, CRB, and University of Sherbrooke's	Forest & agricultural residues	Pentose derivatives, lignin derivatives & cellulosic fibre pulp or ethanol	Destructuring & disaggregation of the lignocellulosic matrix, fractionation & depolymerization of the constitutive fractions ("FIRST")	Pilot plant
Sun Opta	Wheat straw, oat hulls and wood chips	Cellulosic ethanol and butanol, Xylitol and fibre	Pretreatment of biomass for subsequent enzymatic hydrolysis to produce fermentable sugars.	Pilot plant
Advanced Biorefinery Inc.	Wood residues and animal manure	Bio-oil and charcoal, wood alcohol, acetone and acetic acid	Rapid pyrolysis to produce charcoal and bio oil, chemicals.	Pilot plant
NovaGreen	Straw, wood chips and agricultural residues	Cellulosic ethanol, xylitol , lignin	Steam explosion and fermentation technology to produce cellulosic ethanol, xylitol and lignin.	Pilot plant
Woodland Biofuels Inc.	Wood and agriculture residues, pulp sludge	Cellulosic ethanol, acetic acid, vinyl acetate monomers and formaldehyde	Gasification technology to convert biomass into fuels and chemcials	Pilot plant
Atlantec Bioenergy Corp	Sugar beets	Ethanol, fertilizer, electricity	Anaerobic digestion, genset, and nutrient refinery	Pilot plant
BioTerre	Manure	Biogas	Anaerobic digestion	Pilot plant
Vider Biomass	Wheat straw	Pellets, CHP	Vitrification, 2-stage combustion	Pilot plant
Great Northern Power	Wood waste	CHP	Gasification	Pilot plant
Denmark				
Inbicon	Wheat straw	Ethanol, solid fuel, animal feed	Production of bioethanol and solid fuel from wheat straw	Pilot plant
Technical University of Denmark /BioGasol	Lignocellulose	Bioethanol, hydrogen, biogas	Integrated production of bioethanol, hydrogen and biogas from biomass	Piltot plant
France				
Procethol 2G	Wheat straw	Bioethanol	Production of cellulosic ethanol on the existing sugar-beet and wheat biorefining site of Bazancourt	Pilot plant

Table 7 Biorefinery pilot plants in Germany and the Netherlands.

Country	Feedstock	Products	Description	Status
Germany				
Agrar-genossenschaft Bergland Clausnitz e.G.	Biomass	Biogas (5.000 t/a, 175 kWel)	Solid state fermentation, slurry free, tub reactor, bioleaching	Pilot plant
CUTEC-Institut GmbH, Clausthal-Zellerfeld	Biomass	Biofuels (1 l/h)	Artfuel process, gasification, FT-Synthesis, BtL	Pilot plant
Forschungs-zentrum Karlsruhe, Karlsruhe	Biomass	Biofuels (500 kg/day)	Bioliq-process Dentralized (flash-) pyrolisis of biomass, centralized gasification, Methanolsynthisis, BtL fuel synthesis	Pilot plant
Fraunhofer Pilot Plant Center (PAZ) at Schkopau ValuePark	Various feedstocks	Biopolymers, Biomaterials	Polymer synthesis & processing	Pilot plant
Fraunhofer Institute for Chemical Technology, Pfinztal	Various feedstocks	Biopolymers, Biomaterials	Chemical biomass conversion. Several units and arrays for polymer engineering & processing, Microwave arrays, units for membrane technology, units for processing in supercritical fluids	Pilot plant
Fraunhofer Institute for Environmental, Safety and Energy Technology, Oberhausen,	Renewable Resources	Adsorbents made from renewable resources	Rotary kiln pilot plant for the development and sample production of specific high-performance adsorbents made from renewable resources.	Pilot plant
Fraunhofer Institute for Environmental, Safety and Energy Technology, Oberhausen,	Renewable Resources	Biopolymers	Biodegradable plastics, polymers from renewable resources, nanocomposites, pilot and small-scale series production	Pilot plant
Fraunhofer-Institute for Environmental, Safety and Energy Technology, Oberhausen	Wood chips	500 kW: 150 kW electricity, 250 KW heat	Gasification, circulating fluidised bed gasifier for wood chips, gas motor generator plant, biomass feedstock pre-treatment	Pilot plant
Leibniz-Institut für Agrartechnik Potsdam-Bornim, Bornim	Rye (starch)	Lactic acid (10 t/a)	Green biorefinery for a continuous production of lactic acid Feedstock pre-treatment, fermenter, nanofiltration, elektrodialyse, product separation & refining	Pilot plant
Leibniz-Institut für Agrartechnik Potsdam-Bornim, Bornim	Hemp fibre	Fibre-pulping process (300 kg/h)	Feedstock pre-treatment,	Pilot plant
Sauerkraut- und Gemüse-verarbeitungs-GmbH, Ritschenhausen	Algae	Fatty acids, lipids, carotenoids (6 t/a)	Photobioreaktor to produce microalgal species	Pilot plant
Subitec GmbH, Stuttgart	Microalgae from polluted water and CO2	Fatty acids, lipids, carotenoids, (1,5 t/a) Feed, food, pharmacy and cosmetics	Marine biorefinery: high value products from microalgae	Pilot plant
Technische Universität Hamburg-	Flax fibre	Fibre-pulpe	Feedstock pre-treatment, fibre-pulping process	Pilot plant

Harburg, Hamburg				
Uhde Inventa-Fischer GmbH, Berlin	Lactic acid	Biopolymers, PLA, (50 kg/d)	Miniplant, polymerisation of lactic acid to PLA, downstream operations	Pilot plant
Netherlands				
Agrologistiek	Arable crops	Bioethanol, feed, biogas, CO2	Small-scale bioethanol from arable crops	Pilot plant
Bioport R'dam	Import	2nd generation biofuels + value-added bio-based products	Lignocellulosic feedstock biorefinery	Pilot initiative
Biorefinery Cluster	Process residues	Various	Multi-industrial biorefinery	Pilot initiative
Grass refinery (Courage)	Grass	Green juice and pressed fibres	Grass refinery: from grasses to value added products	Pilot plant
Nedalco	Lignocellulosic residues	Bioethanol	Bioethanol from lignocellulosic materials	Pilot plant
NUON	Multi-fuels	Power and syngas	Thermo-chemical conversion (HT gasification)	Demo
TNO	Wet organic streams	Biocrude, fuels, chemicals	Hydro Thermal Conversion	Pilot plant
WUR BBP	Aquatic biomass	Various bio-based products and bioenergy	Growing and fractionation of microalgae	Pilot plant
ECN	Aquatic biomass	Various bio-based products and bioenergy	Growing and fractionation of seaweeds	Pilot plant

Table 8 Biorefinery demo plants in IEA Bioenergy Task 42 countries.

Country	Feedstock	Products	Description	Status
Canada				
Lignol	Wood and agriculture residues	cellulosic ethanol, lignin, acetic acid, furfural and xylose	Organosolve-based fractionation & hydrolysis, enzymatic saccharification and fermentation.	Demo Plant
Syntec Biofuels	Wood and agriculture residues	Methanol and ethanol	Gasification and catalytic synthesis, and steam reforming	Under development
Growing Power Hairy Hill	Manure for biogas; wheat for ethanol and DDGS	Ethanol, electriticy	Integrated biogas and ethanol plant	Demo plant
Highmark	Manure for biogas; wheat for ethanol and DDGS	Ethanol, electriticy	Integrated biogas and ethanol plant	Demo plant
Denmark				
Inibicon	Wheat and straw	Bioethanol, solid fuel, feed	Integrated production of bioethanol, solid fuel and feed from wheat and straw	Demo plant (from 2009)
Biogasol	Wet biomass	Bioethanol, pellets, biogas	Conversion of wet biomass into bioethanol, pellets and biogas	Demo plant (from 2009)
France				
CEA	Biomass	FT-fuels	Gasification of biomass and FT-fuel production	Demo plant (from 2009)
Solvay	Glycerine	Epichlorhydrin	Production of epichloridrin from glycerine	Demo plant
SICA Atlantique	Fats	FAEE	Production of Fatty Acid Ethyl Esters (FAEE)	Demo plant
Germany				
Aufwind Schmack Betriebs-GmbH & Co, München	Biomass	Biogas (920 Nm^3/h)	Conditioning and injection of biogas into the gas distribution system	Demo plant
Biogas-Brennstoffzellen GmbH, Leonberg	Biowaste	Biogas, electricity (250 kWel)	Fermentation, conditioning and use of biogas in fuel cell “hot module”	Demo plant
Bioprodukte Prof. Steinberg GmbH, Klötze	Micoalgae	Fatty acids, lipids, carotenoids (130 t/a)	Photobioreaktor to produce microalgal species	Demo plant
Brandenburg	Alfalfa and wild mix grass (30kt/yr)	high valuable proteins, Amino acids, lactic acid, fodder	Green biorefinery: production of green juice for high valuable proteins and lactic acid	Demo plant
CHOREN Industries GmbH, Freiberg	Wood	FT/BtL-biofuels (15.000 t/a)	Carbo-V process, feedstock pre-treatment, gasification, FT-synthesis, BtL (sundiesel)	Demo plant
Emsland-Stärke GmbH, Wietzendorf	Whole crop biorefinery (potato starch & biogas), (demonstration & commercial)	Integrated unit for bioproducts and bioenergy	Private, Public (federal funding)	Demo plant
Kreiskrankenhaus Wolgast, Wolgast	Rapeseed oil	240 kW electricity, 310 KW heat, 258 kW for cooling	gas motor with alternative fuel generator plant, co-generation heat/power and cooling energy	Demo plant
Landwirtschafts-zentrum Eichhof, Landesbetrieb Landwirtschaft Hessen, Bad Hersfeld	Biomass	Biogas, electric power (35 kWel)	Use of biogas in a microgasturbine	Demo plant
Nordhanf GmbH Rosenow	Hemp fibre	Fibre-pulpe (10.000 t/a)	Feedstock pre-treatment, Fibre-pulping	Demo plant

Postdam	Lignocellulose	Bioethanol	Bioethanol from lignocellulosic feedstock	Demo plant
PYTEC GmbH Thermochemische Anlagen, Lüneburg	Biomass	Biofuels (6 t/day)	Ablative flash pyrolysis	Demo plant
Schornbuscher Biogas GmbH & Co KG, Euskirchen	Energy Plants	Biogas, electricity (500 kWel)	Slurry free fermentation of energy plants	Demo plant
Stadtwerke Düsseldorf AG, Holzvergaser-anlage Arnsberg-Wildshausen	Biomass	270 kW electricity, 410 KW heat	Gasification, gas motor generator plant, biomass feedstock pre-treatment	Demo plant
Vattenfall Europe AG, Biomasse-HKW Sellessen	Wood	2,5 MW electricity, 3,5 MW heat biomass-fuels, woody-feedstocks	Steam generator plant, biomass firing, feedstock pre-treatment	Demo plant
Ireland				
County Mayo	Biomass	Bioethanol, lactic acid, polylactide	Production of bioethanol and platform chemical from biomass	Demo plant
Netherlands				
Bio MCN	Glycerine	Biomethanol	Production of green biomethanol from glycerine	Demo plant
Biovalue	Vegetable oil	Biodiesel, glycerine, pharmaceutical acetates	Production of biodiesel, glycerine (to fuel additive) and pharmaceutical acetates	Demo plant
NUON	Multi fuels	Power and syngas	HT gasification	Demo plant
DBI*	various	various	various	Demo plant

In the NL in 2009 the Dutch Biorefinery Initiative (DBI) will be implemented. The DBI is a Research, Development and Demonstration Programme within the biorefinery field. Within the DBI framework several biorefinery pilot and demo plants will be implemented within the following fields: domestic crops (grass, beets, maize, ...), aquatic biomass (algae, seaweeds), imported biomass (thermochemical and/or (bio)chemical conversion lignocellulosic biomass; upgrading of biofuel process residues), upgrading of defined and undefined process residues in multi-industrial intitiatives. The pilot/demo initiatives are selected based in specific strengths in The Netherlands, such as: strong agrocluster, chemical sector, and energy sector; advantageous position in the European market (Bio-HUB for Europe), and strong Knowledge Infrastructure (plant breeding, white biotechnology, concept development, offshore engineering, ...).

11. Activities of research and development (national projects and stakeholders)

A key driver for the development and implementation of biorefineries is the growth in demand for energy, fuels, and chemicals. Accordingly, the aim of research is in developing new technologies and creating novel processes, products, and capabilities to ensure the growth is sustainable from economic, environmental and social perspectives. The most relevant national biorefinery projects for IEA Bioenergy Task 42 countries are listed in Tables 9 – 12. For each project, it's type (European, national or international), the national coordinator, a short description and the website (where possible) are given.

Further research and technology adoption will indicate which new products and processes contribute to more sustainable performances compared to conventional fossil based systems. The term itself of sustainability needs an agreement on a common definition and criteria for its evaluation. This will be necessary for communication with non-governmental organizations (NGOs), the general public, regulators and policy makers about, for example, CO_2 reductions.

IEA Bioenergy Task 42 addresses a new and very broad biomass-related field with a very large application potential. Releasing this potential will require collaboration between industry, the knowledge infrastructure (KIS) both institutes and universities, government and NGOs to identify appropriate R&D priorities and programmes as well as commercialization and market introduction strategies. Joint international priorities and RD&D-programs among industry, research institutes, universities, governmental bodies and NGOs are therefore necessary. Tables 13 – 15 report a list of the most relevant national stakeholders who are actively involved in biorefinery concepts. The numerous different stakeholders are grouped in four groups:

1. Knowledge Infra Structure (KIS) – both institutes and universities
2. Industry-producing companies
3. Governmental organizations
4. Other (e.g. non-governmental organization, plant constructors and engineering, associations and land owners).

Table 9 Main national projects on biorefinery in Austria and Canada.

Country	Name of project	Type of project	National Coordinator	Description	Website
Austria	Biosynergy	EU	Joanneum Research	Biomass for the market competitive and environmental friendly synthesis of bioproducts and secondary energy carriers through the biorefinery approach	www.biosynergy.eu
	Bioenergy NOE - Network of Excellence	EU	Joanneum Research	The network aims at growing its joint research activities into a Virtual R&D Bioenergy Centre that can spearhead bioenergy research in Europe.	www.bioenergy-noe.com
	RENEW	EU	TUV	The aim of the project is to develop a production process for liquid biofuels from biomass (sunfuel)	www.renew-fuel.com
	REFUEL	EU	Joanneum Research	The refuel project is designed to encourage a greater market penetration of biofuels, by developing a biofuels road map (consistent with EU biofuel policies)	www.refuel.eu
	Austrian Green Biorefinery Initiative	National	Joanneum Research	Primary processing and utilization of fibres from green biomass	n.a.
	Green Biorefinery (SUSPRISE)	International	Joanneum research	Technical, economic and ecological optimization of value chains by the introduction and efficient use of sustainable raw materials	n.a.
Canada	Canadian Triticale Biorefinery Initiative (CTBI)	International	Agriculture and Agri-Food Canada (Lethbridge, Alberta)	Fully integrated program for crop development, processing technology, conversion technology and downstream product development for chemicals and materials	n.a.
	Natural Fibres for a Green Economy (NAFGEN)	National	Flax 2015	Fully integrated program for sustainable crop development, processing technology, conversion technology and downstream product development for high value materials and chemicals for oilseed flax and industrial hemp	Na
	Hemicellulose utilization from kraft pulp mills	National	FPInnovations & universities associated under 'PAPIER'	Recovery of biofuels and chemicals from hemicellulose	n.a.
	FPInnovations & Universities associated under 'PAPIER'	National	Natural Resources Canada, Canadian Forest Service	Numerous Projects	Na
	Biofixation of Co2 Through Microalgae	National	Innoventures Canada	Biofixation of carbon dioxide via microalgae growth, integrated with biodiesel and cellulosic ethanol production	n.a.
	13 networks	National	Agriculture and Agri-Food Canada, Agricultural Bioproducts Innovation Program	Designed to support new & existing research networks and the development of clusters for the advancement of a sustainable and profitable Canadian bioeconomy. Develop new economic opportunities for agriculture in the areas of bioproducts and bioprocesses such as biofuels, other forms of bioenergy, biochemicals, biopharmaceuticals, etc.	www4.agr.gc.ca/AAFC-AAC/display-afficher.do?id=1195569629682&lang=e

Table 10 Main national projects on biorefinery in Denmark and France.

Country	Name of project	Type of project	National Coordinator	Description	Website
Denmark	From sugar to polyester	National	Novozymes	Use of biomass for production of chemicals	n.a.
	2nd generation biofuels for future cars	National	DONG Energy	Optimization of bioethanol production from biomass and integration of processes	www.Inbicon.com
	Renescience - waste to fuel and energy	National	DONG Energy	Flexible process for production of heat, power and liquid fuel from biomass and waste	www.Inbicon.com
	Bio.REF	National	Technical University of Denmark	Biorefinery for sustainable reliable economical fuel production from energy crops	n.a.
	Biotroll	EU	University of Copenhagen	Integrated biological treatment and agriculture reuse of live mill effluents with the concurrent recovery of energy sources	n.a.
	Biopack	EU	Technical University of Denmark	Proactive biobased cheese packaging	n.a.
	Europectin	EU	Danisco	Upgrading of sugar beet pectins by enzymatic modification and molecular farming	n.a.
	Enhance	EU		Green chemicals and biopolymers from rapeseed meal with enhanced end-performances	n.a.
	IBUS	EU	DONG Energy	Integrated biomass utilization for production of biofuels	www.Inbicon.com
	Biocomp	EU	Risoe National Laboratory	New classes of engineering composite materials from renewable resources	www.biocomp.eu.com
	Nanobiosaccharides	EU	Danisco	Nanotechnologies for Bio-inspired polysaccharides: biological decoys designed as knowledge based, multifunctional biomaterials	www.nanobiosaccharides.org
	Ecobinders	EU	University of Copenhagen	Eco-friendly, emission-free, moisture resistant and 100% renewable binders	www.ecobinders.net
	Sustainpack	EU		Innovation and sustainable development in the fibre based packaging value chain	www.sustainpack.com
	Flexfuel	EU	VE-Organisation Ærø	Demonstration of a flexible plant processing organic waste, manure and/or energy crops to bioethanol and biogas for transport	n.a.
France	BioHub	National	Roquette	The program aims at getting the most out of agricultural resources by developing new chemical and biochemical processes to synthesize chemical products from Isosorbide	**www.biohub.fr**
	Osiris	National	Soufflet	Development of biofuels, food, feed and biological crops protection products from cereals	n.a.
	Nile	EU	IFP	Cost effective production of clean bioethanol from lignocellulosic biomass	www.nile-bioethanol.org/
	Biorefinery Euroview	EU	Industries and Agro-Resources Cluster	This project aims at preparing for future RTD activities	**www.iarpolefr.nexenservices.com/biorefinery/public/index2.html**

Table 11 Main national projects on biorefinery in Germany.

Name of project	Type of project	National Coordinator	Description	Website
Agrobiogas	Eu		An integrated approach for biogas production with agricultural waste	http://www.dgs.de/1693.html
Bee	EU	University of Freiburg, Germany	Biomass Energy Europe - harmonising biomass resource assessments, focusing on the availability of biomass for energy in Europe and its neighbouring countries.	http://www.eu-bee.net/
BioEnergie 2021	National		Upcoming program: BioEnergie 2021 - Forschung für die Nutzung pflanzlicher Biomasse	www.fz-juelich.de/ptj/bioenergie2021
BioHub	EU	Roquette, France	Development of cereals-based chemical products to the point that they are sustainable substitutes for fossil-origin products.	www.biohub.fr
BioLog	National	CUTEC-institute	: Devopment, Evaluation, testing and demonstration of new logistic concepts for Biofuel	http://www.cutec.de/thermische_biolog.php
Biomass methanisation	National		Joint research Optimization of anaerobic biomass degradation for methane production	www.fnr.de
Biopol	EU	WUR	Assessment of biorefinery concepts and the implications for agriculture and forestry policy	http://www.biorefinery.nl/biopol
Ecobinders	EU	WUR	Eco-friendly, emission-free, moisture resistant and 100% renewable binders	www.ecobinders.net
Epobio	EU	WUR	Bioproducts from non-food crops	http://www.epobio.net/epobio.htm
ERA-IB	EU		ERA-Net Industrial Bioptechnology -First Call "Industrial biotechnology for Europe: an integrated approach"	http://www.era-ib.net/default.asp?cid=96
Field grass for Biogas	National		Breeding and use of field grass for biogas production	www.fnr.de
Glyfinery	EU	Technical University of Denmark	Sustainable and integrated production of liquid biofuels, bioenergy and green chemicals from glycerol in biorefineries	n.a.
IG-Biotech	International	Fraunhofer WKI	Biotechnological conversion of raw glycerol to high value products for polymer chemistry	http://www.wki.fraunhofer.de/publikat/pm_ig-biotech_07-07.html
Lignocellulose-Biorefinery	National	DECHEMA	Joint research project: Preparation of cellulose, glucose, hemicellulose, xylose and lignin as well as testing of carbohydrates for fermentation processes	www.ft.uni-karlsruhe.de/FORDAT/PROJEKTE/ka11445.htm
Metaglyc	National		Joint research project: functionalized Glycerol derivatives	www.fnr.de
Nanobiosaccharides	EU	WWU Münster, Germany	Nanotechnologies for Bio-inspired polysaccharides: biological decoys designed as knowledge based, multifunctional biomaterials	www.nanobiosaccharides.org
New Enzymes	National	Dechema	Joint research project: new enzymes and enzyme systems for the degredation of lignocellulose for fine chemicals	www.fnr.de
Nile	EU	IFP, France	Cost effective production of clean bioethanol from lignocellulosic biomass	www.nile-bioethanol.org/
Propanenergy	EU	TUHH, Germany	developing an integrated bioprocess to convert technical glycerine from biodiesel production into biogas and two value-added products 1,3-propanediol (PDO) and fertilizer in a biorefinery approach.	http://www.propanergy.eu/cms/
Sustainpack	EU	STFI-Packforsk, S	Innovation and sustainable development in the fibre based packaging value chain	www.sustainpack.com
Thermoplastic elastomers	National		Joint research project: Development and production of thermoplastic elastomers from olefines	www.fnr.de
Other projects dealing with partial aspects of biorefineries available at **www.fnr.de**				

Table 12 Main national projects on biorefinery in Ireland and the Netherlands.

Country	Name of project	Type of project	National Coordinator	Description	Website
Ireland	Carbolea	National	University of Limerick	Evaluate Biorefining Technologies and Feedstocks for Ireland Design and Operate a Pyrolysis/Gasification Unit	n.a.
	FP5 BESUB EU	EU			n.a.
Netherlands*	Biocoup	EU	UT	Co-processing of upgraded bio-liquids in standard refinery units	www.biocoup.eu
	Biopol	EU	WUR	Assessment of biorefinery concepts and the implications for agriculture and forestry policy	www.biorefinery.nl/biopol
	Biosynergy	EU	ECN/WUR	Biomass for the market competitive and environmental friendly synthesis of bioproducts and secondary energy carriers through the biorefinery approach	www.biosynergy.eu
	Epobio	EU	WUR	Bioproducts from non-food crops	www.epobio.eu
	Bioref-Integ	EU	WUR	Development of advanced biorefinery schemes to be integrated into existing industrial (fuel) producing complexes	www.bioref-integ.eu
	Sustoil	EU	WUR	Focus on biodiesel sector	www.sustoil.eu
	Green biorefinery (SUSPRISE)	International	WUR	Technical, economic and ecological optimization of value chains by the introduction and efficient use of sustainable raw materials	-
	BBASIC	National	TUD	Process development for biomass conversion into chemicals using biocatalysts as micro-organisms and enzymes	www.b-basic.nl
	CATCHBIO	National	NIOK	Fuels, chemicals and pharmaceutical from biomass	www.catchbio.com
	Biobuthanol	National	WUR	Production of buthanol from biomass	www.biobutanol.nl
	Coraf	National	TU/BTG	Co-refining of biomass in existing refineries	-
	LignoValue	National	WUR	High grade valorization of lignin for optimal biorefinery of lignocellulose to energy carriers and products	www.biobutanol.nl/lignovalue
	N-Ergy	National	WUR	Micro-biological co-production of N-chemicals and ethanol from biomass fractions	www.vpp.wur.nl

	Pectin Challenge	National	Nedalco	Pectine valorization	www.nedalco.nl
	Furabeet	National	Avantium/Cosun	Furanics production from side streams	**www.avantium.com**
	Hyvolution	EU	WUR	Bio-H2	www.hyvolution.eu
	Optimal lignocellulose hydrolysis	National	WUR	Maximizing the bioenergy potential of lignocellulose biomass by mitigating the effect of hydrolysis inhibitors	www.ete.wur.nl

The Dutch Biorefinery Initiative (DBI) RD&D-programme will run from 2009 – 2015, and will cover a variety of both strategic/fundamental and applied biorefinery research projects.

Table 13 Main national stakeholders on biorefinery in Austria and Canada.

Country	KIS	Industry-producing companies	Governmental Organisation	Other
Austria	University of Technology Vienna and Graz	Lenzing Ag (pulp and paper)	FJ-BLT Wieselburg	Andritz AG (pulp and paper)
	Ubiversity of Linz and Graz	OMV (oil refinery company)	Ministry of Innovation and Technology	Repotec (biomass gasification)
	Joanneum Research	AGRANA (bioethanol)	Ministry of Forestry, Agriculture, Water and Environment	Vogelbusch (sugar and starch bioethanol)
	Institute of industrial ecology	Energie AG Oberösterreich (electricity)	Ministries for economic affairs	BDI (biodiesel)
		New Energy capital investment (investment company)	National and regional energy agencies	VTU (biotechnology)
Canada	McGill University	Iogen (Ottawa, ON)	Natural Resources Canada - Canadian Biomass Innovation Network (CBIN) - *R&D program*	Shell, Petro-Canada (stakeholders in Iogen)
	University of Sherbrooke, Industrial Research Chair on Cellulosic Ethanol	Lignol (Burnaby, BC)	Sustainable Development Technology Canada - *program*	Canadian Renewable Fuels Association
	Queen's University	Ensyn (Ottawa, ON)	Agriculture and Agri-Food Canada - research, programs, policies	BIOTECanada
	University of Guelph	Sun Opta (Toronto, ON)	National Research Council - research institutes and Industrial Research Assistance Program (IRAP)	Canadian Bioenergy Association (CANBIO)
	University of Western Ontario and its Bio-Industrial Innovation Centre in Sarnia	Enerkem (Sherbrooke, QC)	Natural Resources Canada - Energy Technology and Programs Sector (bioenergy and biofuels) - research, programs, policies	Forest Products Association of Canada
	University of Saskatchewan	Greenfield Ethanol (Toronto, ON)	Natural Resources Canada - Canadian Forest Service - research, programs, policies	AgWest Bio (Saskatchewan)
	University of Alberta	Tembec (Temiscaming, ON)	Environment Canada - policies and regulation	Québec Centre for the Valorisation of Biotechnologies
	Network on Advanced Foods and Biomaterials	Woodland Biofuels (Mississauga, ON)	Industry Canada - programs and policies	Ontario Chemical Value Chain Initiative
	Network on Sustainable Forest Management	Nova Green Refining (Vegreville, AB)	Ontario Ministry of Research and Innovation	
	National Research Council	Syntec Biofuels (Vancouver, BC)	Québec Ministry of Natural Resources & Fauna	
	Centre de recherche industrielle du Québec	Chemical Industry Cluster (Sarnia, ON)	British Columbia Innovation Council	
	Alberta Research Council		Other provincial ministries of economic development, natural resources and agriculture	
	Saskatchewan Research Council			
	FPInnovations & 'PAPIER'			

Table 14 Main national stakeholders on biorefinery in Denmark, France and Germany.

Country	KIS	Industry-producing companies	Governmental Organisation	Other
Denmark	University of Copenhagen	Novozymes	Danish Energy Authority	Danish Agriculture Association
	Technical University of Denmark/Riso	Danisco/Genecor	Ministry of Food, Agriculture and Fisheries	Danish Forest Association
	University of Southern Denmark	DONG Energy/Inbicon	Energynet.dk	Confederation of Danish Industries
	Aarhus University	Vattenfall	The Danish Agency for Science, Technology and Innovation	Innovation Center for bioenergy and environmental technology
	Danish Technological Institute	Xergi		Danish Biomass Association
		Haldor Topsoe		Danish Biogas Association
		Biogasol		
		Daka		
		CP Kelco		
France	National center for scientific research (CNRS)	DG enterprise	French innovation agency	French petroleum institute (IFP)
	National institute for agronomic research (INRA)		SME development agency	
			National research agency	
			French environment and energy management agency	
			French atomic energy commission (CEA)	
Germany	Leibniz institutes	Mineral Oil Industry (Shell, BP)	Ministries (BMELV, BMBF, BMU)	DECHEMA, DBU
	Universities	Automotive Industry (VW, Ford, Daimler)	Agencies (FNR, PTJ, CARMEN, EnergieAgentur NRW)	Several Regional Biorefinery Networks,
	vTI (whole chain from feedstock to chemicals/materials)	Chemical Industries (Südzucker, Evonik, BASF, Henkel, Cognis, Bayer, Südchemie, Wacker, Dow)		Biovision 2030 group
	Deutsches Biomasse Forschungs Zentrum GmbH, Leipzig (DBFZ)	Engineering Industry (Uhde, Linde, BMA, Sauter)		Ufop,, LAB
	Helmholtz institutes	Primary sector		Dt. Bauernverband (DBV)
	Fraunhofer institutes			Dt. Forstverein, AGDW, DHWR, DFWR

Table 15 Main national stakeholders on biorefinery in Ireland and the Netherlands.

Country	KIS	Industry-producing companies	Governmental Organisation	Other
Ireland	University of Limerick	Biofine	Teagasc	Biorefinery Ireland
	University College Galway	Recycled Products Ltd	The Department of Communications, Energy and Natural Resources	Ecology Foundation
		Maxol Ltd	Sustainable Energy Ireland	Combined Bioenergy Ireland
		Conoco Phillips		
		Greyhound Recycling & Recovery Ltd		
		Eco Ola		
		Biogreen Energy Products Ltd		
		Kilkenny Cereals Ltd		
		Eilish Oils Ltd		
		Bioverda		
Netherlands	WUR A&F BBP	DOW Europe	SenterNovem	Biorefinery.nl
	WUR-PRI	Avantium	Ministries	ACTS
	ECN	Avebe	GAVE	Rabobank
	TNO	Eneco		NIOK
	University of Leiden	Meneba		KCPK/VNP
	University of Delft	Royal Nedalco		Greenpeasce
	University of Twente	Shell		MVO
	University of Eindhoven	ADM		VNPI
	University of Groningen	Akzo Nobel		WWF
	University of Utrecht	Albermarle Cat.		VNCI
		BTG		DSTI
		Cargill		
		Cosun		
		DSM		
		Ports		
		Unilever		
		AquaPhyto		
		CCL		
		Campina		
		Sabic		
		Sasol		
		BASF (Engelhard)		

12. IEA Bioenergy Task 42 on Biorefineries: National Task Leaders

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