Annual Report 2017

IEA Bioenergy

IEA BIOENERGY : EXCO : 2018 : 02

IEA Bioenergy is an international collaborative agreement set up in 1978 by the International Energy Agency (IEA) to improve international co-operation and information exchange between national bioenergy RD&D programmes. IEA Bioenergy aims to achieve a substantial bioenergy contribution to future global energy demands by accelerating the production and use of environmentally sound, socially accepted and cost-competitive bioenergy on a sustainable basis, thus providing increased security of supply whilst reducing greenhouse gas emissions from energy use.

Front Cover: Bio-CLC (chemical looping combustion) pilot in Bioruukki piloting centre, Espoo.

Vice-chair Paul Bennett and Chair Jim Spaeth

To: IEA Headquarters, Paris

IEA BIOENERGY ANNUAL REPORT 2017

Under the IEA Framework for International Energy Technology Cooperation the Executive Committee of each Technology Collaboration Programme (TCP) must produce an Annual Report for IEA Headquarters.

This document contains the report of the IEA Bioenergy Executive Committee for 2017. This year, we have presented a special feature 'BIO-CCS and Bio-CCUS in climate change mitigation and extended use of biomass raw material' prepared by Task 41 Project 5.

The contributions from the Task Leaders and Operating Agents to this report are gratefully acknowledged.

Jim Spaeth
Chairman

Pearse Buckley
Secretary

Contents

Editor: Pearse Buckley, IEA Bioenergy Secretary, Dublin, Ireland

Design and layout: Clevercat Design, Dublin, Ireland

Preparation, of colour section: Kristin Onarheim and Antti Arasto

Preparation of text and tables: Paul Derham, Dublin, Ireland.

Further information on IEA Bioenergy can be obtained from the Executive Committee Secretary, see back cover of this Annual Report.

The opinions and conclusions expressed in this report are those of the authors.

IEA Bioenergy – Selected Highlights From 2017

1. Technology Roadmap: Delivering Sustainable Bioenergy

As part of its series of technology roadmaps, the IEA had published two documents relating to bioenergy; one on biofuels for transport (2011) and one on bioenergy for heat and power (2012). The aim of this project was to produce a single roadmap encompassing bioenergy for transport, heat and power, which would update the previous publications in light of developments in policy and technology and allow a holistic approach taking account of the fact that some of the key issues around feedstock availability and sustainability were relevant for all sectors. The roadmap was produced as a joint effort between the IEA Secretariat and the IEA Bioenergy TCP, with inputs from a range of other expert organisations including OECD, FAO, IRENA and the European Commission. In the Roadmap, modern bioenergy plays an essential role in the International Energy Agency (IEA) 2°C Scenario (2DS), providing nearly 17% of final energy demand in 2060 compared to 4.5% in 2015. Bioenergy provides almost 20% of the cumulative carbon savings to 2060. It would be difficult to replace this important contribution. To play this important role, bioenergy must be produced and used in a sustainable way – significantly reducing greenhouse gas (GHG) emissions compared to fossil fuels and helping to achieve sustainable development goals. The report is available at http://www.iea.org/publications/freepublications/publication/Technology_Roadmap_Delivering_Sustainable_Bioenergy.pdf.

2. The role of industrial biorefineries in a low-carbon economy

Workshop held in collaboration with the IEA IETS TCP

The transformation to a low carbon-economy requires a change in the whole system. An important contribution will be required from industry in terms of energy conservation and shifting to renewable feedstocks. Industrial biorefineries play a central role in this process towards efficient and low-carbon production systems. A clear time perspective is needed, as the societal conditions and surrounding systems for industrial production will also change. This workshop, which was a collaboration between IEA Bioenergy and the IEA

IETS TCP examined the role of industrial biorefineries in the transformation to a low-carbon economy, with a number of successful examples and interactive discussions with the audience on how such transition could be realised. It was an excellent example of the added value of collaboration between TCPs and resulted in a jointly produced workshop summary available at http://www.ieabioenergy.com/wp-content/uploads/2017/10/IEABioenergy-IETS-Industrial-Biorefineries-Workshop-Report.pdf.

3. Bioenergy for sustainable development

This paper is the result of a collaboration involving IEA Bioenergy, IRENA and FAO. It originated from a joint workshop involving IEA Bioenergy, GSE, FAO and IRENA, which was held in Rome in May 2016 on the theme *Mobilising sustainable bioenergy supply chains: opportunities for agriculture*. Some key messages from the workshop and the paper include the following:

- bioenergy can play an important and constructive role in achieving the **UN Sustainable Development Goals** and implementing the **Paris Agreement on Climate Change**, thereby advancing climate goals, food security, better land use and sustainable energy for all.
- there are several **options for sustainable bioenergy expansion**, including sustainable intensification and landscape planning, sustainable forest management, using waste and organic residues (respecting soil conditions), restoring degraded or marginal lands and reducing losses in the food chain.
- **multi-functional land uses** can be promoted, also in developing countries, providing sufficient food and animal feed, as well as biomass for energy and other valuable bio-based products.
- bioenergy is part of a larger bioeconomy. The attitude towards biomass production for food, bioenergy and other purposes should evolve from single end-use orientation to **integrated production systems**.

The paper can be downloaded at http://www.ieabioenergy.com/publications/bioenergy-for-sustainable-development/.

BIO-CCS and Bio-CCUS in climate change mitigation and extended use of biomass raw material

Kristin Onarheim and Antti Arasto, VTT Technical Research Centre of Finland,
IEA Bioenergy Task 41 Project 5

What is Bio-CCU and Bio-CCS?

What is Bio-CCS?

The term Bio-CCS describes concepts that combine biomass use with carbon capture and storage. As opposed to fossil CCS, which only decreases the rate of CO_2 entering the atmosphere to nearly zero at best, Bio-CCS has the potential to achieve net removal of CO_2 from the atmosphere. By binding atmospheric carbon during growth of biomass and subsequently capturing CO_2 from the biomass conversion process for permanent storage in geological formations carbon is extracted from the carbon cycle. Provided that the biomass use is sustainable, Bio-CCS has the potential to generate net negative emissions, and can remove historic CO_2 emissions from the atmosphere and offset CO_2 emission from sectors more challenging to decarbonise. The terminology in the literature is not fully consistent. Both Bio-CCS and BECCS (bioenergy and carbon capture and storage) are being used interchangeably. However, Bio-CCS usually has a wider context, including for instance biochemical production, whereas BECCS is literally referring to applications in the energy sector.

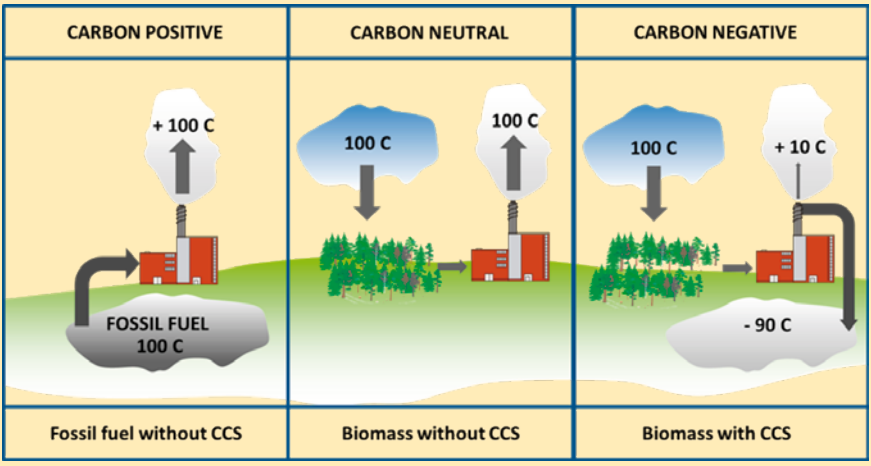

Figure 1. Conceptual comparison of carbon flows in fossil energy, bioenergy and Bio-CCS processes

What is carbon capture and utilisation (CCU)?

Carbon capture and utilisation refers to the use of pure CO_2 or CO_2-containing gas mixtures as a feedstock to produce fuels, chemicals and materials. When fuels, chemicals and materials are produced using low-carbon energy sources, these products could displace their fossil counterparts and reduce net carbon emissions to the atmosphere.

The CO_2 molecule is at the lowest energy potential and the conversion of CO_2 into fuels or chemicals is highly energy-intensive. Consequently, the effectiveness of the whole CCU system as a climate mitigation option mainly depends on two conditions:

- Whether the energy input for CO_2 conversion originates from low-carbon or fossil sources
- Whether the CO_2 utilised as feedstock comes from a fossil or atmospheric source

In traditional, fossil resources based processes, carbon and energy originate from the same source. CCU enables different inputs for energy (e.g. electricity) and carbon (CO_2). In this context, carbon originating from the atmosphere (mixture of biogenic and fossil), captured either through direct air capture or by sustainable biomass is defined as atmospheric carbon. Fossil carbon is defined as carbon originating from fossil sources such as oil, gas and coal, whose extraction from below ground and whose anthropogenic use adds more CO_2 to the atmosphere unless permanently stored.

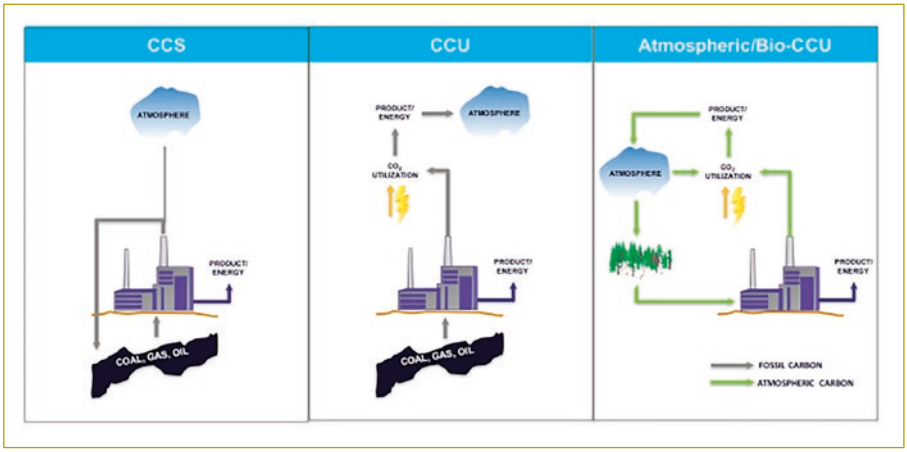

Figure 2. CCU is fundamentally different from CCS

CCU and climate impact

For CCU to be able to offer neutral emission solutions and have an impact as a climate mitigation measure there are two essential requirements:

- Low-carbon/carbon neutral energy input for CO_2 conversion
- The carbon used as feedstock needs to be atmospheric

Unless these two prerequisites are met, fossil CO_2 will eventually reach the atmosphere, either by producing energy from fossil sources for the conversion of CO_2 to products or when releasing fossil CO_2 contained in the product at the end of its lifetime. With few exceptions, CCU delays CO_2 emissions on average by ~6 years (average of all products). For hydrocarbon fuel this average delay is less than a year. In order to have a climate impact, the delay should be at least in the order of centuries (>>100 years). CCU only has positive climate impact if it enables a higher amount of low carbon input (solar, wind, etc.) to the system than without CCU. If electricity can be used in the system as electricity, the efficiency is far better than going through a CCU cycle, and less input to the entire system is needed. This means, that it is more effective to replace fossil electricity with the new renewable electricity than to use it in other sectors via CCU with lower cyclic efficiency. When low carbon electricity cannot be absorbed by the system (where the electricity sector is more or less decarbonised), CCU can act as a means to indirectly electrify the system in addition to serving as a means for energy storage, if that is required to balance the electricity generation and demand. This means that CCU itself is not a means to lower GHG emissions. It can be a tool to decarbonise the input to the system, which indirectly (by replacement) lowers GHG emissions. Whether this leaves more oil in the ground, and in that case how much, determines the impact of CCU on climate change.

Why do we need Bio-CCUS?

Paris Agreement and climate change

A business as usual projection of the current energy consumption trends indicates a cumulative CO_2 emission of 4,200 Gt until the end of the century. This translates into a global temperature increase of up to 3-4.5°C. Already at 1.5°C global temperature rise there is a risk of climate change affecting unique biodiversity systems and causing weather extremes. With an increase in global temperature of 3°C or higher these risks escalate, leading to higher local and global risk and more extreme effects in terms of large scale disruption.

Currently 174 of 197 parties to the convention have ratified the Paris Agreement. The agreement entered into force in November 2016. The main intention of the agreement is to unite all nations in a joint effort to mitigate climate change. The primary method to achieve this is to limit the global temperature increase to "well below 2°C above pre-industrial levels and to pursue efforts to limit the temperature increase even further to 1.5°C [1]." The goal of limiting the global temperature increase will be met through following up on national implementation efforts and contributions to achieve the purpose of the agreement.

Carbon budget and emission scenarios

With the successful ratification of the Paris Agreement we are taking another important step towards reducing greenhouse gas emissions and mitigating climate change. However, we do face challenges ahead. The cumulative CO_2 emissions from the latter half of the last century until the present have consumed a large share of the carbon budget available when aiming at a 2°C limitation in global temperature increase.

The Intergovernmental Panel on Climate Change (IPCC) [2] has estimated that in order to stay below 2°C we have around 1,000 – 1,600 Gt left in the carbon budget. This corresponds to a $CO_{2eq.}$ concentration of 450-500 ppm in 2100. At a concentration of less than 500 ppm the IPCC considers it likely that we can stay below 2°C over the 21st century. For comparison, the probability of restricting the global temperature increase by 1.5°C is already small, and limited to an atmospheric concentration of CO_2 of a maximum of 450 ppm. As a direct result of the Paris Agreement the IPCC is currently preparing a special report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas pathways. The report is expected to be published in 2018.

Currently, there is no one single technology that can stop and possibly reverse the effects of increased CO_2 concentrations in the atmosphere. Nevertheless, bioenergy and negative CO_2 emissions represent a possible mitigation tool. The IPCC and the IEA identify CCS as a significant climate mitigation tool. Bio-CCS plays an important role in the CCS portfolio, both as a technology that can extract CO_2 from the atmosphere and as a market tool that can promote large-scale commercialisation of CCS. Bio-CCS is considered to be a crucial factor to limit the global temperature increase to 1.5°C, and scenarios without Bio-CCS options tend not to achieve this target or else offer solutions that will be extremely expensive.

Numerous emission projection scenarios have been developed in an attempt to forecast the CO_2 emissions in the future. Most of these scenarios are in agreement, recognising the tight carbon budget for achieving a 2°C limitation of global temperature increase. The majority of the scenarios incorporate negative emissions and typically consist of four distinct phases; (I) emission peak around 2020-2030, (II) steep emission reductions from 2030-2060, (III) carbon neutrality from 2060-2080, and (IV) zero or negative emissions from 2080. In addition, most scenarios showing a 2°C limitation that include negative emissions allow for overshooting the carbon budget in mid-century and subsequently using negative emissions to return to the carbon budget limit, see Figure 1 [3].

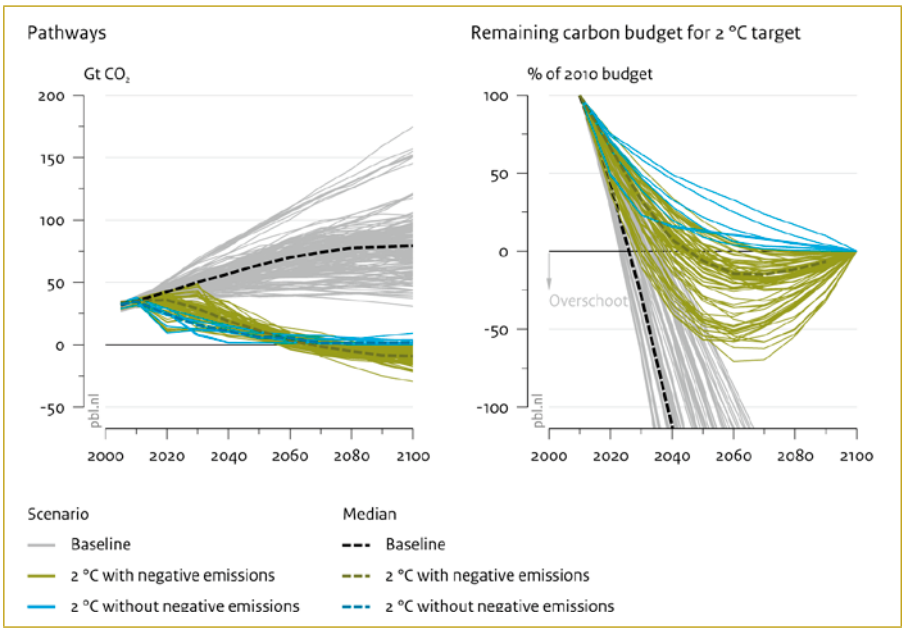

Figure 3. CO_2 emission pathways and remaining carbon budget. Figure from van Vuuren [3], based on data from the IPCC AR5 database.

The last few years have seen a radical transformation in the global energy market, especially in terms of electricity demand. Renewable energy sources continue to penetrate the electricity market. In 2016 alone half of the growth in global electricity demand was supplied by renewable electricity and the sales of electric cars increased by 40%. The energy sector is currently the largest overall source of greenhouse gas emissions, being responsible for 60 – 70% of total global GHG emissions.

The IEA has previously developed a series of scenarios outlining alternative energy system pathways, including different emission trajectories, in an attempt to predict the resulting average global temperature increase. In the scenario simulations various energy technologies have been optimised in order to predict the potential of driving down CO_2 emissions while simultaneously providing sufficient energy services to society.

Traditionally the 2°C Scenario (2DS) has been the main focus, depicting the energy system deployment consistent with limiting the temperature increase to 2°C. Achieving the 2DS restricts the total cumulative global energy-related CO_2 emissions to 1,000 Gt by 2100. This includes reducing CO_2 emissions by up to 60% (compared with 2013) by 2050. The total global CO_2 emissions in 2013 were approximately 32 Gt, which translates into a reduction in CO_2 emissions the next roughly 30 years of more than 19 Gt CO_2, or more than 0.5 Gt per year starting immediately (IEA, 2016). This number, which is just below 2% of the total annual CO_2 emissions may seem low, and reaching the 2DS is still technically possible, provided that the reductions start immediately. This time scale poses challenges. Even though the energy system is transforming quickly the increased penetration of renewable energy into the energy system will most probably not be able to make up for this reduction in such a short time frame.

In the recently published Energy Technologies Perspectives 2017 (IEA, 2017) the IEA takes a new approach towards the scenario development. The new baseline scenario, the Reference Technology Scenario (RTS), takes into account the pledges made in the Paris Agreement. In the new RTP, CO_2 emissions will continue to increase towards 2040 and somewhat beyond, but by 2050 the emission trajectory will even out. The new 2DS is still central to the future projections. The 2DS optimises the energy system to cut the CO_2 emissions to less than 1/3 of today by 2060. In addition, the modelling horizon has been extended from 2050 to 2060. As illustrated in Figure 1, the major CO_2 emission reduction options in the 2DS consist of energy efficiency and renewable energy, these together providing 75% of the CO_2 emission reduction. CCS accounts for 14%, which is an increase from the previous edition of the 2DS where CCS contributed 12% of the emission reduction (IEA [a], 2016). CO_2 capture from both the power sector and industrial sectors are included in the CCS technology area, including also BECCS and Bio-CCS.

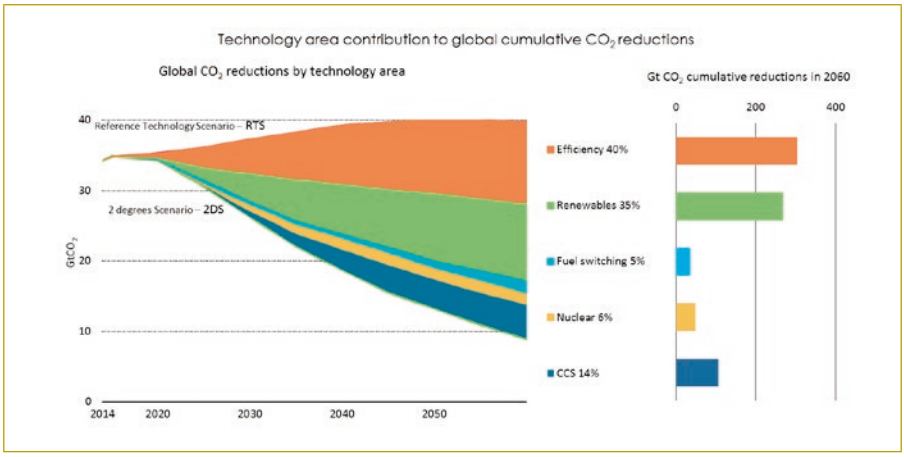

Figure 4. Updated IEA 2°C Scenario in Energy Technology Perspectives 2017.

The new ETP also presents a new, additional scenario; Beyond 2°C Scenario (B2DS). This scenario is more ambitious than the 2DS. In the B2DS all the available technologies are exploited to the maximum practical limit. The realisation of the B2DS would allow for a CO_2 neutral energy sector by 2060. Also in the B2DS the main technology areas include energy efficiency and renewable energies, totalling almost half of the contribution needed. However, the shares of both energy efficiency and renewable energies decline in the B2DS. The reason is that in the 2DS there are still CO_2 emissions being released to the atmosphere as the reduction potential of the abatement technologies in the 2DS are not pushed to the limit as in the B2DS. In the 2DS the less expensive technology areas have been applied first, which results in the renewable energy option being the best option. The B2DS exhibits a more significant reduction pathway, exploring alternatives that were too challenging and complex for the 2DS, such as CCS from industrial sectors like cement production and iron and steel production. As a result, the role of CCS as an emission reduction technology becomes much more important in the B2DS.

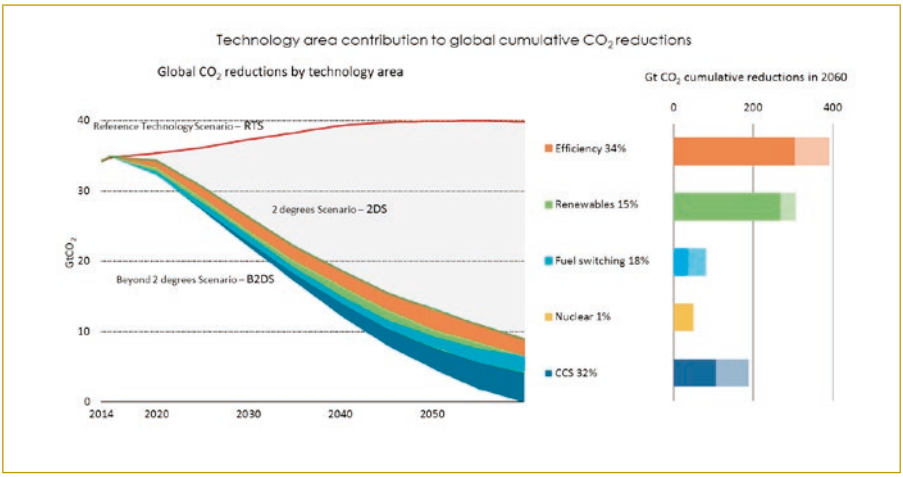

Figure 5 The IEA Beyond 2°C Scenario in Energy Technology Perspectives 2017.

Bio-CCS is included in the IEA scenarios. Negative emissions have two principal roles;

- Compensate for residual emissions in sectors where direct mitigation is difficult or cost-prohibitive, and
- Counterbalance near-term carbon budget "overshoot", which increases with more ambitious reduction targets

According to the IEA, negative emissions are needed in order to achieve net-zero emissions by 2060. In the 2DS negative emissions start to contribute before 2020, while in the B2DS negative emissions will be effective already at present. Both power production and biofuel production (other transformation) play an important role in achieving negative emissions, especially in the B2DS. The cumulative negative emissions of these two sectors amount to 70-75 Gt. This translates into a power production coefficient of -10 g CO_2/kWh in 2060, which will be an important measure for removing CO_2 from the atmosphere.

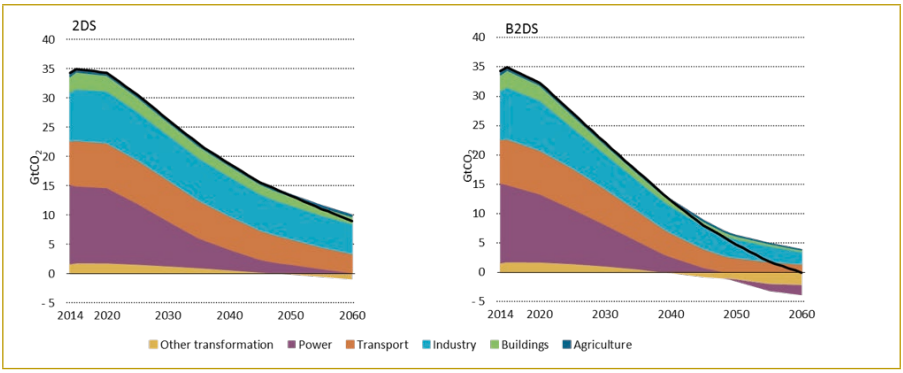

Figure 6 Negative emissions in IEA scenarios.

The implementation of Bio-CCS and negative emissions is not on track to realise the emission reductions required in order to meet the 2DS or B2DS targets, mainly as a result of the absence of policy incentives. The implementation of Bio-CCS combines challenges from two already challenging sectors; the biomass sector demanding sustainable bioenergy feedstock and the CCS sector where infrastructure could pose a major obstacle, especially for small bioenergy installations that have no possibility for developing CCS infrastructure.

Sustainability of Bio-CCS

The negative emission potential of Bio-CCS is not clear-cut and it remains critical to look at the sustainability of biomass utilisation. Sustainability issues regarding the use of biomass are related to social, environmental and economic factors.

Water, energy, carbon and land are all factors that need to be taken into consideration when accounting for the sustainability of Bio-CCS. Different types of biomass and crops can represent large variations in footprint, depending on yields and fertiliser input. The use of biomass involves the potential for direct and indirect land use changes. Direct land use change is a result of, for instance, clearing of land and is directly tied to the type of land being utilised for bioenergy production. Implementing CCS in, for instance, biofuel production requires energy, and the emissions from this energy production may be just as high as in the original process. Implementing CCS in biomass-fired power plants will reduce their efficiency. In order to replace this energy the total feedstock rate to the plant increases and the result may not be as negative as first imagined. The situation is illustrated in Figure 7 where two different combined heat and oxy-CFB power plants with CCS were compared to a power plant operated with fossil fuel. In CCS1 the parasitic load caused by the CCS plant has been replaced with electricity produced with coal, and in CCS2 with electricity produced based on the Finnish average, which has a lower emission factor.

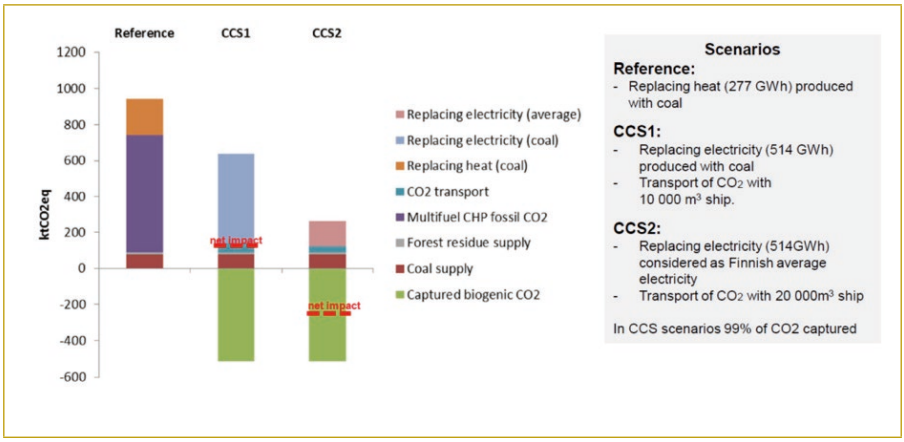

Figure 7. Example of GHG impact from Bio-CCS

It is fundamental for net negative CO_2 emissions from Bio-CCS systems that the biomass utilised has been grown and harvested in a sustainable manner. Emissions induced as a result of land use changes (direct or indirect) during production of biomass for bioenergy can render the negative emissions from Bio-CCS smaller than the total net CO_2 capture. Furthermore, in relation to slow rotation biomass (e.g. forests), it is important to understand the ongoing scientific debate on the climate impacts. The CO_2 released in combustion of slow rotation biomass will spend some time in the atmosphere before being sequestered back to growing plants. During this period in the atmosphere the CO_2 will have a warming effect. As a consequence of this temporal scale, it could be argued that the net negative emission effect is not immediate, but will only be achieved once the carbon is fixed in the biomass again, see Figure 8.

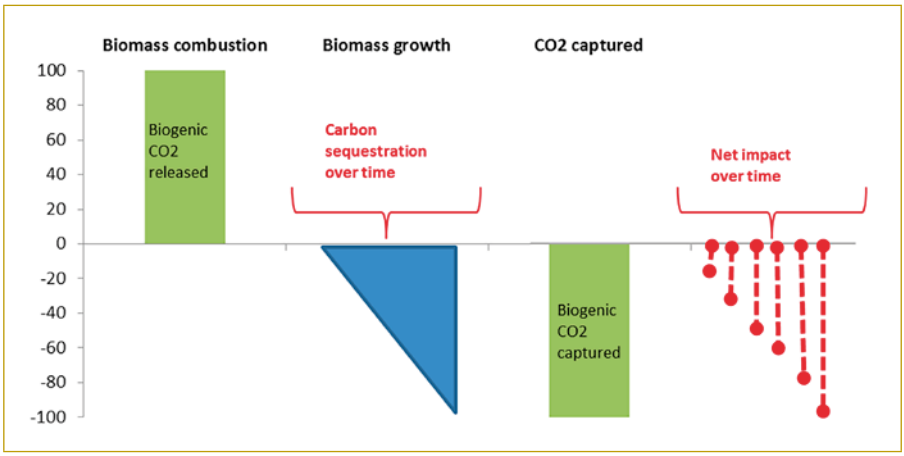

Figure 8 Carbon sequestration over time

The carbon breakeven time, or the time required for the system to reach carbon neutrality, depends on land type and crop type and can vary significantly. On average, the carbon breakeven time for energy crops is around 4-30 years.

Another important issue is the so called foregone carbon sequestration, meaning the lower carbon sequestration of forests in intensive harvesting scenarios compared to less intensive harvests. From an atmospheric point of view, this lost carbon sequestration can be considered similar to carbon emissions and the resulting impact could be attributed to the products produced from biomass. The use of residual biomass is often considered sustainable and the best option for the climate as the residues could otherwise decay quite rapidly and release the carbon anyway. The situation is illustrated in Figure 9.

Figure 9 The effect of additional wood harvesting on the carbon balance on landscape level

Biomass production, transport and processing also impact the carbon footprint of the biomass feedstock. In particular, the utilisation of nitrogen based fertilisers has a double impact on the carbon footprint, from both the CO_2 released during the production of the chemical, and the emissions of N_2O after application on the field. Direct land use changes (LUC) for cropland is moderate as this is typically low carbon debt land, but on the other hand the effect of indirect land use change (ILUC) for cropland on the carbon footprint can be significant. The carbon intensity of a power plant decreases with increased biomass co-firing and higher CO_2 capture rates. However, this effect can be offset and even be carbon positive when accounting for the entire supply chain including LUC and ILUC. For instance, under certain supply chain conditions (high direct and indirect land use change, drying and pelletisation, long transport distance) 50% co-firing of a woody biomass such as willow will no longer be a carbon negative option. This serves to underscore the importance of a thorough, case-by-case assessment of BECCS projects [4].

To illustrate the effect of an optimistic scenario of Bio-CCS on land use and fresh water consumption the sequestration of 50 Mt CO_2/a would require 0.05–2 Mha land annually, 7–150 billion m^3 water (compared to the total agricultural withdrawal of water in Europe of 334 billion m^3) and between 11 and 223 x 500 MW Bio-CCS units. The total land use required for limiting the global temperature warming to 2°C is estimated at 500 Mha for growing bioenergy. Currently, around 4,500 Mha is used for food production [5].

Biomass potential is a key question when discussing Bio-CCS. An analysis of the amount of biomass required after 2050 in the different IPCC scenarios ranges from 25 EJ/a up to more than 350 EJ/a. Utilisation of primary energy for bioenergy purposes may be sustainable up to 100 EJ/a. Higher rates of primary energy utilisation may interfere with forestry and farm land and we might see a need for changes, and above 300 EJ/a there might even be potential for conflict. This begs the question whether the planet can sustain a society based on 50% or more bioenergy, taking into account the growing population on earth, and whether it is realistic to use as much biomass as some of the scenario models suggest. Adding to the utilisation of biomass is the final storage of captured CO_2. A quick calculation shows that even for a moderate Bio-CCS scenario the number of wells can amount up to 10,000.

Bio-CCS does not allow us to peak later

Without social acceptance there are few incentive mechanisms to drive the development of Bio-CCS. A general misunderstanding among the public is that Bio-CCS and the production of energy crops is competing for land and resources with food production and forest development. There is also a perception that especially Bio-CCS could even prevent large scale implementation of renewable energy. Another critical misconception is that Bio-CCS offers a possibility for using negative emissions as a delaying tactics or a quick fix for continuing business as usual. It is important to recognise that negative emissions are not a licence to continue the current trajectory. Negative emissions may offer the possibility to temporarily overshoot the carbon budget, but it is not a tool to postpone the time when we need to take action to reduce emissions. This impression is especially unfortunate if it reaches policy makers, who might oppose development of the technologies. The significant gap between the current situation and where we need to be in terms of climate mitigation changes requires additional emission reduction pathways as well. Bio-CCS has a key role in curbing CO_2 emissions and can be an important remedy in a transition period towards cleaner renewable energy systems, but it is not the only means that should be included in the climate change mitigation toolbox.

Changing trends in carbon capture and electricity production

Recent years have seen a shift in carbon capture from carbon capture and storage (CCS) towards carbon capture and utilisation (CCU). This shift is driven by the lack of internationally binding agreements to significantly reduce CO_2 emissions, including functional emission trading systems and emerging economic opportunities. In North America both fossil and biogenic CO_2 is used for enhanced oil recovery (EOR) and development is driven by the demand side. Over several years the EOR business has supported the development of the CCS and CCU technologies, resulting in existing infrastructure such as pipeline systems that is vital to new investments. In Europe, on the other hand, the situation is radically different. CCS is for the most part a stranded discussion, except in Norway where the infrastructure for storage is to a large extent existing. Europe has abundant biomass resources and biogenic CO_2 emissions. However, these facilities are often significantly smaller than the typical coal-fired power plants in North America providing CO_2 for EOR. Since EOR is not a big business in Europe the European model is dependent on a situation where everything fits together in a business case. As a result, a more probable pathway for implementing bio-CC(U)S in Europe would be based on decentralised installations with isolated electricity and CO_2 resources.

In addition to the economic driver, timing is another argument concerning the renewable electricity market. Much of the renewable electricity currently produced is concentrated far away from consumers. With production rates reaching several terawatts the lack of gridlines and suitable and sufficient electricity storage, electricity is in some cases produced in excess. This could be an advantage in the implementation of Bio-CCU technologies by transforming excess electricity into energy storage that can be easily transported to consumers. Another important driver is the end use; CO_2 used as feedstock for fuels will have a larger demand than chemicals, materials and mineralisation.

Industrial implementation of (Bio-)CCUS under the current market conditions and policy scenarios will be expensive. However, changes in these conditions may facilitate large-scale implementation in certain sectors. These first movers in Europe will most probably be restricted to certain locations with ideal boundary conditions for businesses based on CO_2 capture. One important aspect to consider will be the supply of hydrogen. Several terawatts of excess hydrogen are currently combusted annually to produce heat and electricity. Investing in electrolysers to make use of the excess electricity and convert it back to hydrogen would not be feasible at the moment. As a result, industrial processes that today burn hydrogen or carbon monoxide, for instance in the steel industry and chemical industry, could be suitable first movers. Important features for scaling up the technologies will among other issues be the ability to manufacture large-scale key components such as electrolysers. Large scale production will drive down costs. Whether Bio-CC(U)S itself will drive implementation is another aspect. The oil and gas industry has been at the forefront concerning development of CCS for a long time, yet still fuel manufacturers who see a business possibility are thought to drive the implementation of Bio-CC(U)S in the short term. In the longer term, policies and regulations instigated by the growing urge to reduce emissions and even realise negative emissions would need to become the main driver for wide Bio-CC(U)S deployment.

Next steps for Bio-CCUS

The shift in the discussion from Bio-CCS to Bio-CCU is mainly based on development driven by industry, this being based on commercial interest. One major reason for this in Europe is the limitations of the EU ETS and the lack of recognition for negative (biogenic) CO_2 emissions in the trading system. As a result, with the current low price of CO_2 there is no incentive to invest in Bio-CCS.

Liquid fuels from CCU can replace oil derivatives in both light and heavy-duty transport. In addition, CO_2-derived fuels could offer a dispatchable service to the grid in an energy system where the main renewable energy sources are intermittent. This enables a flexible grid system during high and low load periods. Liquid CO_2-derived fuel also offers a sustainable alternative to for example the transport sector that is more resistant to change and where electrification is more challenging. However, economics is a major concern for Bio-CCS and Bio-CCU. In Bio-CCU the CO_2-derived product can pay for the capture and for the CO_2 avoidance cost, but the emission reduction potential is weaker than for Bio-CCS as the CO_2 used in Bio-CCU will in any case be emitted back to the atmosphere.

One key question is what the EU will do in terms of regulations that govern the use of CO_2, and some of the open elements in the REDII will be a key factor in this development. In order for the industry to be able to create business cases from Bio-CCU the EU must incentivise production of sustainable fuels from CCU as they scale rapidly without side-effects. How life-cycle analysis is applied to carbon capture and energy transformation is also a key to business models.

Bio-CCU is claimed to be an enabler for Bio-CCS, by setting the scene for industrial CO_2 capture and providing infrastructure that can be further developed. However logical this assertion may sound, the reality is not quite that simple. Bio-CCU could probably contribute to increased understanding of industrial CO_2 capture from biomass-based industries. On the other hand, permanent storage is one of the most prominent bottlenecks for Bio-CCS, and Bio-CCU would not facilitate the storage infrastructure that is needed for large scale Bio-CCS. Another point of debate with Bio-CCU in general and Bio-CCU as an enabler for Bio-CCS is the urgency in reducing emissions and mitigating climate change. It has been shown above that a reduction in emissions and realising negative emissions needs to start before long. As a consequence, there is no time to wait for Bio-CCU to pave the way for Bio-CCS. Based on this, the latest shift in focus away from Bio-CCS to Bio-CCU could be an unfortunate diversion from the real aim – to mitigate climate change.

Conclusions

As the potential of Bio-CC(U)S is very much bound to the availability and usage of biomass raw materials, the sustainability of the raw materials is of the essence. The current biomass flows and potentials set the initial limits for the wider deployment of Bio-CC(U)S. Efficient utilisation of constrained resources is an essential question, when the target is to optimise the impact at the system level, from the society point of view. One objective is to offer suggestions as to whether deployment really leads to the desired impact on the CO_2 concentrations in the atmosphere. As biomass can be used in many ways, the primary purpose of utilisation and products containing biogenic carbon also add up to this. When biomass is utilised for products other than energy, the impact on the environment and economy differs. The opportunities with these solutions, realistic potential and the main threats related to Bio-CC(U)S need to be discussed in the light of sustainability and economic potential.

Concepts and terms such as CCU, CCS, Bio-CCU and Bio-CCS are used interchangeably, sometimes incorrectly, in general discussion and therefore need clarification. The justifications of technologies differ. If the driver is GHG emission reduction, only storage can result in the removal of CO_2 from the atmosphere on a life cycle basis. The average lifetime of utilisation products is in the order of 6 years (less than a year for fuels). In order to have a direct climate mitigation impact, the carbon molecule would need to be isolated from the atmosphere for at least ~100 years. Hence, the only GHG impact CCU can provide is indirect. This means that if applying CCU technology would leave more fossil resources underground than without CCU, or if more sustainable energy input to the system is generated than without CCU, CCU will be positive from the climate change mitigation perspective. If the electricity system is more or less decarbonised, a significant role for CCU can be in balancing the intermittent nature of some renewable energy sources (RES) and in indirectly electrifying other, more hydrocarbon dependent sectors.

In order to be able to invest in and realise Bio-CCS and negative emissions, some major prerequisites include: Policy instruments and market conditions: Accounting for negative emissions in emission trading systems (Bio-CCS), or otherwise enabling the development of business cases (Bio-CCU). These will be indispensable for industries to invest in carbon negative technologies

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International Energy Agency

The International Energy Agency (IEA) is an autonomous organisation which works to ensure reliable, affordable and clean energy for its 29 Member Countries and beyond. Founded in response to the 1973-74 oil crisis, the IEA's initial role was to help countries co-ordinate a collective response to major disruptions in oil supply through the release of emergency oil stocks to the markets. While this continues to be a key aspect of its work, the IEA has evolved and expanded. It is at the heart of global dialogue on energy, providing authoritative and unbiased research, statistics, analysis and recommendations. Today, the IEA's four main areas of focus are:

- Energy security: Promoting diversity, efficiency, flexibility and reliability for all fuels and energy sources;
- Economic development**:** Supporting free markets to foster economic growth and eliminate energy poverty;
- Environmental awareness**:** Analysing policy options to offset the impact of energy production and use on the environment, especially for tackling climate change and air pollution; and
- Engagement worldwide**:** Working closely with partner countries, especially major emerging economies, to find solutions to shared energy and environmental concerns.

Objectives

- Secure member countries' access to reliable and ample supplies of all forms of energy; in particular, through maintaining effective emergency response capabilities in case of oil supply disruptions.
- Promote sustainable energy policies that spur economic growth and environmental protection in a global context – particularly in terms of reducing greenhouse-gas emissions that contribute to climate change.
- Improve transparency of international markets through collection and analysis of energy data.
- Support global collaboration on energy technology to secure future energy supplies and mitigate their environmental impact, including through improved energy efficiency and development and deployment of low-carbon technologies.
- Find solutions to global energy challenges through engagement and dialogue with non-member countries, industry, international organisations and other stakeholders.

Organisation

The IEA is an autonomous agency based in Paris. The main decision-making body is the Governing Board, composed of energy ministers from each Member Country or their senior representatives. A Secretariat, with a staff of energy experts recruited on a competitive basis primarily from OECD Member Countries, supports the work of the Governing Board and subordinate bodies. The Secretariat is headed by an Executive Director appointed by the Governing Board. The Secretariat collects and analyses energy data, organises high-level workshops with world experts on new topics and themes, assesses Member and non-Member Countries' domestic energy policies and programmes, makes global energy projections based on differing scenarios, and prepares studies and concrete policy recommendations for governments on key energy topics.

Members

Australia, Austria, Belgium, Canada, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Japan, Korea, Luxembourg, the Netherlands, New Zealand, Norway, Poland, Portugal, the Slovak Republic, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the USA. The European Commission also participates in the work of the IEA.

Introducing IEA Bioenergy

Welcome to this Annual Report for 2017 from IEA Bioenergy.

IEA Bioenergy is the short name for the international bioenergy collaboration under the auspices of the International Energy Agency – IEA. A brief description of the IEA is given on the preceding page.

Bioenergy is energy derived from biomass. Biomass is defined as material which is directly or indirectly produced by photosynthesis and which is utilised as a feedstock in the manufacture of fuels and substitutes for petrochemical and other energy intensive products. Organic waste from forestry and agriculture, and municipal solid waste are also included in the collaborative research, as well as broader 'cross-cutting studies' on techno-economic aspects, environmental and economic sustainability, systems analysis, bioenergy trade, fuel standards, greenhouse gas balances, barriers to deployment, and management decision support systems.

The IEA Technology Collaboration Programme (TCP) on Bioenergy, which is the 'umbrella agreement' under which the collaboration takes place, was originally signed in 1978 as IEA Forestry Energy. A handful of countries took part in the collaboration from the beginning. In 1986 it broadened its scope to become IEA Bioenergy and to include non-forestry bioenergy in the scope of the work. The number of participating countries has increased during the years as a result of the steadily increasing interest in bioenergy worldwide. By the end of 2017, 23 parties participated in IEA Bioenergy: Australia, Austria, Belgium, Brazil, Canada, Croatia, Denmark, Finland, France, Germany, Ireland, Italy, Japan, the Republic of Korea, the Netherlands, New Zealand, Norway, South Africa, Sweden, Switzerland, the United Kingdom, the USA, and the European Commission.

IEA Bioenergy is now 40 years old and is a well-established collaborative agreement. All OECD countries with significant national bioenergy programmes are now participating in IEA Bioenergy, with very few exceptions. The IEA Governing Board has decided that the Technology Collaboration Programmes may be open to non-Member Countries, i.e., for countries that are not Members of the OECD. For IEA Bioenergy, this has resulted in a number of enquiries from potential participants, and as a consequence new Members are expected. Three non-Member Countries currently participate in IEA Bioenergy – Brazil, Croatia, and South Africa.

The work within IEA Bioenergy is structured in a number of Tasks, which have well defined objectives, budgets, and time frames. The collaboration which earlier was focused on Research, Development and Demonstration is now increasingly also emphasising Deployment on a large-scale and worldwide. There were 11 ongoing Tasks during 2017:

- Task 32: Biomass Combustion and Co-firing
- Task 33: Gasification of Biomass and Waste

- Task 34: Direct Thermochemical Liquefaction
- Task 36: Integrating Energy Recovery into Solid Waste Management Systems
- Task 37: Energy from Biogas
- Task 38: Climate Change Effects of Biomass and Bioenergy Systems
- Task 39: Commercialising of Conventional and Advanced Liquid Biofuels from Biomass
- Task 40: Sustainable Biomass Markets and International Bioenergy Trade to Support the Biobased Economy
- Task 41: Bioenergy Systems Analysis
- Task 42: Biorefining in a Future BioEconomy
- Task 43: Biomass Feedstocks for Energy Markets

Members of IEA Bioenergy are invited to participate in all of the Tasks, but each Member is free to limit its participation to those Tasks which have a programme of special interest. The Task participation during 2017 is shown in Appendix 1.

A progress report for IEA Bioenergy for the year 2017 is given in Sections 1 and 2 of this Annual Report.

ExCo79 study tour group on visit to GoBiGas

Progress Report

1. THE EXECUTIVE COMMITTEE

Introduction and Meetings

The Executive Committee (ExCo) acts as the 'board of directors' of IEA Bioenergy. The committee plans for the future, appoints persons to do the work, approves the budget, and, through its Members, raises the money to fund the programmes and administer the Agreement. The Executive Committee also scrutinises and approves the programmes of work, progress reports, and accounts from the various Tasks within IEA Bioenergy. Other functions of the ExCo include publication of an Annual Report, production of newsletters and webinars, and maintenance of the IEA Bioenergy website. In addition the ExCo produces technical and policy-support documents, and organises workshops and study tours for the Member Country participants.

The 79th ExCo meeting took place in Gothenburg, Sweden on 16-18 May with 43 participants. The 80th ExCo meeting was held in Baden, Switzerland on 18-20 October and there were 30 participants. Simone Landolina represented IEA Headquarters at ExCo80.

Kees Kwant of The Netherlands chaired both ExCo meetings in 2017 with Jim Spaeth of the USA in the role of Vice-chair. At ExCo80, Jim Spaeth was elected as Chair and Paul Bennett of New Zealand was elected as Vice-chair for 2018.

Secretariat

The ExCo Secretariat is currently based in Dublin, Ireland under the Secretary, Pearse Buckley. The fund administration for the ExCo Secretariat Fund and Task funds is consolidated with the Secretariat, along with production of ExCo publications and newsletters, and maintenance of the website.

The contact details for the Executive Committee can be found in Appendix 7 and for the Secretariat on the back cover of this report. The work of the ExCo, with some of the achievements and issues during 2017, is described below.

Implementing Agreement

The current term of the IEA Bioenergy Technology Collaboration Programme (TCP) ends on the 29th February 2020.

Contracting Parties/New Participants

A complete list of the Contracting Parties to IEA Bioenergy is included in Appendix 3.

Estonia has still to formally sign the Agreement and this is expected to happen early in 2018. There are ongoing discussions with China, India, Mexico, and Poland with a view to engaging them in IEA Bioenergy.

Supervision of Ongoing Tasks, Review and Evaluation

The progress of the work in the Tasks is reported to the Executive Committee twice per year at the ExCo meetings. The ExCo has continued its policy to invite Task Leaders to each ExCo meeting so that they can make presentations on the progress in their Task and programme of work personally. This has improved the communication between the Tasks and the Executive Committee and has also increased the engagement of the ExCo with the Task programmes.

The work within IEA Bioenergy is regularly evaluated by the IEA Committee for Energy Research and Technology (CERT) via its Renewable Energy Working Party (REWP) and is reported to the IEA Governing Board.

Approval of Task and Secretariat Budgets

The budgets for 2017 approved by the Executive Committee for the ExCo Secretariat Fund and for the Tasks are shown in Appendix 2. Total funds invoiced in 2017 were US$1,775,200, comprising US$253,100 of ExCo funds and US$1,522,100 of Task funds. Appendix 2 also shows the financial contributions made by each Member Country and the contributions to each Task. Very substantial 'in-kind' contributions are also a feature of the IEA Bioenergy collaboration but these are not shown because they are more difficult to recognise in financial terms.

Fund Administration

The International Energy Agency, Bioenergy Trust Account, at the Bank of Ireland Global Markets in Dublin is working well. The Trust Account consists of a Call Deposit account and a Fixed Deposit account both of which bear interest. The Call Deposit account is accessed electronically while the Fixed Deposit account is accessed through the Bank's dealers. Both accounts are denominated in US dollars. The currency for the whole of IEA Bioenergy is US dollars. Details for making payments are provided with each invoice.

The main issues faced in fund administration are slow payments from some Member Countries and fluctuations in exchange rates. As of 31 December 2017, there was US$77,200 of Member Country contributions outstanding.

At ExCo78, unanimous approval was given to the appointment of KPMG, Dublin as independent auditor for the ExCo Secretariat Fund until 31 December 2018. The audited accounts for the ExCo Secretariat Fund for 2016 were approved at ExCo79.

The Tasks also produce audited accounts. These are prepared according to guidelines specified by the ExCo. The accounts for the Tasks for 2016 were approved at ExCo79, except for Tasks 38. The accounts for Task 38 were approved at ExCo80.

The audited accounts for the ExCo Secretariat Fund for the period ended 31 December 2017 have been prepared and these will be presented for approval at ExCo81 in Ottawa.

Task Administration and Development

Task Participation

In 2017 there were 99 participations in 10 Tasks. Please see Appendix 1 on page 107 for a summary of Task Participation.

There were four active projects under Task 41 and three Inter-Task projects in 2017 – see below under '**Strategic Fund/Strategic Outputs'.**

Strategic Planning and Strategic Initiatives

Strategic Plan

The Strategic Plan 2015-2020 continues to be the guiding document for the IEA Bioenergy work programme. Work on a new strategic plan for the period 2020-2025 is set to begin and in view of this the Executive Committee approved a working group at ExCo80 in Baden.

Technical Coordinator

During 2017, the Technical Coordinator continued with his work of facilitating increased collaboration between the Tasks. In this context he has attended a number of Task meetings and associated conferences. He has maintained an updated schedule of deliverables and worked with the Task Leaders to achieve deadlines. He has also continued to organise the webinars, which have become an important forum for dissemination of IEA Boenergy outputs. The Technical Coordinator has played a key role in the organisation of ExCo workshops at ExCo79 (in conjunction with the IEA IETS TCP) and ExCo80 (external workshop in conjunction with the Swiss Federal Office of Energy). In particular, prior to the ExCo80 internal workshop in preparation for the new triennium, he organised a survey of the broad stakeholder community to inform the workshop discussions. He has been very active in engagement with IEA Headquarters and with other international organisations including FAO, IRENA, GBEP, Biofuture Platform, Mission Innovation and SEforALL. The Technical Coordinator was a contributor to the *Technology Roadmap: Delivering Sustainable Bioenergy*, which was produced by the IEA in collaboration with IEA Bioenergy in 2017.

Communication Strategy

Communications is an important part of IEA Bioenergy activity and the Executive Committee has maintained its focus on the communication strategy through the work of the Communications' Team. Some of the outcomes are presented here. The Twitter following has continued to increase steadily and the Communications Team has continued to consider ways to further enhance this development. The use of webinars as a dissemination tool has continued with five webinars in 2017 – (i) *Algae Bioenergy State of Technology review*, (ii) *The European wood pellet market for small scale heating*, (iii) *Bioenergy & grid balancing*, (iv) *Integrated Bioenergy Hybrids – Flexible Renewable Energy Solutions* and (v) *The Hotspots of the Global Wood Pellet Industry and Trade 2017*. Two-page summaries of Task reports have been produced and uploaded to the website alongside the main reports. Another new feature that has been added to the website is the pro-active material, which has been uploaded under FAQ. The first topic covered under this dealt with the question "Is energy from woody biomass positive for the climate?" – see http://www.ieabioenergy.com/iea-publications/faq/.

Strategic Fund/Strategic Outputs

At ExCo53 it was agreed that from 2005, 10% of Task budgets would be reserved for ExCo approved work. The idea was that these 'Strategic Funds' would be used to increase the policy-relevant outputs of IEA Bioenergy.

Progress with strategic initiatives has continued. The summary and conclusions from the ExCo78 workshop 'Drop-in biofuels for international marine and aviation markets' has been published and can be download at http://www.ieabioenergy.com/wp-content/uploads/2017/04/ExCo78-Drop-in-biofuels-for-marine-and-aviation-markets.pdf; the summary and conclusions from the ExCo79 workshop 'The role of industrial biorefineries in a low-carbon economy' has been published and can be downloaded at http://www.ieabioenergy.com/wp-content/uploads/2017/10/IEABioenergy-IETS-Industrial-Biorefineries-Workshop-Report.pdf. All previous ExCo workshop publications are available at http://www.ieabioenergy.com/iea-publications/workshops/.

Task 41 Project 5: Bio-CCS/CCUS: This two-year project is continuing with a workshop on Market-driven future potential of Bio-CC(U)S in 2017. Summary reports for all the workshops are available at http://task41project5.ieabioenergy.com/publications/market-driven-future-potential-bio-ccus/.

Task 41 Project 6: Bioenergy and Grid Storage: This project has been completed and the report has been published at http://www.ieabioenergy.com/wp-content/uploads/2017/02/IEA-Bioenergy-Bioenergy-in-balancing-the-grid_master_FINAL-Revised-16.02.17.pdf.

Task 41 Project 7: Bioenergy RES Hybrids: This project has been completed and the report published at http://task41project7.ieabioenergy.com/wp-content/uploads/2017/03/IEA-Bioenergy-RES-hybrids-FINAL-report.pdf.

Task 41 Project 8: Bioenergy Roadmap 2017: This collaborative project between IEA Bioenergy and IEA has been completed and the report has been published at http://www.iea.org/publications/freepublications/publication/Technology_Roadmap_Delivering_Sustainable_Bioenergy.pdf.

Inter-Task Project: Bioenergy Success Stories: The project template has been finalised and ten success stories have been selected and developed. It is expected that they will be published on the IEA Bioenergy website early in 2018.

Inter-Task Project: Measuring, governing and gaining support for sustainable bioenergy supply chains: In 2017, the project (http://itp-sustainable.ieabioenergy.com/) achieved a number of important goals, including the publication of a series of peer reviewed papers and case studies. The case studies included one looking at biogas production in Germany and another on forestry, linking measurement and governance. An international workshop was held in Gothenburg in May 2017 and a 40-page workshop summary has been published and is available at http://itp-sustainable.ieabioenergy.com/wp-content/uploads/2017/12/Intertasks-Sustainability.-Workshop-summary-05.12.2017.pdf. The project has an upcoming workshop in Copenhagen in April 2018 on the topic "Governing sustainability of bioenergy, biomaterial and bioporduct supply chains from forest and agricultural landscapes" – http://www.ieabioenergy.com/ieaevent/governing-sustainability-of-bioenergy-biomaterial-and-bioproduct-supply-chains-from-forest-and-agricultural-landscapes/.

Inter-Task Project: Fuel pre-treatment of biomass residues in the supply chain for thermal conversion: The goal of the project (http://itp-fueltreatment.ieabioenergy.com/) is to expand the biomass resource base. It seeks to demonstrate this with examples. The structure of six case studies has been agreed. It has been decided that the proposed fourth case study on *torrefaction for dry liquefaction* was not suitable and this has been replaced with a case study on *leaching of herbaceous biomass*. All six case studies are nearing completion, after which the policy report and pre-treatment database will be produced. The project is expected to finish in the second quarter of 2018.

ExCo Workshops

At ExCo79 in May a successful workshop was held on the topic of 'The role of industrial biorefineries in a low-carbon economy'. This workshop was organised in collaboration with the IEA Industrial Energy-Related Technologies and Systems (IETS) TCP. In October at ExCo80 a successful workshop on the topic of 'Bioenergy grid integration' was organised in collaboration with the Swiss Federal Office of Energy.

Seminars, Workshops, and Conference Sessions

A large number of seminars, workshops, and conference sessions are arranged every year by individual Tasks within IEA Bioenergy. This facilitates effective exchange of information between the participants and information transfer to stakeholders. These meetings are described in the progress reports from the Tasks later in this Annual report. The papers presented at some of these meetings are listed in Appendix 4. Examples of this outreach are:

- Task 33 organised a workshop on "Fluidized Bed Conversion of Biomass and Waste" in Skive, Denmark in October 2017 together with IEA-FBC (Fluidized Bed Conversion) TCP
- Task 38 organised a workshop on "Climate impacts of bioenergy systems" in Gothenburg, Sweden in May 2017 together with Chalmers University
- Task 43 organised a joint seminar on "From resource to sustainable business" with Grebe project (Interreg-EU) in Joensuu, Finland in February 2017.

Collaboration with International Organisations and Implementing Agreements

Advanced Motor Fuels Implementing Agreement

IEA Bioenergy and the Advanced Motor Fuels (AMF) Technology Collaboration Programme continue to maintain close communications. This is facilitated, particularly through the work of Task 39 which can often be linked to AMF activities. The work programmes of the two TCPs are reviewed regularly to identify opportunities for collaboration.

GBEP

The collaboration in the framework of GBEP Activity Group 6 has been completed and included the joint report Examples of Positive Bioenergy and Water Relationships - see http://www.globalbioenergy.org/fileadmin/user_upload/gbep/docs/2015_events/AG6_workshop_25-26_August_2015/AG6_Examples_of_Positive_Bioenergy_and_Water_Relationships_Final.pdf. Two new activity groups – 'Activity Group 7 – Biogas' and 'Activity Group 8 Advanced Biofuels' – are being developed by GBEP and IEA Bioenergy is considering opportunities to collaborate in these areas.

FAO

The collaboration with FAO under the MoU signed in 2000 is continuing with discussions on areas for collaboration.

IRENA

The collaboration with IRENA is continuing with both organisations reviewing outputs from each other's work programmes and regularly monitoring opportunities for potential cooperation.

SEforALL

IEA Bioenergy is collaborating with SEforALL on the Biofuels Below 50 Initiative through Task 39. Other areas are being examined including resource work that would involve Task 43.

Biofuture Platform/Mission Innovation

IEA Bioenergy has ongoing discussions with both the Biofuture Platform and Mission Innovation to investigate appropriate collaboration. The *Technology Roadmap: Delivering Sustainable Bioenergy* was launched at a Mission Innovation meeting in Ottawa in November 2017.

Promotion and Communication

The effective communication of IEA Bioenergy activities and information to stakeholders, in particular to decision makers, is a key priority of ExCo, which is re-emphasised in the new Strategic Plan 2015-2020. The wide range of promotional material available through the Secretariat includes Annual reports, technical brochures, copies of IEA Bioenergy news, the new Strategic Plan, strategic papers, and workshop proceedings. The IEA Bioenergy website is central to this publishing activity.

The 2016 Annual report included the special colour section on "*Integrated bioenergy hybrids – Flexible renewable energy solutions* ". Some copies from the original print run of 600 remain, with substantially increased distribution in electronic format.

The newsletter 'IEA Bioenergy News', which is distributed in June and December each year following the ExCo meetings, continues to be widely circulated. Two issues were published in 2017. As a special theme the first issue featured bioenergy in Sweden and the second issue featured bioenergy in Switzerland. The newsletter is also produced in electronic format and is available from the IEA Bioenergy website. A single page electronic newsletter covering recent ExCo and Tasks' activities was also produced and distributed at the end of March and September 2017. A free subscription to the Agreement newsletters is offered to all interested and there is a wide distribution outside of the normal IEA Bioenergy network.

Two contributions under the banner of 'IEA Bioenergy Update' were provided to the journal Biomass and Bioenergy in 2017 bringing the total to 63. This initiative provides excellent access to bioenergy researchers as the journal finds a place in major libraries worldwide.

Interaction with IEA Headquarters

There is continuing contact between the IEA Bioenergy Secretariat, and IEA Headquarters in Paris and active participation by ExCo representatives in relevant meetings. The Chairman, Technical Coordinator, Secretary, and key Task Leaders have worked closely with Headquarters staff at both administrative and technical levels. In 2017 the Technical Coordinator was involved with IEA Headquarters in the production of the *Technology Roadmap: Delivering Sustainable Bioenergy*. He has also reviewed the IEA Medium-Term Renewable Energy Market Report (MTRMR) 2017 and provided input on behalf of IEA Bioenergy. He has had regular engagements to facilitate information exchange from IEA Bioenergy to IEA Headquarters and vice-versa.

The Chair of IEA Bioenergy, Kees Kwant, attended the REWP meeting in Paris in March and presented the IEA Bioenergy Annual Briefing report to the IEA. He also attended the REWP meeting in October in Lisbon.

Adam Brown attended ExCo79 and Simone Landolina attended ExCo 80 on behalf of IEA Headquarters. This participation by Headquarters is appreciated by the Members of the ExCo and helps to strengthen linkages between the Technology Collaboration Programme and relevant Headquarters initiatives.

Status reports were prepared by the Secretary and forwarded to the Desk Officer and the REWP following ExCo79 and ExCo80. Information was also sent to Carol Burelle, Vice Chair of the End Use Working Party (EUWP) for the Transport sector. This forms part of the exchange of information between Technology Collaboration Programmes and the Working

Parties. Regular contributions are provided to the IEA OPEN Energy Technology Bulletin. This provides a very useful platform for distributing the IEA Bioenergy newsletter and publications to stake holders. The Bulletin is also one of the most used referral mechanisms for introduction to the IEA Bioenergy website.

IEA Bioenergy Website

The IEA Bioenergy website (www.ieabioenergy.com) has had incremental development in 2017. The content has been updated as required during the year.

From the website statistics for the year 2017 the key data were as follows:

- Total number of users: 26,430
- Total number of sessions: 39,420
- Total number of page views: 155,920

2. PROGRESS IN 2017 IN THE TASKS

TASK 32: Biomass Combustion and Co-firing

Overview of the Task

Task 32 aims to stimulate expansion of biomass combustion and co-firing for the production of heat and power on a wider scale. The widespread interest in the work of the Task illustrates the relevance of biomass combustion and co-firing in society. Combustion applications vary from domestic woodstoves to industrial combustion technologies, dedicated power generation and co-firing with conventional fossil fuels.

Biomass combustion technologies are commercially established with high availability and a multitude of options for integration with existing infrastructure on both large and small-scale levels. Nevertheless, there are still a number of challenges for further market introduction, the importance of which varies over time. The areas covered by the Task through different activities in the current triennium are:

- WP1. Decentralised heat production
- WP2. Efficient industrial combustion and CHP
- WP3. Near zero emissions from industrial combustion
- WP4. Co-firing and full conversion
- WP5. Low grade fuels and fuel pretreatment
- WP6. Climate impact of biomass combustion and bio-CCS
- WP7. Dissemination and outreach

The specific actions of Task 32 involve collecting, sharing, and analysing the policy aspects of results of international/national R&D programmes in the above areas. The results of these actions are disseminated in workshops, reports, handbooks, databases etc. In addition, a number of specifically designed, strategic actions are carried out by the Task to catalyse this process.

While most of the above areas are of a technical character, Task 32 also addresses non-technical issues on fuel logistics and contracting, environmental constraints and legislation, public acceptance and financial incentives. An example is the policy report on renewable heat, which is currently being drafted.

Participating countries: Austria, Belgium, Canada, Denmark, Germany, Ireland, Italy, Japan, the Netherlands, Norway, South Africa, Sweden, and Switzerland.

Task Leader: Ir Jaap Koppejan, Procede Biomass BV, the Netherlands

Sub-Task Leader for Co-firing: Marcel Cremers, DNV-GL, the Netherlands

Sub-Task Leader for Industrial Combustion: Claes Tullin, SP, Sweden

Sub-Task Leader for Small Scale Combustion: Thomas Nussbaumer, Verenum, Switzerland

Operating Agent: Ir Kees Kwant, NL Agency, the Netherlands

The Task Leader directs and manages the work programme, assisted by sub-task leaders for specific areas. A National Team Leader from each country is responsible for coordinating the national participation in the Task.

For further details on Task 32, please refer to Appendices 2, 4, 5 and 6; the Task website task32.ieabioenergy.com and the IEA Bioenergy website www.ieabioenergy.com under 'Our Work: Tasks'.

Progress in R&D

Task Meetings and Workshops

In 2017, the Task organised two internal meetings and two workshops. The internal meetings were used to monitor progress in different Task activities and plan and reflect on new Task activities. Another important aspect of the Task meetings is that actual developments on application of biomass combustion are shared amongst the member countries of the Task, thereby facilitating an important learning effect.

Workshops are a proven concept to gather and disseminate information in a structured and effective manner. Normally, invited speakers present the latest insights on one aspect of biomass combustion and/or co-firing, and thereby provide expert information for the participants. These workshops are usually organised in conjunction with high profile bioenergy conferences to attract as wide an audience as possible. The results of the workshops are reported and published on the Task website, and key results are fed back to both the Task participants and the ExCo for evaluation and further dissemination.

In Jan 2017, Task 32 organised a workshop as part of the Central European Biomass Conference in Graz, Austria on the topic of real life emissions from boilers and stoves. The workshop showed that the new load cycle methods that have been developed for logwood stoves and pellet boilers in the framework of recent research programmes, better reflect real life emissions than actual test methods. It was therefore concluded that efforts should be made together with industry and national governments, to introduce such methods.

In June 2017, Task 32 met at the European Biomass Conference in Stockholm. The meeting was combined with a field trip to the Mälarenergie WtE plant in Västerås. The site houses the largest waste fired CFB boiler in the world (130 MW_{th}/50MW_e), fuelled with about 480 ktons of SRF produced from household waste annually.

In September 2017, Task 32 co-organised a workshop and associated field trip on 'Biomass Co-firing and Full Conversion' as an integral part of the Wood Pellets Association Conference in Ottawa, Canada. The workshop itself was attended by approx. 100 participants representing pellet production, power production, research and policy making. A number of recent, good examples on full biomass conversion were presented, such as the Atikokan and Thunder Bay plants by Ontario Power Generation. Shortly after the workshop these plants were also visited. The workshop and field trip illustrated that it is possible to fully convert a typical pulverised coal fired power plant to wood pellets or black pellets, and showed the consequences of these different approaches in terms of CAPEX, OPEX and operational performance. In the recent 10-15 years, Task 32 has been addressing the opportunities for biomass co-firing, with or without thermal pretreatment, and is committed to continue doing so in the coming years.

Several other workshops will take place in this triennium. All workshop reports can be downloaded from the Task 32 website. Reports from internal Task meetings are available to member countries only, using login credentials.

Work Programme

The progress achieved during 2017 is shown below:

Technical report on particle emission measurement techniques for boilers and stoves

This report aims to summarise the opportunities of different particle emission measurement techniques and provide recommendations as to which method should be used in future. The report was delayed but will be endorsed at the next Task meeting (June 2018).

Policy paper with background report on the health impact of combustion aerosols

In June 2017 a policy paper with background report was published on emission factors and health related impacts of emissions from various biomass fired stoves and boilers. This is generally considered as one of the key issues related to small scale combustion. The report gives a clear overview on differences in emissions and health impacts between various combustion appliances. The policy paper, which provides an easy to read statement from Task 32 on this topic, was published. A webinar was held on 22 March 2018 to further elaborate the content of the report.

Strategic study on the potential for renewable heat from biomass boilers, including options for optimal technical integration of biomass boilers with other renewable energy forms for heat (for policy makers and equipment manufacturers).

This study provides insights into how biomass can be optimally used to provide heat in the future energy system. It provides good examples of conducive policy cases that helped in realising relevant projects. The work is co-funded by the Swedish Energy Authority. The project will be finalised in 2018.

State of the art report on application of biomass combustion based CHP with case studies and identification and assessment of innovative developments (for potential end users)

This report will provide insight into the success factors for application of biomass CHP on the basis of actually built installations. It will also provide insight into new developments on small scale CHP technologies. The actual work started in 2017 and will be finalised in 2018.

Report on consequences of real life operation on boiler performance (efficiency and emissions (for policy makers)

This project recognises that the real life emissions from biomass boilers and stoves can be significantly higher when compared to optimal circumstances. The project evaluates new measurement methods for stoves and boilers through two separate reports for boilers and stoves (to be published in 2018). A workshop on the same topic was also held in Graz, Jan 2017.

Workshop on options for co-firing in existing and new power plants (for power producers)

As part of the Wood Pellets Association Conference in Ottawa, Canada (Sept 2017), Task 32 organised a session on biomass co-firing and full conversion. The workshop provided an update on recent developments in biomass co-firing in particularly in North America and Europe.

Review on the implication of high percentage co-firing on fly ash utilisation (for policy makers and traders)

This review provides an analysis of current uses of biomass ashes and provides recommendations for improved use. For various countries, analyses were performed in 2017. The report will be finalised in July 2018.

Updated co-firing database (for utilities)

This database contains information on coal fired power plants with experience in biomass co-firing. As in other years, a number of records were updated or added in 2017.

Inter task project to evaluate the costs/benefits for fuel pretreatment of biomass residues in the supply chain for thermal conversion (with task 33, 34, 36, 40 and 43)

This is a project jointly carried out with Task 33, 34, 36, 40 and 43, under the guidance of Task 32. It consists of six case studies that describe how pretreatment of biomass can make the fuel supply chain more cost effective and efficient, or help to broaden the resource base. In addition, good examples of new companies converting biomass from one form to another will be included as a new database module in the existing IEA Bioenergy Technology database. In 2017, progress was made in the case studies. In 2018 these will be finalised, together with a policy synthesis report.

Website

The Task website (www.ieabioenergytask32.com) was relocated to http://task32.ieabioenergy.com. It attracts about 4,000 visitors every month and is one of the key tools for information dissemination. Main products that are being downloaded from the website are publications and meeting reports, the database on experience with biomass co-firing in different power plants, and the databases on the composition of biomass and ash from actual combustion plants. The website is updated on a regular basis. Task participants and ExCo Members can obtain access to a secured section of the website which includes internal reports and work in progress.

Collaboration with Other Tasks/Networking

The Task collaborates directly with industry and through industrial networks such VGB Powertech. Within the IEA family, interaction is also solicited with other Bioenergy Tasks or other Technology Collaboration Programmes such as the IEA District Heating and Cooling TCP and the Clean Coal Centre. Market relevance is also enhanced by the active involvement of ExCo Members in the selection of Task participants, based on their national programmes. Several power companies are currently directly involved in the Task. Effective coordination is achieved through joint events, and the exchange of meeting minutes and reports.

Deliverables

The following milestones were achieved in 2017. Organising and minuting of two Task meetings. Organising and reporting of a workshop on "Practical test methods for small-scale furnaces"; Organising and reporting of a workshop on "Biomass Co-firing and Full Conversion"; Publication of a report on 'Aerosols from biomass combustion', and a policy statement on 'the need for reduction of particle emissions'. Further there was updating of the international overview of initiatives for biomass co-firing; and maintenance of the Task website. The Task also produced progress reports and audited accounts for the ExCo.

TASK 33: Gasification of Biomass and Waste

Overview of the Task

The objectives of Task 33 are (1) to promote commercialisation of biomass gasification, including gasification of waste, to produce fuel and synthesis gases that can be subsequently converted to substitutes for fossil fuel based energy products and chemicals, and lay the foundation for secure and sustainable energy supply; (2) to assist IEA Bioenergy Executive Committee activities in developing sustainable bioenergy strategies and policy recommendations by providing technical, economic, and sustainability information for biomass and waste gasification systems.

Participating countries: Austria, Denmark, Germany, Italy, The Netherlands, Norway, Sweden, Switzerland and USA.

Task Leader: Professor Kevin Whitty, University of Utah, USA

Operating Agent: Jim Spaeth, U.S. Department of Energy, USA

The Task Leader directs and manages the work program. A National Team Leader from each country is responsible for coordinating the national participation in the Task.

For further details on Task 33, please refer to Appendices 2, 4, 5 and 6; the Task website task33.ieabioenergy.com and the IEA Bioenergy website www.ieabioenergy.com under "Our Work: Tasks."

Progress in R&D

Task Meetings and Workshops

The first Task 33 meeting for 2017 was held 2-4 May in Innsbruck, Austria and it was organised by Task 33 and Vienna University of Technology. MCI hosted the workshop. The task business meeting was held on the first day and a workshop entitled "Small scale gasification for CHP" was held on the second day. The third day included technical tours to the SynCraft industrial biomass gasification-based CHP system in Innsbruck and GE Jenbacher's manufacturing facility in Jenbach.

The second Task 33 meeting was held 23-25 October 2017 in Skive, Denmark, by Task 33 jointly with IEA FBC and was hosted by EA Energyanalyse. The Task business meeting was held during the first day and a workshop "Fluidized bed conversion of biomass and waste" was held the second day. Technical tours, on the third day, were conducted to the thermal biomass gasification plant in Skive and to the test centre for large wind turbines in Østerild, Denmark.

Both meetings and workshops were well attended and provided very good opportunities for valuable information exchange. All presentation can be found at the Task 33 website.

Work Scope, Approach and Industrial Involvement

The scope of work for the current triennium is built upon the progress made in the previous triennia. In the previous years, information exchange, investigation of selected sub-task studies, promotion of coordinated RD&D among participating countries, selected plant visits, and industrial involvement in technical workshops at Task meetings have been very effective. These remain the basic foundations for developing and implementing a program of work that addresses the needs of the participating countries.

Furthermore, the aim is to increase the number of countries participating in Task 33. Australia, Brazil, Canada, France, Japan, Spain and the UK, for example, are very active in thermal biomass gasification and their membership would be profitable for all participants.

The Task monitors the current status of key operations and R&D efforts relating to biomass and waste gasification, and identifies hurdles to advance further development, operational reliability, and economics of gasification systems. The Task meetings provide a forum to discuss the technological advances and issues critical to scale-up, system integration, and commercial implementation of these processes. These discussions lead to selection of sub-task studies and/or technical workshops that focus on advancing the state-of-the-art technology and identify the options to resolve barriers to technology commercialisation.

The Task has continued the practice of inviting industrial experts to the Task workshops to present their practical experiences and to discuss the options for development of critical process components to advance state-of-the-art biomass and waste gasification systems. The interaction with industry provides the opportunity for the National Team Leaders (NTLs) to evaluate refinements to existing product lines and/or processes. Academic experts are also invited to share information and foster cooperation in order to address and support basic research needs.

Work Program/Sub-task Studies

The current work program includes the following elements:

- Plan and conduct semi-annual Task meetings including workshops on sub-task studies selected by the NTLs, and address matters related to the Task mission and objectives. Details are:

Meeting	Associated Workshop	Dates and Location
1st Task meeting	Small scale gasification for CHP	2-4 May 2017 Innsbruck, Austria
2nd Task meeting	Fluidized bed conversion of biomass and waste	23-25 October 2017 Skive, Denmark

- Prepare and publish reports on issues relating to gasification of biomass and waste. During year 2017 the following reports were started and will be finalised in 2018 and published on the Task 33 website.
  - Waste gasification
  - Biomass gasification for CCUS
  - Gasification-based hybrid systems
  - Biomass gasification history and lessons learned
  - Valorisation of by-products from small-scale gasification
  - Gas sampling in biomass gasification
- Survey the current global biomass and waste gasification RD&D programmes, commercial operations and market opportunities for gasification, and identify the technical and non-technical barriers to commercialisation of the technology. Use the survey results to prepare and update Country Reports for information dissemination.
- Conduct joint studies, conferences, and workshops with related Tasks, Annexes, and other international activities to address issues of common interest to advance biomass and waste gasification technology.
- Identify research and technology development needs based on the results from the work described above as a part of the workshop reports.
- Publish results of the work program on the Task website (www.task33.ieabioenergy.com) for information dissemination. Maintain the website with Task updates.
- Maintain Task 33 database on thermal gasification facilities worldwide.

Observations from Workshop 1: *Small scale gasification for CHP*

The workshop took place in Innsbruck, Austria and was organised by IEA Bioenergy Task 33 and Vienna University of Technology. The workshop, which focused on Small scale gasification for combined heat and power production, was hosted by MCI.

The workshop program was divided into following sessions:

Session I:	Small scale gasification for CHP – experience reports
Session II:	Byproducts from thermal gasification

The first session began with an overview of small scale gasification in Germany, Austria and Switzerland given by FEE, followed by an experience report given by Urbas. There were also innovative technologies presented during the workshop such as entrained flow gasification by MEVA, the WoodRoll technology by Cortus Energy, staged gasification by Ronda Engineering and early commercialisation plant by CMD Engine. An interesting presentation on utilisation of special gases with gas was given by a representative of GE Jenbacher.

The second session started with an overview on byproducts from thermal gasification such as bio-char and ash, which could be used as a valuable fertiliser. During this session, the technology of SynCraft was described as well as modular gasification of torrefied biomass by Torrgas. The quality of ash from thermal gasification of sewage sludge and biomass for use as fertilisers was presented by DTU. The following table offers an overview on the workshop presentations.

- **Status quo from biomass gasification CHP-plant systems in Germany**
  Bernhard Böcker-Riese, FEE
- **Urbas small scale gasification for CHP**
  Peter Urbas, Urbas
- **Small-scale CHP with MEVA entrained flow gasification**
  Niclas Davidsson, MEVA
- **WoodRoll® – breakthrough technology for cleanest energy gas from biomass**
  Rolf Ljunggren, Cortus Energy
- **Utilization of special gases with gas engines – Requirements and experiences**
  Martin Schneider, GE Jenbacher
- **CMD ECO20: a small-scale combined heat and power system at early commercialization based on gasification and syngas conversion in an ICE**
  Maurizio La Villetta, CMD Engine
- **Staged gasification by Ronda Engineering**
  Giovanni Ronda, Ronda Engineering

- **Valorization of by-products from small scale gasification (ssg)**
  Martin Rüegsegger, ETECA
- **Co-production of bio-energy and biochar**
  Guadalupe Aranda Almansa, ECN
- **The carbon makes the difference – Decentralised wood power plant with valuable carbon as by-product**
  Marcel Huber, SynCraft
- **Modular gasification of torrefied biomass**
  Robin Post van der Burg, Erwin Eymans, Torrgas
- **Quality of ashes from thermal gasification of sewage sludge and biomass for use as CPK fertilizers**
  Tobias Thomsen, DTU

The workshop with 56 participants from 11 countries was very well attended and built a platform for information exchange which is one of the aims of Task 33.

All presentations as well as a summary workshop report can be found at the IEA Bioenergy Task 33 website (task33.ieabioenergy.com).

The site visits to SynCraft in Innsbruck and GE Jenbacher in Jenbach took place on the 4th May 2017.

SynCraft (www.syncraft.at) is a supplier of turn-key wood power plants based on floating bed gasification, it was founded in 2009. GE Jenbacher (www.ge.com) manufactures gas engines and cogeneration modules.

Observations from Workshop 2: *Fluidized bed conversion of biomass and waste*

Fluidised bed technology is well-suited for thermal processing of solid fuels such as biomass and waste. Combustion and gasification, in particular, are demonstrated technologies and today there are many commercial installations processing biomass-based feedstock in fluidised bed reactors. The following table offers an overview of the presentations given at the workshop.

- **Heat and mass transfer to fuel particles in fluidized bed combustors and gasifiers**
  B. Leckner, Chalmers University of Technology, Sweden
- **Ash and bed material research in fluidized bed gasification of biomass from lab to industrial scale**
  M. Kuba, bioenergy 2020+, Austria
- **Co-firing of torrefied biomass and coal in oxy-FBC with Ilmenite bed material**
  R. Hughes, CanmetENERGY, Canada
- **GoBiGas – 10 000 hours of gasification**
  A. Larsson, Gothenburg Energy, Sweden
- **Biomass utilization status and example in fluidized bed boilers in Korea**
  K. Park, KEPCO, South Korea
- **Fluidized bed gasification and combustion of biomass**
  T. Kumagai, IHI Corp., Japan
- **State of art CFB gasifiers and boilers for biomass and waste**
  J. Isaksson, Valmet, Finland
- **Low-temperature corrosion in fluidized bed combustion of biomass**
  E. Vainio, Abo Akademi University, Finland
- **Hydrogen production from biomass feedstocks utilising a spout fluidized bed reactor**
  P. Clough, Cranfield University, UK
- **Opportunities of hybridization of CSP plants by biomass gasification**
  A. G. Barea, University of Seville, Spain
- **Bed material-alkali interactions during fuel conversion in fluidized bed**
  P. Knutsson, Chalmers University of Technology, Sweden
- **Assessing CFB combustors flexibility with respect to load changes and fuel type**
  A. Nikolopoulos, CERTH, Greece
- **Research, development and its application of ciclulating fluidized bed boiler technology in China**
  J. Lyu, Tsinghua University, China
- **Results from the 100 kW dual fluidized bed gasifier at Vienna University of Technology**
  F. Benedikt, Vienna University of Technology, Austria
- **Biggest BFB for biomass combustion in France – Lessons learned**
  M. Insa, EDF, France
- **Wrap up**
  K. Whitty, University of Utah, USA

The workshop on Fluidized Bed Conversion of Biomass and Waste was jointly organised by IEA Bioenergy Task 33 (Gasification of Biomass and Waste) and IEA-FBC (Fluidized Bed Conversion) and included 15 presentations from experts on R&D, implementation, challenges and successes of fluidised bed processing. Over 40 experts from 16 countries all over the world participated in the workshop. All the workshop presentations are available online at the Task 33 website and a workshop report will be published soon.

The participants of the workshop had a possibility to visit Skive gasification plant as well as Østerild – National Test Centre for Large Wind Turbines on the second day. The bubbling fluidised bed gasification plant in Skive was designed to utilise wood pellets and/or chips. The gasifier is operated at a maximum of 2 bar over pressure and temperature of 850°C. Air is used as a gasification medium and olivine as a fluidised bed material. The product gas generated has a heating value of about 5 MJ/kg. The Wind Test Centre Østerild, which is operated by DTU, was established with seven test stands during 2012 and allows for erection of wind turbines of up to 250 meters.

Website and database

The Task website (www.task33.ieabioenergy.com) is the most important tool for dissemination of information and results from this Task. Descriptions of the gasification process and a description of the Task including the contact data of national experts are provided. Within 2 weeks after each Task meeting, all presentations in PDF form (Country Reports, Workshop presentations) can be found on the Task website. The Minutes are posted on the member's area of the website as soon as all Task members provide their feedback. The summaries of the workshops can be found on the website in a Report form.

A Google-map based interactive database of implementations of gasification plants has been incorporated into the Task website. At the moment, there are over 150 gasification facilities, mostly in member countries, registered in the database. The database is interactive, which means that the technology, type, and status of the gasifiers can be chosen to filter all the gasification facilities registered in the database. The possibility to filter also based on the feedstock/raw material was recently added to the database. The database is updated regularly and provides a good overview on gasifiers throughout the world.

In 2016 a status report on thermal biomass gasification in member countries was completed. The report includes the description of the technology, synthesis gas applications and a list of all biomass gasification facilities in member countries, which are active in the Task 33 database. At the end of 2018/beginning of 2019 an update of the status report is planned.

Deliverables

The Task deliverables include planning and conducting two semi-annual Task meetings focused on the workshops selected by the Task participants, involving academic and industrial experts; the preparation and distribution of workshop reports and newsletter; updating and publishing country reports; conducting joint studies, conferences, and workshops with related Tasks, Annexes, and other international bodies to address mutually beneficial issues; and preparation of periodic progress, financial and annual reports as required by the IEA Bioenergy Executive Committee (ExCo).

TASK 34: Direct Thermochemical Liquefaction

Overview of the Task

The objective of Task 34 is to facilitate commercialisation of liquid fuels from biomass as energy carriers. Of particular interest are fast pyrolysis and hydrothermal processing to maximise liquid product yield and production of renewable fuel oil and transportation fuels. The Task contributes to standardisation efforts of these energy intermediates, the resolution of critical technical areas and disseminating relevant information particularly to industry and policy makers. The scope of the Task is to monitor, review, and contribute to the advancement of issues that will permit more successful and more rapid implementation of biomass liquefaction technology, including identification of opportunities to provide a substantial contribution to bioenergy.

The Task scope includes all steps in a process of liquid fuels production from biomass extending from reception of biomass in a raw harvested form to delivery of a marketable product as liquid fuel, heat and/or power, chemicals and char by-product. The technology review may focus on the thermal conversion and applications steps, but implementation requires the complete process to be considered. Process components as well as the total process are therefore included in the scope of the Task, which will cover optimisation, alternatives, economics, and market assessment.

The work of the Task aims at concerns and expectations of stakeholders such as:

• Conversion technology developers	• Bio-oil/biocrude application developers
• Equipment manufacturers	• Bio-oil users
• Chemical producers	• Utilities providers
• Policy makers	• Decision makers
• Investors	• Planners
• Researchers	

Industry is actively encouraged to be involved as Task participants, as contributors to Workshops or Seminars, as Consultants, or as technical reviewers of Task outputs to ensure that the orientation and activities of the Task match or meet their requirements. At least three of the existing National Task Leaders (NTL) have continuing and close relationships with industrial partners that are currently commercialising liquefied biomass as energy carriers in Finland, the Netherlands, and Canada.

Participating countries: Canada, Finland, Germany, Netherlands, Sweden, New Zealand, Norway, and USA

Task Leader: Mr Alan Zacher, Pacific Northwest National Laboratory, USA

Operating Agent: Mr Jim Spaeth, US Department of Energy, USA

A National Team Leader from each country is responsible for coordinating the national participation in the Task.

For further details on Task 34, please refer to Appendices 2, 4, 5 and 6; the Task website task34.ieabioenergy.com and the IEA Bioenergy website www.ieabioenergy.com under 'Our Work: Tasks'.

Work Programme and Progress in 2017

National team leaders were engaged in a number of formalised and informal collaborations that they leveraged to provide value to the member countries of IEA Bioenergy, the international thermal liquefaction research community, as well as the interests of the individual member states. Is some cases, Task meetings were held in conjunction with both international and regional Bioenergy meetings and workshops in order to capitalise on value to the Task and to having the opportunity to influence and support planning and research in thermal liquefaction for us in renewable energy. Task work in 2017 included Task meetings, providing support to standards development for thermally liquefied biomass energy carriers, providing information resources to support growing commercialisations work in some member countries, providing IEA thought leadership through Task participation in Bioenergy workshops, and continued information dissemination to stakeholders through Task periodicals, publications, and web resources.

The collaborative efforts in the DTL Task 34 consists of influence and guidance of standardisation efforts, publications and outreach, Task meetings, technical seminars, technical tours, and Task projects, in addition to management and ExCo support actions. The work efforts in 2016 included:

- Task meetings coinciding with guidance and support of Bioenergy workshops and conferences in member countries.

- Publication of the PyNe newsletter to highlight current research, collaborations, and successes in Bioenergy through thermal liquefaction of biomass.
- The prior Round Robin on bio-oil production of various biomasses and technologies was published in the form of a journal article to provide comprehensive detail around the conclusions that were disseminated as posters previously. This was published in Energy and Fuels for dissemination to the dedicated research community. Additionally, as the stakeholder audience is wider than the researchers that subscribe and follow detailed journals, the results were summarised in the IEA Bioenergy 2-page format to provide free access to the conclusions and recommendations and published on the Task and main IEA Bioenergy websites.
- Development of standards and norms for bio-oil intermediates has continued in both Europe and the US with Task member input to the standardisation committees. Current progress is detailed in PyNe newsletter during 2017.
- The Task website has made the full transition from the prior PyNe servers that have been the face of this collaboration in its evolution from the Pyrolysis Network, ThermalNET, and Task 34 under IEA bioenergy. The old website was shuttered in 2017 and redirected to http://task34.ieabioenergy.com bringing a modern face and focus to the biomass liquefaction community.
- Reporting and publicising ongoing collaborations and research in Bioenergy in the form of sharing of country reports by country representatives at Task meetings. This serves as a method for identifying and forming alignments between research organisations at member states to advance research and commercialisation efforts.
- Updates are being maintained to the web-based demo plant database developed by Bioenergy 2020+

Workshops and associated Task Meetings

There were two primary meetings that were held and associated with regional and international workshops and sites. The first was in Sweden and the second in Canada.

Luleå/Piteå, Sweden and Gothenburg, 15-17 May 2017

The first Task 34 meeting of 2017 was commenced in Luleå/Piteå, Sweden and carried on to Gothenburg to be adjacent to ExCo79, and provide Task influence and participation in the Advanced Biofuels Conference (ABC) in Gothenburg. The programme included a number of technical tours of the vibrant Swedish biofuels industry. Attending were Fernando Preto (Canada), Anja Oasmaa (Finland), Kristin Onarheim (Finland), Nicolaus Dahmen (Germany), Bert van de Beld (Netherlands), Ferran de Miguel Mercader (New Zealand), Magnus Marklund (Sweden), and Alan Zacher (US). Country reports were given by all NTLs.

Discussions began with the Round Robin status and progress. A historical perspective was presented by USA on the outcome of all 24 years of PyNe and Task 34 Rounds Robin. Identified unanswered questions with respect to most needed analytical methods and the need for expansion of similar work to encompass bio-crudes (from hydro- and solvo-thermal liquefaction). Finalised RR approach as comparative analyses of bio-oils and bio-crudes based on unanswered questions from prior RR. Request was made to summarise the Historical Perspective into an IEA Bioenergy format two-page summary.

Direct Thermochemical Liquefaction (DTL) systematisation scheme was presented by Germany for use in preparing a new DTL brochure and to replace the technology tree and organisational scheme for the Task 34 website.

Publication Strategy session was held to critique the transferred Task 34 website for revision, identified topics for future 2-page summaries, determined the format for upcoming DTL brochure, and identified input for PyNe41.

Informal workshop and research review was held with BOBIC (Bothnia BioIndustries Cluster) by Ulf Westerberg at the Piteå Science Park, and with RISE ETC with research in biomass liquefaction and characterisation as well as future upgrading presented and reviewed. Technical tours and Site Visits included:

- Liquefaction, characterisation, and upgrading facilities at RISE ETC.
- External tour of the forestry and wood processing facilities in and around Piteå
- In-depth examination and tour of the entire LTU GreenFuels gasification synthesis plant
- Tour of the SunPine tall diesel factory
- Tour of the PREEM refinery
- Tour of Volvo
- Tour of Södra cell

This was a rare experience expressing the full usage chain of biofuels in Sweden for forestry related biofuels from biomass growth, processing, fuels extraction, upgrading, and end use. From this NTLs participated in various aspects of the ABC in Gothenburg including a "Biofuels in Aviation and Maritime Transport" session hosted by Magnus Marklund of Task 34 session along with presentations from Task 34 NTLs Nicolaus Dahmen, Alan Zacher, Fernando Preto, as well as an industrial contribution from Martin Porsgaard. Topics included strategies for hydrotreating, needs for upgrading to conventional transportation fuels, critical factors for operating IC engines on bio-oils, and progress and hurdles towards getting biofuels in the air. Proceedings are available at https://advancedbiofuelsconference.org/

HTP-Forum Liepzig, Germany, 12-13 September 2017

The Task co-chaired the HTP-Forum on hydrothermal processing in Germany in September. While the event was primarily to attract regional stakeholders on advancing hydrothermal processing, an international session was added to reflect on the international state-of-the-art. In this session, Nicolaus Dahmen reported on the work of Task 34 along with it recent adjustments and focus to include hydrothermal and solvo-thermal liquefaction approaches in addition to the historical focus on Pyrolysis.

The organisers of the HTP-Forum are looking to prepare a report for the IEA Bioenergy PyNe newsletter that will be included with PyNe41 or PyNe42 depending on when it can be completed.

Ottawa, Canada, 28 November – 2 December 2017

The second Task meeting of 2017 was held in Ottawa Canada coinciding with Task involvement in two other external Bioenergy conferences, Bioenergy for the Future and the Scaling Up 2017 conference, and then followed by an Analytical Workshop at CanmetENERGY. The programme included technical tours of a number of bioenergy operations at Canmet, but the hoped for tour of the commercialised Ensyn pyrolysis production facility in Renfrew, Ontario could not be arranged. Member countries were represented by Fernando Preto (Canada), Kristin Onarheim (Finland), Axel Funke (Germany), Bert van de Beld (Netherlands), Ferran de Miguel Mercader (New Zealand), Magnus Marklund (Sweden), and Alan Zacher (US). ExCo was represented by Alex MacLeod (Canada) and Jim Spaeth (USA).

The first event was the Bioenergy for the Future, part of the Mission Innovation where Task 34 participated in the rollout of the Bioenergy Roadmap supported by IEA Bioenergy. Task input to this had been coordinated by Fernando Preto.

Following this the Task provided speakers and interactions at the Scaling Up 2018 conference in Ottawa. The Task and IEA Bioenergy were represented in various Question and Answer panels, which made up the bulk of this interactive bioenergy event. The panels covered the range of subject matter experts including environmental, research, policy, financing, commercialisation, and recruiting future talent, all with the common theme that there is a need to push biofuels towards scale-up immediately to have meaningful impact on our global renewable energy due to the lengthy period that is required to bring technologies to market. Discussions centered around ideas on how to advance scale-up of Bioenergy and removing or avoiding barriers that would reduce or delay successful adoption of biomass energy.

The Task also organised and led an Analytical Workshop for thermochemical liquefaction technologists in Canada and from the gathered international representatives. A number of different technologies were represented in the spectrum of conversion of biomass and to transportable energy intermediates, upgradable intermediates, as well as direct energy

use. Included in the mix were inputs from a broad range of biomass, waste feedstocks, and potential energy intermediates that provided valuable insight into the all-of-the-above approach that Canada is considering in the search for renewable energy. Discussions involved assessing analytical needs, existing gaps in understanding of biomass and energy carriers and considering additional and new standardisation, with unique contributions from Ottawa ministry for the environment, towards the importance of standardisation to allow for permitting of bioenergy technologies to regulatorily differentiate them from hazardous waste incinerators that could conceivably attempt to operate abusing a bioenergy permitting process. The discussions from this workshop were used by the Task to target and refine the Round Robin approach and capture additional insights on challenges that the international thermal liquefaction research community must address to enable wider adoption.

The proceedings included a technical tour of the wide variety of large scale research and capabilities at Canmet. This included examination of the biomass handling and transportation, multiple pilot scale fast pyrolysis systems for production of bio-oil intermediates, demonstration scale system for biomass gasification, multiple systems for biomass and bio-oil direct combustion for thermal energy, shakedown of small scale heat and power biomass energy systems for remote communities, and slurry-phase catalytic hydrotreating and hydrocracking of bio-oil intermediates to hydrocarbons for transportation fuels.

The series of events provided an opportunity to plan and advance the Task collaborations, to have Task influence on the international dialogue on Bioenergy within Canada, and to harvest additional pathways to collaboration on advancing and scaling-up biomass energy through direct thermochemical liquefaction.

Newsletter

In 2017 the PyNe newsletter was produced twice to publicise and highlight ongoing research and collaborations in member countries. Continuing the tradition of the last 21 years, the newsletter was used as a vehicle to provide information on current research and commercialisation efforts in liquefied biomass energy carriers. A mixture of pyrolysis and pressure liquefaction research was featured in both issues. PyNe40 also provided a retrospective of the previous 20 years of influence that the Pyrolysis Network and the IEA Bioenergy have served in advancing bioenergy and reducing barriers to commercialisation. PyNe41 featured ongoing collaborations in Europe as well as the fruit of standardisation efforts in Europe.

A new distribution service was utilised in 2017 to enable analytics for determining readership and impact of the distribution, as well as an opportunity for IEA Bioenergy ExCo to survey the Pyrolysis Network for input for future Task structure and focus. The newsletter is now circulated to participants via the Task 34 website in electronic format. Along with historical archives going back to its inception in the 1990s.

Website/Dissemination

The Task 34 website is an important mechanism for information and technology transfer. The website was fully transitioned to the IEA Bioenergy servers. The old PyNe website has now been shuttered, and traffic has been redirected to the new server. The Task is continuously updating the format and information with more recent technical information and progress along with incorporating resources around the new focus on DTL. This is still a work in progress.

Deliverables

Deliverables for 2017 included: Publication of the Round Robin in Energy and Fuels, publication of the two-page stakeholder summary of the Round Robin on IEA Bioenergy, reporting to the ExCo (Annual Report, progress reports, and audited accounts); updating of the Task website on bioenergy servers; Two task newsletters PyNe40 and PyNe41; organisation and minutes of Task meetings.

TASK 36: Integrating Energy Recovery into Solid Waste Management Systems

Overview of the Task

In 2012 the World Bank estimated that there is around 1.3 billion tonnes of waste produced per annum globally and that this will grow to 2.2 billion tonnes/year by 2025. They attributed this rise in waste production to increased urbanisation in developing and emerging economies and the increase in per capita production of waste as a result of this trend. This trend is a considerable challenge for many countries. To meet the challenge there will need to be intensive legislative, managerial and institutional changes, including the introduction of strategic direction aimed at decreasing and controlling waste production; and the development of recycling, reduction and re-use as well as energy technologies to decrease the impact of waste. IEA Bioenergy Task 36 investigates the interface between waste management and energy recovery. Our prime aim is to understand the implications of technical and policy changes in the waste area that impact the integration of energy into solid waste management; and to provide support by disseminating and exchanging information on these developments.

Waste production varies markedly across the world, in terms of composition and quantity. Strategies and solutions that are appropriate in one region may not be right elsewhere. The consequence of this is that countries have different approaches to challenges in waste arisings, reflected in different mixtures of treatment and disposal. Nevertheless there are also common themes. Uppermost in these are concerns relating to the increasing quantities of waste needing to be treated and the impact of landfilling mixed wastes on the environment. In some regions additional pressures arise from decreasing available landfill void space. This

is driving policy makers to examine alternatives to landfill, including reduction and recycling of waste, and recovery of value from waste, commonly encompassed in the 'Waste Hierarchy', which is governed by a set of principles dedicated to minimising the impacts of waste and improving resource use. In some regions there are calls for 'zero waste to landfill' and for policy to encourage the circular economy or 'smart waste management'. These moves are most advanced in the European Union and other regions where landfill is expensive or scarce. Elsewhere, notably in North America and Australia, countries continue to rely on landfill, but in these countries there are also increasing pressures to reduce waste production and to recycle or recover where possible, leading to increased interest in recovery of energy from the residual waste. Globally these policy pressures have led to a proliferation of research work on waste management, including policy development, environmental systems analysis, technology development and economic drivers. Whilst this has assisted in the development of more sophisticated waste management systems, in many cases it has also delayed deployment of energy recovery systems (specifically for residual wastes), in particular due to confused policy making, public awareness (and opposition) and uncertainty over environmental performance and technology performance.

Against this background decision makers continue to require guidance and information on waste and resource management systems that are environmentally and economically sustainable. Task 36 provides a unique opportunity to draw together information on how systems, policies and technologies are being applied in different countries to provide guidance for decision makers on key issues.

Participating countries: France, Germany, Italy, Singapore (observer), and Sweden.

Task Leader: Mr. Inge Johansson, RISE Research Institutes of Sweden, Sweden

Operating Agent: Dr. Åsa Forsum, Swedish Energy Agency, Sweden

The Task Leader directs and manages the work programme. A National Team Leader from each country is responsible for coordinating the national participation in the Task.

For further details on Task 36, please refer to the Appendices 2, 4, 5 and 6; Task website www.task36.ieabioenergy.com and the IEA Bioenergy website www.ieabioenergy.com under 'Our Work: Tasks'.

Progress in R&D

Task meetings and workshops

The Task's core work was undertaken as structured Task meetings, each of which was accompanied with a themed workshop. The aim of these workshops is to allow Task members to present work on the nature of the issues concerned within their own country; to invite speakers to present work of relevance and to allow discussion of the issues presented.

The first workshop focused on the circular economy and what role Waste-to-Energy could play. *Paris, January 2017. The workshop was arranged at Ademe.*

Workshop aim:

Today there is a general agreement that the linear approach to resource management that have been dominating for quite a while, is not sustainable. The wish for a more circular economy where resources are reused and recycled in an efficient manner is discussed both on a political and a societal level. The aim of the workshop was to discuss what implications this has on bioenergy/energy from waste

Workshop outcomes:

When the circular economy is illustrated, it is often depicted as one loop for inorganic technical materials and one loop for organics (mainly food). The illustrations seldom cover the upcoming biomaterials that are used and not necessarily fit into the "normal" bio loop. These materials are becoming more and more important when discussing the bio economy and must not be forgotten.

The role of waste-to-energy is normally depicted as something to be minimised in the circular economy. In an ideal circular economy that might also be the case – even though all recycling/recovery operations still need energy to function. The function to act as a kidney in society, destroying toxic substances as well as concentrating other toxic elements to be disposed of in a safe manner will continue to be important for the foreseeable future. The lifespan of products means that there are a large stock of undesirable substances, already built up in society, that will need to be treated when they become waste. The conclusion was that there will be a role for waste to energy in the circular economy – although that role might be different from today. The presentations from the workshop are available at the homepage. (www.task36.ieabioenergy.com).

The second workshop dealt with the potential of using Alternative thermal treatments for feedstock recycling, *Karlsruhe, December 2017.*

Workshop aim:

There are quite a number of limitations on mechanical recycling of materials for example. The content of unwanted chemical substances in wood or plastics is one of those major limitations. Thermochemical recycling (feedstock recycling) could be a solution to that and the aim was to give an overview of such methods.

Workshop outcomes:

Although gasification and pyrolysis of waste today mainly acts as two stage combustion processes there is potential to use the technologies to convert the value chain into a value cycle and generate new valuable resources. However there are large challenges when looking at the demand for processes that can handle feedstock flexibility, which is needed to achieve economics of scale. This demand gives rise to challenges for most parts of a plant (thermal conversion step, cleaning step and synthesis step). During the workshop more general presentations were mixed with insights into the challenges and possibilities seen from the view of different technical suppliers. The presentations are available at the homepage. (www.task36.ieabioenergy.com)

Task Meetings and site visits

January 2017, task meeting in Paris together with a site visit to Isséane

June 2017, Task meeting in Stockholm together with a site visit to Mälarenergi

December 2017, Task meeting in Karlsruhe together with a site visit to the Bioliq® plant at KIT

Deliverables

The deliverables for the Task in 2017 have included presentations from the workshops and minutes from the Task meetings. The first newsletter was published late in 2017. The Task also prepared two progress reports for ExCo together with the annual report.

Website

The website (task36.ieabioenergy.com) is the key tool used for dissemination of information from the Task. It provides access to the latest publications produced by the Task, including the presentations from the workshop. The website also provides access to past reports, articles, case studies and presentations at workshops associated with Task meetings. In addition, it provides a 'members only' forum, to allow rapid access to the latest drafts of documents and to information on Task meetings. During 2017 there were about 1600 visitors to the site. Where the country of origin is known, the most page views were from users in the USA, China, UK, Canada and Germany. There was a significant increase in traffic after the first newsletter was published late in 2017.

TASK 37: Energy from Biogas

Overview of the Task

The main objective of the Task 37 work programme is to address the challenges related to the economic and environmental sustainability of biogas production and utilisation. While there are thousands of biogas plants in OECD countries, operation in the vast majority of cases can only be sustained with the help of subsidies to be able to compete with the fossil energy industrial sector. There is a clear need to enhance many of the process steps in the biogas production chain, particularly at small farm-scale, in order to reduce both investment and operating costs and to increase income.

The approach of Task 37 involves the review and exchange of information and promotion of best practices for all steps of the process chain for anaerobic digestion (AD) of biomass residues and energy crops for the production of biogas as a clean renewable fuel for use either directly in combined heat and power generation or after up-grading to biomethane where it replaces natural gas. In addition, there is growing interest in the use of biogas and biomethane to help stabilise power grids that are increasingly fed from variable sources of generation like wind and solar.

The Task also addresses utilisation of the residues of the AD process, the digestate, and the quality management methods for conversion to high quality organic fertiliser. The scope of the work covers biogas production at small and large farm-scale, in waste water treatment plants and treatment of the biodegradable fraction of municipal waste (biowaste), energy crops and algae.

Only recently have the environmental performance of biogas production and utilisation been assessed in detail. Recent studies have identified key sources of emissions of greenhouse gases at various stages of the biogas production chain. Task 37 has addressed emissions and is directing attention to environmental sustainability of biogas production and utilisation and is working towards defining best practices for emissions reduction.

Through the work of the Task, communication between RD&D programmes, relevant industrial sectors and governmental bodies is encouraged and stimulated. Continuous education is addressed through dissemination of the Task's publications in workshops, conferences and via the website. Information and data collected by the Task is used increasingly for providing support to all levels of policy making and the drafting of standards in Member Countries.

Participating countries: Australia, Austria, Brazil, Denmark, Finland, France, Germany, Ireland, Korea, the Netherlands, Norway, Sweden, Switzerland, and the United Kingdom.

Task Leader: Prof Jerry D Murphy, MaREI Centre, Environmental Research Institute, University College Cork, Ireland

Operating Agent: Matthew Clancy, Sustainable Energy Authority of Ireland, Dublin, Ireland

The Task Leader directs and manages the work programme. National Team Leaders are responsible for coordinating the national participation in the Task and for coordinating specific topics in the work programme.

For further details on Task 37, please refer to Appendices 2, 4, 5 and 6; the Task website http://www.task37.ieabioenergy.com and the IEA Bioenergy website www.ieabioenergy.com under 'Our Work: Tasks'.

Progress in R&D

In 2017 the work programme consisted of the following Topics:

- Preparation of technical reports;
- Collaboration with other Tasks;
- Country Reports and Databases;
- Success Stories and Case Studies;
- Website, Newsletters and Webinars;
- Task Meetings and Workshops;
- Deliverables of Task 37 in 2017.

Preparation of Technical Reports

The progress on the content of new technical brochures/reports is summarised below.

Methane Emissions

This report is now published with a date of December 2017. We have also published the 2 page summary. These are available on line. This is a long detailed report, which describes and assesses methodologies for assessing fugitive methane emissions from biogas facilities, the main sources of emissions, how to minimise such emissions and the impact of these emissions on the sustainability of biogas systems. It was also the subject of a webinar with an audience in excess of 400 in January 2018.

Two conference presentations were made based on this report:

- *J. Liebetrau, T. Clauß, T. Reinelt, Alessandro Agostini, Jerry Murphy. (2017) "Methane emissions from biogas plants – methods for determination results and relevance for greenhouse gas balances"" 15th International Water Association Anaerobic Digestion 17 – 20 October 2017, Beijing China*
- *Alessandro Agostini, J. Liebetrau, T. Clauß, T. Reinelt, Jerry Murphy. Evaluation of the impact of methane emissions on the carbon footprint of biogas plants. 4th International Conference on Renewable Energy Gas Technology, 22 – 23 May 2017, Parchi del Garda, Italy*
- *Jan Liebetrau (2018) Emissions from Biogas plants – methods for measurement, results and overall evaluation, Conference of the European biogas association, January 24-26 Antwerp*

Food Waste Digestion Systems

The emphasis of this report will be on how food waste digestion can be done successfully, within the circular economy. It is crucial to define what we mean by food waste and distinguish from biowaste. Collection systems (frequency of collection, size of bin, contamination) have a significant impact on the feedstock. Mono-digestion of food waste is dominant in UK. Scale varies up to 130,000 t/a. Circular economies using hub and pod concept balancing nutrients between urban and rural farming are of great interest. Digestate from food waste is fairly pure as it comes from food we would have eaten. Quality assurance is important. Food waste biorefining through carboxylate platform or through C1 fermentation of gaseous products of AD is also of interest. The report will include for some case studies

Grid Injection and Greening of the Gas Grid

This report will be published in February 2018 and exists as an advanced draft. The report deals with the Green Gas Commitment including 6 European Gas Grids who have an ambition of substituting 100% of natural gas with green renewable gas by 2050. The report discusses how such an industry will evolve. It will discuss the gas grid, gas quality and the role of the gas grid in the future. It will discuss why biogas would be used to produce biomethane instead of CHP. It will set out the importance of green gas in supplying renewable energy in transport and in renewable heat such as for industries on the gas grid. The potential route to green gas and scale of the potential industry may be outlined by member countries.

A paper was published based on this report:

- *Wall, M.D., McDonagh, S., Murphy, J.D. 2017. Cascading biomethane energy systems for sustainable green gas production in a circular economy. Bioresour. Technol.* https://doi.org/10.1016/j.biortech.2017.07.115

A conference presentation was made based on this report:

- *Jerry D Murphy, David Wall (2017) " Use of circular economy and cascading bioenergy systems in ensuring sustainable biogas production " 15th International Water Association Anaerobic Digestion 17 – 20 October 2017, Beijing China*

Local applications of anaerobic digestion towards integrated sustainable solutions

The objectives are to provide information on cost effective biogas technologies. The target Group is NGOs. The report will detail a number of proposed exemplars from across the world. The concept of what sustainability actually means for these biogas plants will be discussed. This will include the conflicts between small simple digesters utilising the proximity principle (with potential for methane slippage) and large industrial digesters with high levels of sophistication.

The Role of Anaerobic Digestion and Biogas in the Circular Economy

Anaerobic digestion systems tend to form parts of circular economies. It is difficult to compare anaerobic digestion to a wind turbine. Biogas is more than a fuel and without biogas and anaerobic digestion a number of processes would not be sustainable. Anaerobic digestion is a multi-process system including waste treatment, environmental improvement, renewable energy production and biofertiliser production. Anaerobic digestion processes can be considered scavenger type systems producing biogas from a large variety of wet organic wastes, residues and feedstocks. Biogas is an incredibly flexible end product having applications in renewable electricity, heat and transport fuel. Innovative systems will be described. Seaweed biogas may have a role in multi-trophic aquaculture. Micro-algae may scrub CO_2 from a bioenergy power plant and provide feed for a biogas plant. Anaerobic digestion has applications in liquid biofuel and biorefinery systems.

Veracity and Applicability of Biomethane Potential Assay Results

The BMP assay is a limited test in which the inoculum is usually twice the quantity of the substrate. This has the tendency to mask limitations in the feedstock such as non-ideal C/N ratios and lack of micronutrients. The importance of inoculum in the BMP result will be discussed and whether the inoculum is suitable for the feedstock. It may be prudent to allow for acclimatisation when the substrate is different to the substrate in the system, which produced the inoculum. Different BMP systems can yield different BMP results. Neither does the BMP assay give data on optimal organic loading rate and operating conditions for a digester. It may be more beneficial (but also more costly) to undertake continuous digestion of the substrate over a period of time to give specific methane yields (SMY) corresponding to different organic loading rates (OLR) and hydraulic retention times (HRT).

Biomethane as a transport fuel

This will be a short report yielding up to date data on assessment of modern natural gas vehicle engines. It is suggested that the report be renamed "Experiences in Biomethane Buses." Potentially this may be published in 2019.

Collaborations with other Tasks

IEA Bioenergy Inter-Task Strategic Project: State of Technology Review – Algae Bioenergy

This extensive report (ca. 150 pages and 450 references) was published in February 2017. This was led by Task 39 and included contributions from Task 37 in seaweed biomethane and in micro algal biogas.

Sustainable Bioenergy Chains

This task is led by Task 40 and will include contributions from Task 37. There are three objectives: (1) Calculation method and tools to asses biogas sustainability; (2) Approaches on how to govern and verify sustainability (3) The involvement of stakeholders in the different market phase of biogas development

National Biogas Mirror Groups

The Task maintains close links with national mirror groups. An example includes the Mercosul Ad Hoc Group on Biofuels (GABH). This includes for Argentina, Brazil, Paraguay, & Uruguay. IEA Task 37 funded the translation of this report to English and placed it on the country report section.

Country Reports

The Task published an updated Country Report Summary for 2016 in November 2017. The 63 page document summarises information on the biogas sector in 14 Task member countries, including energy recovery data, biogas utilisation data, details of support schemes and key research projects.

In October 2017 the Task produced the 2016 upgrading plant list. This included details of approximately 548 upgrading facilities; 480 of these are in Task member countries with details of a further 68 outside Task member countries.

Success Stories and Case Studies

Three case studies were published in 2017:

1. DEN EELDER FARM: Small farm scale mono-digestion of dairy slurry, March 2017
2. GREEN GAS HUB: Provision of biogas by farmers by pipe to a Green Gas Hub with a centralised upgrading process, April 2017
3. BIOMETHANE DEMONSTRATION: Innovation in urban waste treatment and in biomethane vehicle fuel production in Brazil, November 2017

A list of further proposals for success and case stories includes for:

1. A brewery in Austria at Goesser;
2. Biomethane at a sugar beet factory with up-grading in Switzerland;
3. Application of biogas to the pork industry in Australia;
4. A case study on very large digesters built in Denmark (Linkogas);
5. Case study of gas to grid system in Oxfordshire;
6. Case study of a food waste digester at Battlefarm in Oxfordshire;
7. Grass digester with production of biolplastic and fibres for insulation;
8. Schmack Biogas MicroBEnergy Power to Gas facility;
9. Landfill gas to gas grid in France.

Website, Newsletter and Webinars

Website

The website (www.iea-biogas.net & http://task37.ieabioenergy.com) is updated with news, biogas data and publications (including national biogas reports using a new "biogasreports" tool – www.biogasreports.com). The Country Reports as well as the Task publications, proceedings of the workshops and newsletters were made available along with important publications from the participating countries. The website was updated a number of times.

- The Task 37 report "Methane emissions from biogas plants" (Dec 2017):
- The two-page summary of the "Methane emissions from biogas plants" (Dec 2017);
- The presentations of the IEA Task 37 Workshop on Biogas Externalities in Esbjerg, Denmark Sep 14, 2017
- The presentations of the joint meeting with Inter Baltic Biogas Arena, Poznan, Poland August 23, 2017
- The presentations of the IEA Task 37 Workshop on innovation in and grid injection of biomethane in Vlijmen, The Netherlands April 6, 2017
- The upgrading plant list 2016
- The IEA Task 37 Country Report Summaries 2016
- The Mercusor report 2016
- Th3 latest country report presentations
- The case study DEN EELDER FARM: Small farm scale mono-digestion of dairy slurry, March 2017

- The case study GREEN GAS HUB: Provision of biogas by farmers by pipe to a Green Gas Hub with a centralised upgrading process, April 2017
- The case study BIOMETHANE DEMONSTRATION: Innovation in urban waste treatment and in biomethane vehicle fuel production in Brazil, November 2017

Data on website visits for the 12 month period January 1st to December 31st 2017 is outlined in table 1. Data on twitter activity for the 5 last months of 2017 is outlined in table 2

Table 1. Results of visits to web page http://task37.ieabioenergy.com/ between January 1, 2017 and 31st December 2017

	Total	Average per month
Users	6,184	515
Sessions	9,980	832
Page views	27,605	2,300

Table 2. Twitter Account @JerryDMurphy66 Professor and Chair of Civil Engineering, UCC. Director of SFI MaREI centre. Task Leader of International Energy Agency Bioenergy Energy from Biogas

	Tweets	Tweet Impressions	Profile Visits	Mentions	New Followers
December	19	23,300	492	13	23
November	53	48,600	902	66	48
October	50	43,200	1,306	122	57
September	36	24,800	975	26	22
August	40	36,500	1,316	8	26

Newletters

There were 11 newsletters issued in 2017.

Webinars

19 July 2017 – IEA Bioenergy Task 37 – Australia Biogas Country Report and Guest Presentation – An international perspective of bioresource mapping to identify anaerobic digestion opportunities – (invited speakers Prof. Jerry Murphy (University of Cork, Ireland and Task 37 Leader) and Richard O'Shea (University of Cork) and A/Prof Bernadette McCabe (UoSQ NCEA and Australia's NTL for IEA Bioenergy Task 37) http://www.bioenergyaustralia.org/pages/resources.html#record

There were 63 registrations for this event. According to Connie Crookshanks of Bioenergy Australia it was the longest Australia Bioenergy Webinar and one of the best with further feedback from the US below: **Feedback:** "*I just wanted to let you know we missed the actual webinar but we watched the recorded version yesterday and it was outstanding. Very informative and it provided us with a lot of follow up opportunities with the primary presenters.*" – **Daniel Avery** Senior Policy Analyst Oregon Department of Energy 550 Capitol Street N.E., 1st Floor Salem, Oregon.

Task Meetings and Workshops

Task 37 Meeting Vlijmen, The Netherlands, April 2017

A Task meeting was held from April 5 to April 7 in Vlijmen, The Netherlands. On the 6th of April a workshop with ca. 100 delegates was hosted with two sessions: Grid Injection of biomethane; and Innovations in the biomethane market. Presenters included: Jörg Gigler (manager of the topsector Gas); Prof Murphy (Task 37 leader); Gerard van Pijkeren (Chairman of New Energy Group of Gasunie); Pieter Mans (Alliander and Chairman Expert Group New Gases of the Gridoperators); Jan Liebetrau (DBFZ, and German representative Task 37); Niels den Heijer (Pentair Process Technologies); and Boris Colsen (manager Colsen bv)

The Task visited two biogas facilities: Den Bosch and Waalwijk.

Task 37 Meeting Esbjerg, Denmark, September 2017

A Task meeting was held from September 12 to 15 in Esbjerg, Denmark. On the 14th of September a workshop was presented on Biogas Externalities. The workshop included the following presentations:

1. Jerry D Murphy, Task Leader – IEA Task 37: IEA Bioenergy Task 37: Goals and work programme;
2. Kurt Hjort Gregersen, AGROTECH, Denmark: Biogas from corporate economy to socio-economy: Externalities not included
3. Henning P. Jørgensen, SDU Esbjerg, Denmark: Local societies and the potential economic impacts of investments in biogas plants
4. Karetta Timonen, LUKE Finland: Village level green economy indicators in Lapland
5. Jakob Lorenzen, DFFB, Denmark: Danish Biogas Centre: Role, objectives and activities within the Danish biogas sector.

The Task visited two biogas facilities on Friday September 15th: LinkoGas (Lintrup): One of the first generation, large AD plants (300,000 tons/year) in Denmark. Totally refurbished and with enlarged capacity. Biogas upgrading unit. Organic biogas under development.

Holsted Biogas (Brørup): A new built, manure based co-digestion plant (400,000 tonnes biomass/year, 13 mill. Nm3 upgraded biogas). Largest upgrading unit.

Workshop Presentations:

1. Mattias Svensson (2017) "The role of biogas in the circular economy," Mobilising sustainable bioenergy supply chains: opportunities for agriculture. IEA Bioenergy Task 36 Workshop on Circular economy and the role of energy (from waste), Paris, France, 10 January 2017
2. Jerry D Murphy (2017) "From the big picture to the smallest microbes: the role of research in enabling AD to reach its potential" Anaerobic Digestion Bioenergy Association (ADBA) Research and Innovation Forum, London, 28 March 2017.
3. Prof Jerry Murphy, Task Leader Task 37 IEA Bioenergy & Prof Brian O' Gallachoir Chair IEA ETSAP "AD's contribution to meeting carbon reduction targets". UK AD & Biogas and World Biogas Expo 2017, Birmingham, UK, 5 July 2017.
4. Prof Jerry Murphy, Task Leader Task 37 IEA Bioenergy & Prof Brian O' Gallachoir Chair IEA ETSAP "An argument for using greengas as a biofuel". Energy in Agriculture, Tipperary, Ireland, August 22, 2017. 4000 delegates attended this symposium which included for a panel discussion on the topic of application of anaerobic digestion in Ireland.

Planning of Future Task Meetings and Workshops

Task meetings in 2018 will be held in the Jyväskylä Finland (7 – 9 March 2018) and Cork (5 – 7 September 2018)

TASK 38: Climate Change Effects of Biomass and Bioenergy Systems

Overview of the Task

Bioenergy is promoted as a low-carbon renewable fuel, and has been identified to play an important role in achieving climate stabilisation by the Intergovernmental Panel on Climate Change (IPCC). However, the value of bioenergy in climate change mitigation has been challenged with increasing vigour over recent years, by various academic and environmental groups. These concerns have fuelled an on-going debate about the appropriate role for bioenergy in climate policy, particularly in Europe and the USA.

The primary goal of *IEA Bioenergy Task 38* on *Climate Change Effects of Biomass and Bioenergy Systems* is to promote the sustainable use of biomass and bioenergy through improved understanding of the climate change effects of biomass production and utilisation for energy. Task 38 devises and promotes standard methodology for quantifying the climate change effects of bioenergy systems. Our objective is to support decision makers in government and industry, in the development of climate change mitigation strategies involving sustainable bioenergy.

Participating countries: Australia, Finland, France, Germany, Sweden, and USA

Task Leader: Annette Cowie, New South Wales Department of Primary Industries/ University of New England, Australia

Task Manager: Miguel Brandão, Royal Institute of Technology, Stockholm, Sweden

Operating Agent: Mark Brown, Bioenergy Australia, Australia

The Task Leader directs and manages the work programme, with the assistance of the Task Manager. A National Team Leader from each country is responsible for coordinating national participation in the Task by each participating country.

For further details on Task 38, please refer to Appendices 2, 4, 5 and 6; the Task 38 website http://task38.ieabioenergy.com and the IEA Bioenergy website www.ieabioenergy.com under 'Our Work: Tasks'.

Progress in R&D

Task Meetings and Workshops

During 2017 Task 38 held three face-to-face meeting of national team leaders and participated in three workshops.

Task 38 Business Meeting: Växjö (Sweden) 9th and 11th January

Five of the six participating countries (Australia, Finland, Sweden, USA, France) were represented at the meeting.

Key discussion points:

- Finalising paper on choosing the metric with which to compare a bioenergy system;
- Presentations from invited experts on cellulosic ethanol, on Full climate impacts of managed boreal forests, and on Potential of forest management for future climate mitigation;
- Inter-task projects on Bio-CCUS and Sustainable bioenergy supply chains

Task 38 Forest Modelling workshop: Växjö (Sweden) 10th January

The workshop focused on divergent results for the climate change effects of bioenergy from forest systems from two studies in Finland and Sweden. The workshop included discussion to clarify details of the methods and draw out key factors that influence the results. General discussion then considered the strengths and weaknesses of the approaches of the two studies, and identified aspects for which further information is required, to gain a more complete understanding of the results of each study. The group then summarised the points of difference identified, and finally noted some ideas for future work.

Task 38 Business Meeting: Gothenburg (Sweden) 15th May

Five of the six participating countries (Australia, Finland, Sweden, USA, France) were represented at the meeting.

Key discussion points:

- Reference systems paper published
- Progress of paper on choosing the metric with which to compare a bioenergy system;
- Consequential LCA book chapter accepted;
- Reports commissioned jointly with Task 43 on albedo and SOC models have been finalised and published on Task 38 and Task 43 websites and reviews were conducted:
- Preliminary study on LCA methodology for wood heating systems,
- EU Commission proposal for new sustainability criteria for bioenergy in EU
- Presentations by members on recent work, other items of interest, country developments;
- Update on international developments: IPCC to prepare a Special report on Climate change and the Land:
- Revision of carbon footprint standard ISO 14067
- Review workplan
- Inter-task projects on Bio-CCUS and Sustainable bioenergy supply chains; and
- Planning for paper comparing Consequential and Attributional Life Cycle Assessment.

Joint Task 38 and Chalmers University on climate impacts of bioenergy systems: Gothenburg (Sweden) 16th May

Task 38 and Chalmers University of Technology co-hosted a workshop on the climate impacts of bioenergy systems, stimulated in part by concerns raised in a recent report by Chatham House: "Woody Biomass for Power and Heat: Impacts on the Global Climate". Climate scientists, energy system modellers and life cycle assessment experts presented their work, and exchanged views on research methods and knowledge gaps. The objectives for the workshop were to advance scientific understanding of the climate effects of bioenergy. Major issues discussed included:

- how bioenergy contributes to the global carbon budget
- short-term vs long-term emission-reduction targets
- how climate effects of bioenergy should be assessed

Task 38 Business Meeting: Angers (France) 6th and 8th November

All six participating countries (Australia, Finland, Sweden, USA, France and Germany) were represented at the meeting.

Key discussion points:

- Future of Task 38;
- Update on current Task papers in preparation, including metrics paper, attributional vs consequential LCA paper, LCA tools harmonisation paper and standard methodology paper;
- Country developments;
- Approaches to modelling biochar systems:
- Planning for workshop with Task 43 on land sector accounting;
- Update on international developments: ISO, IPCC, UNCCD, other; and
- Inter-task projects on Bio-CCUS, Sustainable bioenergy supply chains, including iLUC

Joint Task 38 and Ademe workshop on Understanding Climate Change Effects of Forest biomass and Bioenergy Systems: Angers (France) 7th November

ADEME and Task 38 co-hosted a workshop on "Understanding Climate Change Effects of Forest biomass and Bioenergy Systems". The program included presentations on the mitigation value of forests managed for biomass and other products; use of land clearing biomass for biochar; tools for GHG assessment of biofuels, for LCA of agricultural crops, and for including soil carbon in LCA; and methods to quantify land use change due to bioenergy. Several presentations were based on projects funded by ADEME, and others presented aspects of the Inter-task project "Measuring, governing and gaining support for sustainable bioenergy supply chains".

Next Meeting

The next Task 38 Business Meeting will be held in Sweden in May 2018.

Work Programme

In 2017 the Task:

- Organised three Task 38 face to face business meeting (see above)
- Organised three Task 38 workshops, co-hosted with collaborating organisations (see above)
- Led a response to a report by Chatham House: "Woody Biomass for Power and Heat: Impacts on the Global Climate", published by IEA Bioenergy.
- Published scientific papers:
  - Reference Systems for evaluating climate effects of bioenergy
  - Consequential Life Cycle Assessment: What, how and why
- Progressed scientific papers:
  - Metrics for quantifying the climate effects of bioenergy systems:
- Participated in two Inter-Task projects (Bio-CCUS, "Measuring, governing and gaining support for sustainable bioenergy supply chains")

Scientific Papers

The following two scientific papers are published:

1. Reference systems for evaluating climate effects of bioenergy

   Koponen, K., Soimakallio, S., Kline, K.L., Cowie, A. and Brandão, M., 2017. Quantifying the climate effects of bioenergy–Choice of reference system. *Renewable and Sustainable Energy Reviews*.

   This paper discusses the importance of the reference system in evaluating the climate effects of bioenergy and presents guidance on choosing the most appropriate reference system according to the purpose of the study, with particular focus on the land use reference. A decisions tree is presented to aid researchers and decision-makers in identifying the relevant reference system for their objective.

2. Consequential life cycle assessment

   Brandão, M., Martin, M., Cowie, A., Hamelin, L., Zamagni, A., 2017.Consequential Life Cycle Assessment: What, How, and Why? In: Abraham, M.A. (Ed.), Encyclopedia of Sustainable Technologies. Elsevier, pp. 277–284.

This book chapter published in Elsevier Encyclopedia for Sustainable Technologies provides guidance on conducting consequential life cycle assessment.

The following paper is nearing completion:

3. Metrics for quantifying climate effects of bioenergy

   This paper demonstrates the differences between different metrics used to quantify climate effects of GHG emissions and sequestration. GHG emissions, including those of biomass and bioenergy systems, are traditionally quantified using the cumulative radiative forcing of greenhouse gas emissions (using GWP_{100} to combine impacts of different gases) as the indicator, but other indicators could be used such as global temperature potential or others metrics that take various approaches to differentiating impacts based on timing of emissions and removals. The paper uses three simplified bioenergy systems to illustrate the effects of using different metrics.

LCA methods and models

Several papers are under preparation addressing: (1) tools used in policy implementation for GHG emissions in Europe, United States, and Canada; (2) other environmental impacts for commercial biofuels; and (3) prospective models used in conjunction with technology development evaluation. This work was commenced in collaboration with Task 39 and has been expanded under the Inter-task project "Measuring, governing and gaining support for sustainable bioenergy supply chains".

Inter-task Projects

Measuring, governing and gaining support for sustainable bioenergy supply chains

Annette Cowie and Göran Berndes (Task 43) are co-leading Objective 1, which will provide an overview of calculation methods & tools to assess the sustainability of various biomass and bioenergy supply chains and discuss pros and cons of a global, uniform or harmonised framework. Helena Chum is coordinating the comparison of tools for assessing biofuels. Annette Cowie is assessing the applicability of sustainability criteria to biomass supply chains based on invasive scrub, a common issue in the world's drylands. Miguel Brandão is working with Task 43 members to examine the evidence for iLUC associated with ethanol production in the US.

Website/Communication

Task Website

The Task 38 website (http://task38.ieabioenergy.com/) is the repository of publications and other material produced by Task 38 and predecessor task "Greenhouse Gas Balances of Biomass and Bioenergy Systems".

Information on the site includes:

- publications of Task 38 including statements on timing of emissions, sustainability of bioenergy
- presentations from Task Workshops
- guidance on methods for quantifying greenhouse gas balance of bioenergy systems
- FAQ page
- case studies (identified by both country and process)
- contact details of national team leaders.

Collaboration with Other Tasks

Intertask projects (see above).

Within the inter-Task project "Measuring, governing and gaining support for sustainable bioenergy supply chains" (led by Task 40) Task 38 is co-leading Objective 1, with Task 43, and Task 38 is working with Task 39 to review GHG assessment tools for liquid biofuels.

Task 38 is also contributing to the Bio-CCUS and iLUC projects.

Joint publications:

The following reports were commissioned and published jointly with Task 43:

- **Bernier P and Bright R. – Albedo effects of biomass production: A review**

  This report reviews recent findings on the extent to which changes in albedo can enhance or diminish the climate change benefits of bioenergy. The albedo effect is dependent on the latitude, and the bioenergy system (woody or annual crop, and its management).

- **Stendahl, Repo A, Hammar T & Liski J – Climate impact assessments of forest bioenergy affected by decomposition modelling**

  This report compares the Q and Yasso models, that are used to model decomposition of forest litter. The study found that the choice of the decomposition model results in different quantitative estimates. However, the decomposition model choice does not lead to diverging conclusions about the warming impact of extracting forest residues for bioenergy.

- Annette Cowie worked with Göran Berndes Task 43 and Martin Junginger (Task 40) and Fabiano Ximenes (NSW DPI) to prepare a response to Chatham House report "Woody Biomass for Power and Heat: Impacts on the Global Climate". The response was published by IEA Bioenergy.

- With input from Task 38 and Task 43 members, Task 40 member Uwe Fritsche led preparation of a chapter for the UNCCD's Global Land Outlook:

  Fritsche, U.R., Berndes, B., Cowie, A.L., Dale, V.H., Kline, K.L., Johnson, F.X., Langeveld, H., Sharma, N., Watson, H. and Woods, J., 2017. "Sustainable energy options and implications for land use".

- Resulting from the Task 43/Task 38 study tour conducted in 2016, an opinion piece on the US wood pellet trade:

  Dale VH, KL Kline, ES Parish, AL Cowie, R Emory, RW Malmsheimer, R Slade, CT Smith, TB Wigley, NS Bentsen, G Berndes, P Bernier, M Brandão, H Chum, R Diaz-Chavez, G Egnell, L Gustavsson, J Schweinle, I Stupak, P Trianosky, A Walter, C Whittaker, M Brown, G Chescheir, I Dimitriou, C Donnison, A Goss Eng, KP Hoyt, JC Jenkins, K Johnson, CA Levesque, V Lockhart, MC Negri, JE Nettles, M Wellisch (2017) Status and prospects for renewable energy using wood pellets from the southeastern United States. *Global Change Biology Bioenergy* 9(8) 1296-1305. http://onlinelibrary.wiley.com/doi/10.1111/gcbb.12445/full

- A joint study between Task 43 and Task 38 members:

  Cintas, O., Berndes, G., Cowie, A.L., Egnell, G., Holmström, H., Marland, G. and Ågren, G.I., 2017. Carbon balances of bioenergy systems using biomass from forests managed with long rotations: bridging the gap between stand and landscape assessments. *Global Change Biology Bioenergy*, 9(7), pp.1238-1251.

- Output from the Bio-CCUS joint project:

  Koponen, K. and Hannula, I., 2017. GHG emission balances and prospects of hydrogen enhanced synthetic biofuels from solid biomass in the European context. *Applied Energy*, 200, pp.106-118.

Networking

- Annette Cowie participated in the meetings of ISO TC207 SC7 WG8 revising the standard for Carbon Footprint of a product Angers, France, November 2017 and Halifax, Canada, 2017.

- Intertask project "Measuring, governing and gaining support for sustainable bioenergy supply chains" Workshop 18-19 May, Gothenburg: The 2-day workshop was organised by Task 40, who lead the project. Annette Cowie presented an overview of Objective 1, co-led by Task 38 and Task 43, on tools and methods for assessment of sustainability of bioenergy. In parallel sessions, Annette presented an introductory talk on Understanding the Climate Effects of Bioenergy Systems and Helena Chum presented progress on the study comparing calculators for emissions from biofuels.

- Annette Cowie acted as opponent in the PhD defence of Torun Hammar, Swedish University of Agricultural Sciences (SLU), and met with Johan Stendahl, June, 2017.

- Annette Cowie and Fabiano Ximenes presented a webinar "Native forests: timber production, bioenergy and conservation outcomes" to Bioenergy Australia 21 September 2017.

- Annette Cowie participated in the first lead author meeting of the IPCC Special report Climate Change and Land, Oslo October 2017.
- Miguel Brandão, the Task 38 Manager participated in a symposium on Consequential Life Cycle Assessment and associated workshop on revision of ISO 14040/14044 life cycle assessment standards, Barcelona, November 2017.
- Annette Cowie participated in a panel session on IEA Bioenergy and presented a poster on Task 38 at the Bioenergy Australia conference in November 2017.

Deliverables

Apart from the wide range of deliverables mentioned above, the Task also produced progress reports and audited accounts for the ExCo, and minutes of the Task meetings, and a the "Task focus" section for the IEA Bioenergy December Newsletter. In addition, individual Task members published scientific papers that were informed by interactions with Task members, and some of these outputs were formally reviewed by Task 38 members.

TASK 39: Commercialising Conventional and Advanced Liquid Biofuels from Biomass

Task 39 continues to play a key role in facilitating the commercialisation of liquid biofuels from biomass. While cost competitive production economics remain challenging within a relatively low oil price environment and in the absence of carbon pricing, the past year has seen ongoing progress in the development of advanced biofuel technologies.

The Task actively follows and supports the development of biofuels, and in 2017 increased its focus on biofuels for non-road heavy transport, particularly for the marine sector and especially for the aviation sector, as this is an area where significant industry engagement is happening. The continued use of aviation biofuels (biojet) is tracked on the International Civil Aviation Organisation's (ICAO) Global Framework for Aviation Alternative Fuels website and shows, impressively, that to date 100,000 commercial flights have used some proportion of biojet fuels. While only one commercial facility, AltAir in California, regularly produces biojet fuels (via upgrading of oleaginous feedstocks), five pathways to biojet fuels are now certified under ASTM with more expected to be certified in the future.

The Task also continues to be active in monitoring the technology/commercialisation space, where the crucial role that policy plays, and will continue to play, is increasingly apparent as the world strives to decrease emissions from all transport sectors, especially aviation which is is growing the fastest. The key role and challenge of policy is particularly evident in the international aviation and marine sectors that fall under international jurisdiction, as domestic policies for these sectors can be limited and poorly coordinated with one another. While progress has been made in the various conversion technologies to show the technical ability to produce marine and aviation biofuels from renewable bio-based feedstocks, the right policies

will be essential to advance commercialisation and market penetration of these types of drop-in biofuels. Some of the Task's work in 2017, which will likely continue into the 2019-2021 triennium has been focussed on the opportunities for biofuels in the marine shipping sector and assessing the state of development of drop-in biofuels for marine applications.

Overview of the Task

The goal of Task 39 is to facilitate the commercialisation of liquid biofuels, especially liquid biofuels from biomass, with a focus spanning conventional and advanced technologies, including "drop-in" biofuels and algae-based biofuels. Through a coordinated focus on technology, commercialisation, sustainability, policy, markets and implementation, the Task assists participants in their efforts to develop and deploy biofuels. These biofuels include cellulosic ethanol, biomass-based diesel, renewable aviation fuel ("biojet"), etc., produced through various technology routes such as oleochemical, biochemical, thermochemical and hybrid technologies. It also continues to identify and pursue opportunities for comparative technical assessment and support for policy development. The success of the Task has been, in large part, a direct result of providing a forum for integrated discussions of these topics, aided by the active involvement of participants from industry, government and academia. The Task continues to lead and coordinate activities in three main program areas:

- **Technology and Commercialisation** with a focus to:
  - develop and commercialise improved, cost-effective bio-based processes for the generation of advanced renewable biofuels, particularly "drop-in" biofuels from biomass;
  - work with other IEA Bioenergy Tasks to develop and commercialise improved, cost-effective thermochemical-based processes, such as the Fischer-Tropsch process for converting syngas to synthetic diesel and other advanced biofuels; and
  - understand advancements and challenges in 'next-generation' liquid biofuel technologies, including biomass-to-hydrogen and algae-to-biofuel processes.

- **Policy, Markets, Implementation and Sustainability** encompassing issues that address policy/legislative/regulatory and infrastructure concerns and needs regarding expanding conventional and advanced liquid biofuels; and to provide information and analyses on policies, markets, and implementation issues (including regulatory and infrastructure development) that will help participants foster commercialisation of renewable low carbon liquid biofuels as a replacement for non-renewable fossil-based fuels, by continuing the deployment of conventional (so-called first generation) biofuels and supporting development of advanced (so-called 2nd generation) biofuels and 'future-generation' biofuels.

- A **Multifaceted Communication Strategy** to facilitate knowledge transfer, dissemination of information, outreach to stakeholders, and coordination with related groups both within IEA Bioenergy and externally.

The Task structure allows participants to work together in a comprehensive manner on prioritised issues and challenges identified across the broad area of liquid/transportation biofuels.

Participating countries: Australia, Austria, Brazil, Canada, Denmark, European Commission, Germany, Japan, South Korea, the Netherlands, New Zealand, South Africa, Sweden, and United States of America

Task Leader: Dr Jim McMillan, National Renewable Energy Laboratory, USA

Co-Task Leader: Dr Jack Saddler, University of British Columbia, Canada

Operating Agent: Mr Alex McLeod, Natural Resources Canada, Canada

Task Manager: Dr Susan van Dyk, University of British Columbia, Canada

The Task leadership is shared between the National Renewable Energy Laboratory (USA) represented by Jim McMillan, and the University of British Columbia (Canada) represented by Jack Saddler. Both Task Leaders are engaged in all aspects of the Task's operations. Sub-Task leaders for technology and commercialisation include Antonio Bonomi, Franziska Müller-Langer, Nicolaus Dahmen, Johan van Doesum, Claus Felby, Tomas Ekbom and Steve Rogers. Sub-Task leaders for policy, markets, implementation and sustainability include Warren Mabee, Dina Bacovsky, Timo Gerlagh, Emile van Zyl, Shiro Saka, Jin-Suk Lee, Luisa Marelli and Ian Suckling. The Task leadership is assisted by Susan van Dyk (UBC), who serves as Editor of the Task Newsletter as well as Webmaster for the Task's website. Dina Bacovsky (Austria) manages the Task's demonstration plant database. Franziska Müller-Langer is the Task's primary liaison to IEA's Advanced Motor Fuels (AMF) Technology Collaboration Program (TCP). A National Team Leader (also known as the lead Country Representative) for each country is responsible for coordinating their respective nation's participation in the Task.

For further details on Task 39, please refer to Appendices 2, 4, 5 and 6; the Task website (http://task39.ieabioenergy.com/) and the IEA Bioenergy website (www.ieabioenergy.com) under 'Our Work: Tasks'.

Progress in R&D

Task Meetings and Workshops

Task 39 remains highly active in terms of both business meetings (which involve significant knowledge exchange between participants in the form of Country Reports) as well as special sessions hosted in conjunction with established biofuels-related events. In 2017, the Task held two formal business meetings (Gothenburg, Sweden in May and Brussels, Belgium in September).

The first Task business meeting of 2017 was held in Gothenburg, Sweden on 15 May 2017, in conjunction with the Advanced Biofuels Conference held in Gothenburg, Sweden from 17-19 May. This well attended meeting focused on report updates, review of ongoing progress/meeting deliverables and future planning. It also included presentations from several high profile, local researchers including Professors Goran Berndes (Sustainability of Bioenergy Systems) and Lisbeth Olsson (Biofuels research), both from Chalmers University. Tomas Ekbom, Sweden's national team leader to the Task, presented on Sweden's impressive history of accomplishments in developing biofuels and also its current situation. Michael Persson gave a presentation on bioenergy in Denmark. To try to enhance inter-Task cooperation, Prof. Berndes representing Task 43 discussed potential collaboration projects such as: *how might the nature, amount and sustainability of a biomass resource influence the ease of establishing a biomass-to-biofuels process*? It is hoped that Tasks 39 and 43 will be able to establish joint work in this area in the next triennium.

Task 39 also participated in Sweden's 2017 *Advanced Biofuels Conference* (ABC) held 17-19 May in Gothenburg, organising a session within the conference entitled, "Market and industry perspectives on sustainable biofuels". This session included the following presentations and speakers:

- US progress in the commercialisation of advanced biofuels/cellulosic ethanol. Jim McMillan, National Renewable Energy Laboratory (NREL), USA
- Comparison of biofuel life-cycle GHG emissions assessment tools. The case study of Brazilian sugarcane ethanol. Antonio Bonomi, Brazilian Bioethanol Science and Technology Laboratory (CTBE), Brazil
- Commercial progress in the biomass-to-biojet area. Jack Saddler, University of British Columbia, Canada
- Development and potential of marine biofuels. Claus Felby, University of Copenhagen, Denmark
- Commercialising marine biofuels, a market perspective. Sjors Geraedts, GoodFuels, The Netherlands

Task 39 held its second business meeting of 2017 in Brussels 25-26 September. This also well-attended meeting was generously hosted by the European Commission's (EC) ExCo member Kyriakos Maniatis at the EC's meeting rooms. Twenty-six attendees comprising Task 39 members and visiting guests took part in an stimulating and valuable two days of presentations and discussions about liquid biofuels developments around the globe. This meeting was especially noteworthy and enhanced by the participation of a distinguished visitor/observer delegation, which included representatives from India and China as well as from the Renewable Energy Group (REG), a large North American-based FAME biodiesel and HVO/renewable diesel producer, and $(S\&T)^2$ Consultants, a Canadian life cycle analysis (LCA) modeling consultancy. Indian delegates included Mr. Sandeep Poundrik (Joint Secretary, Ministry of Petroleum and Natural Gas), Dr. Y.B. Ramakrishna (Chair, Biofuels

Working Group, Ministry of Petroleum and Natural Gas) and Dr. Arvind Lali (DBT-ICT, Biofuels Advisor to Ministry of Science and Technology). Dr. Huili Zhang (Professor, Beijing University of Chemical Technology) represented China.

Among the Task's highly informative activities for its membership are annual country report presentations from each participant highlighting and providing insights into recent developments in biofuels production and deployment occurring in Task 39 member countries and also in other important countries like China and India where significant amounts of biofuels are produced and used today and aspirations for expanded production and use are growing. These country report presentations, which included excellent reports on developments in China (by Prof. Zhang) and in India (by Mr. Sandeep and Dr. Lali), took up almost the entire first day of the meeting. This stimulated productive discussion and information exchange between meeting attendees, again demonstrating that these annual country reports remain one of invaluable benefits of Task membership. In this case, the positive momentum for development of advanced biofuels now occurring in both China and India were welcome news to representatives from elsewhere in the world where progress on development and deployment of advanced liquid biofuels has slowed.

The most recent IEA World Energy Outlook projects that China and India will become major global users of transportation fuels as their large economies continue to develop and grow. In coming years, both of these countries will likely play important roles in developing "green" transportation options as their economies and infrastructure are further developed. This is one of the reasons IEA Bioenergy is actively courting both of these countries to join the IEA Bioenergy TCP. We were thus especially honored to have representatives from both India and China as guests/observers at this meeting, actively participating and providing valuable contributions to the Task's deliberations. To build on this encouraging development, Task 39 will hold its next business meeting in Beijing, China, in April 2018, in a further effort to encourage China and India to join IEA Bioenergy and Task 39 for the next triennium (2019-2021).

The Brussels Task 39 business meeting also benefited from the participation of representatives of REG and $(S\&T)^2$ Consultants, especially during discussions on scoping Phase 2 of the Task's on-going LCA model comparison project (in which leading LCA models – GHGenius for Canada, GREET for US, BioGrace for EU, and VSB for Brazil – are being assessed and harmonised). One topic discussed in detail is the accuracy and usefulness of biofuels' LCAs, which vary widely. Greater harmonisation among and confidence in/validation of LCA models is needed. Groups such as REG, $(S\&T)^2$ Consultants, the California Air Resources Board (CARB), as well as LCA expertise within Task 39 membership, are agreed that the public and policy makers need to be confident in the accuracy of LCA models being used to assess the overall "sustainability" of biofuels.

Task 39 also cosponsored an industry session on May 3, 2017 at the 39th Symposium on Biotechnology for Fuels and Chemicals held in San Francisco. This session was entitled, *Progress in the Commercialization of Advanced Biorefineries,* and included the following presentation and speakers.

Presentations and speakers included:

- *Research and deployment of bioenergy production from algae, a state of technology review*. Lieve M.L. Laurens, Melodie Chen-Glasser and James D. McMillan, National Renewable Energy Laboratory, Golden, CO, USA.
- *What is restricting implementation of advanced biorefineries in Scandinavia*? Ola Wallberg, Lund University, Lund, Sweden
- *Using captive fiber to reduce the carbon intensity of 1st gen ethanol processes.* Brandon Emme, Chris Gerken and Jesse Spooner, ICM, Inc, St. Joseph, MO, USA.
- *Problems handling corn stover in pioneer biorefineries and proposed solutions.* Quang A. Nguyen, Neal A. Yancey and Kevin L. Kenney, Idaho National Laboratory, Idaho Falls, ID, USA.
- *Customized enzyme cocktails – A Novozymes update on use of tailored biocatalysts in the first commercial scale biorefineries* Sarah Teter, Novozymes, Inc., Davis, CA, USA.

In addition, on July 12, 2017, Jim McMillan gave an overview presentation on the task at the Bioeconomy 2017 conference held near Washington DC, within the international plenary session "Catalyzing A Global Advanced Bioeconomy" organised and chaired by US ExCo member Jim Spaeth.

The active participation of most country team leaders and representatives at many of the Task 39 meetings is evidence of the value the Task 39 network plays in facilitating excellent international information exchange.

Work Programme

The programme-of-work for the Task included the following elements:

Technical Aspects of Advanced Biofuels

Advanced biofuels remain a topic of key importance for decarbonising the transport sector. The Task continues to focus on cellulosic ethanol production and commercialisation, however production of drop-in biofuels has become a more prominent focus in recent years as conversion technologies have advanced because drop-in fuels offer a direct replacement for petroleum fuels, requiring no changes to infrastructure.

The need for drop-in biofuels is especially relevant in industries such as aviation where no other alternatives to dramatically lowering carbon emissions exist. The Task's "drop-in biofuels report" (Karaztos et al., 2014; available at Task 39 and IEA Bioenergy websites) and ongoing updates to this report – most recently to explore biofuels opportunities in the marine shipping sector – assess the potential and challenges of these advanced biofuels across the whole spectrum of feedstock conversion technology pathways – oleochemical, biochemical, thermochemical and hybrid routes to biofuels. As these technologies develop from research and development through to pilot, demonstration and commercialisation, Task 39 monitors these developments and develops update reports to disseminate information to the biofuels community as an objective observer to give biofuels and transport sector stakeholders, including governments and policy makers, the information and data necessary to support decision-making.

The mounting need for renewable aviation biofuels ("biojet") to reduce emissions in the aviation industry is a specific area that has moved to the forefront internationally. This is driven by voluntary initiatives from aviation organisations, OEMs such as Boeing, as well as by airlines investing in new technologies and entering into offtake agreements for biojet fuels. Task 39 has a critical role in monitoring, evaluating and reporting on developments in this sector, in addition to providing guidance on essential policy to foster and facilitate biojet development and deployment. In addition, the role of biofuels in the international shipping and marine sector has become important as a way of reducing emissions contributed by this industry, which is facing more stringent sulfur emissions regulations going forward. The most recent update to the drop-in biofuels report is a special report on the opportunities for biofuels for marine applications completed during 2017 (Hsieh and Felby, 2017; available at Task 39 website).

Briefs on reports completed or advanced during 2017 follow:

Report on "Biofuels for the marine shipping sector" (Hsieh and Felby, 2017):
The merchant shipping sector is one of the mayor players in world trade, as more than 80% of all goods are transported via international shipping routes. This sector annually consumes more than 330 Mt of fuels and accounts for 2-3% of global CO_2, 4-9% of SOx, and 10-15% of NOx emissions. This report is written for biofuel providers and technology developers with the aim of providing an overview of biofuels opportunities within the shipping sector; the technologies, fuels and regulations associated with the supply and consumption of fuels for marine applications. The different biofuel technologies and their supply potentials are presented and discussed. The report demonstrates that significant opportunities for biofuels exist within this sector. Co-authored by Chia-wen Carmen Hsieh and Claus Felby of the University of Copenhagen and reviewed by Task 39 country representatives, this report was completed in late 2017 and is now available on the Task 39 website.

Survey on Advanced Fuels for Advanced Engines with IEA's Advanced Motor Fuels TCP (AMF): This report surveys the following advanced biofuels/biofuels categories: HVO, FT fuels, DME, OME, methanol, lignocellulosic ethanol, Bio-LNG and LBG. The report examines the fuel properties of these advanced biofuels, chemical reactions among advanced fuel components and additives, and known health and toxicity effects. The final draft of the report has been reviewed and at the time of this writing the authors are incorporating the final edits into the report. This report is expected to become available to the public during 2018.

The Task also published some of the work from the drop-in biofuel report in a peer reviewed journal: (S. Karatzos, J.S. van Dyk, J.D. McMillan, J. Saddler (2017) Drop-in biofuel production via conventional (lipid/fatty acid) and advanced (biomass) routes. Part I – Biofuels, Bioproducts and Biorefining). (View online at Wiley Online Library (wileyonlinelibrary.com); DOI: 10.1002/bbb.1746; Biofuels, Bioprod. Bioref. (2017). Part II of this review, now in early draft, focuses on the potentials for refinery integration and co-processing of bio-based intermediates into petroleum refinery operations.

The Task continues to update its database of advanced biofuels production facilities (http://demoplants.bioenergy2020.eu/), and on-going activity led by Dina Bacovsky, Austria's national team leader. This demoplants database provides up-to-date information on over 100 companies' biofuels production facilities, which encompasses a wide variety of biochemical, thermochemical, and hybrid conversion approaches to producing biofuels. It remains difficult to obtain and maintain detailed and accurate, up-to-date information from many of the companies as their various processing technologies scale up and approach commercialisation. It remains particularly challenging to closely follow the development of production facilities in countries such as China and India that are not (yet) part of the IEA Bioenergy network. This is part of the motivation for the Task's ongoing efforts to recruit these countries to join the IEA Bioenergy TCP.

Policy, Regulatory, Infrastructure and Sustainability Issues of Biofuels

The overall objective of this component of the Task is to provide governments and policy makers with information that will help them identify and eliminate non-technical barriers to deploying liquid biofuels. The Task continues to compile country-specific information on biofuels development such as biofuels usage, regulations and regulatory changes, major changes in policies affecting the development, deployment or use of biofuels, and related items. At at least one Task business meeting each year, time is allocated for country representatives to present updates on developments in their respective countries or regions. Country report presentations along with the meeting minutes and other presentations from these business meetings are posted in the 'members only' section of the Task website. The Task's periodic "Implementation Agendas" report update compiles all of the country specific information into a single document and documents recent trends in policy development, including compare and constrast of policy effectiveness in different global regions. This report is substantially updated and revised at least once per triennium. Through this effort, the Task maintains its role as a central source of relevant policy and regulatory information on biofuels.

Policy plays a key role in advancing (or hindering) the development and deployment of biofuels globally, and lack of stable policy in recent years has had a large detrimental impact on investment in and expansion of the industry. It is also clear that the aviation industry represents a unique sector as a highly international industry and will require a different policy approach to support development of biojet fuels. As biojet fuel is the only long-term solution for the aviation industry to meet its emission reduction targets, establishing a stable, commercial supply of biojet volumes has become imperative. However, even as technologies continue to develop and mature, strong policies at national and international levels will be essential to achieve this important objective.

Biofuels can play an important role in reducing emissions from transportation (air, marine and road transport) to meet long-term climate goals. However, not all biofuels offer the same emissions reduction potentials and the analysis of emission reduction potential of different feedstock and technology combinations has become vital to accurately assess the carbon intensity and sustainability of biofuels. However, lack of standardisation of assessment methodologies hampers this area. While many life cycle analysis (LCA) models are available, they often give substantially different results for the same scenario or quite similar scenarios, and the Task's on-going work (joint with Task 38) in comparing LCA models and providing reliable information on emission reduction potential forms an essential component of the Task's current trienneium plan of work. In 2016-2017, the Task initiated work to systematically compare and harmonise leadling LCA models being used in the EU and Americas via a multiple phase project being led by Antonio Bonomi, Brazil's national team leader. Phase 1 of this project, which focused on assessing models for commercial ethanol production in the Americas and EU, was completed in 2017; peer-reviewed publications documenting this work are forthcoming. Phase 2 of the project will focus on assessing models for commercial production of biodiesel (FAME) and renewable diesel production in the Americas and EU, with completion targeted for later in 2018.

Newsletter

The Task published three newsletters in 2017 (Issues #45-47), profiling biofuels developments in Korea, China, and Africa respectively. These newsletters provide information about Task activities and international events related to biofuels. The newsletter has an active distribution list of about 2,000 individuals worldwide and copies are routinely downloaded from the Task website. The country (or continent) specific feature article in each newsletter provides a unique source of information to biofuel stakeholders worldwide and we regularly receive requests for permission to republish these reports in other magazines e.g. Oils and Fats.

Website

The Task continues to build its influence within the international community working in the liquid biofuels arena. The Task's website is visited regularly and routinely receives enquires that are typically handled by the Task coordinators and webmaster, or referred to experts within the Task 39 network. Specific website statistics are reported in the Progress Reports submitted to ExCo.

Collaboration with Other Tasks/Networking

The Advanced Fuels in Advanced Engines project is a collaboration with IEA AMF and the next phase of the Comparison of GHG Models for Advanced Biofuels project is being carried out in conjunction with Task 38. Task 39 also has and will continue to collaborate with IEA HQ in updating relevant IEA reports. Task 39 also works with the International Renewable Energy Agency (IRENA) on reviewing of reports that are relevant to our expertise.

Deliverables

The deliverables for the Task in 2017 included: organisation of two business meetings during the year; two bi-annual progress reports and audited financial accounts (submitted to ExCo); development and maintenance of the Task 39 website; three newsletters; the update to the Task 39 Advanced Biofuel Demonstration Database; a completed report on "Biofuels in Marine and Shipping"; and completion of a final draft of the "Advanced Fuels in Advanced Engines" survey report. The full library of Task reports, country specific reports, etc. are available through the Task website (http://task39.ieabioenergy.com). These are detailed in the Appendix.

TASK 40: Sustainable International Bioenergy Trade: Securing Supply and Demand

Overview of the Task

There is increasing need to develop biomass resources and exploit biomass production potentials in a sustainable way and to understand what this means in different settings. In 2011, the European Commission started to stimulate the further development of the biobased economy[1], which has shown promising developments in the last four years, in particular investments in technological innovation in several member countries. However, more efforts still need to be made in the establishment of European standards and the related certification of biobased products. The UNFCCC Conference of the Parties, or COP 21

1 http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52012DC0060&from=EN

has come up with historical decisions[2] to reaffirm the goal of limiting global temperature increase to well below 2 degrees Celsius and to establish binding commitments by all parties to make nationally determined contributions as well as to pursue domestic measures aimed at achieving them. The European Union (EU) has committed at the end of 2016 to cut GHG emissions by at least 40% by 2030[3] (from 20% in 2020) while modernising the EU's economy and delivering jobs and growth for all European citizens as well as achieving global leadership in renewable energies.

In view of these perspectives, biomass markets have possibilities to grow, although, they are still immature and vulnerable. Many biomass markets, e.g. solid biofuels, rely on policy support and incentives. Currently, negotiations are ongoing in the EU between parliament, council and commission on the sustainability requirements of various forms of bioenergy. The outcome of these negotiations will to a large extent determine the future of biomass deployment in general, and also affect the possibilities to trade biomass internationally. At the same time, a recent meta-analysis of scenarios of integrated assessment models (co-authored by Task 40 members[4]) shows that substantial deployment and trade of both solid and liquid biomass will be required to meet stringent targets to limit global temperature increase to below 2 degrees. Therefore, it is important to develop both supply and demand for biomass, and energy carriers derived from biomass, in a balanced way and to avoid distortions and instability that can threaten much-needed investments in biomass production, and infrastructure and conversion capacity. Understanding how this is best organised and managed needs further investigation. International biomass markets (industrial and residential) have been mapped and assessment of technological development and policy effects has also been carried out by Task 40. The analyses, statistics, and modelling exercises undertaken so far still have some limitations.

The core objective of the Task is 'to support the development of a sustainable, international, bioenergy market, recognising the diversity in resources, and biomass applications'. Developing a sustainable and stable, international, bioenergy market is a long-term process. The Task aims to provide a vital contribution to policy making decisions by market players, policy makers, international bodies, and NGO's. It does this by providing high quality information and analyses, and overviews of developments. It will also provide a link between different sectors, and act as a clearing-house for information through targeted dissemination activities.

The Task Leaders direct and manage the work programme. National Team Leaders from each country are responsible for coordinating the national participation in the Task.

2 http://newsroom.unfccc.int/unfccc-newsroom/finale-cop21/

3 https://ec.europa.eu/transparency/regdoc/rep/1/2016/EN/COM-2016-707-F1-EN-MAIN.PDF

4 Vassilis Daioglou, Matteo Muratori, Patrick Lamers, Shinichiro Fujimori, Alban Kitous, Martin Junginger, Etsushi Kato, Alexandre C. Koberle, Florian Leblanc, Silvana Mima, Marshal Wise, Detlef van Vuuren (2018). Implications of climate change mitigation strategies on international bioenergy trade. Paper submitted to climatic change, forthcoming.

Participating countries: Austria, Belgium, Denmark, Finland, Germany, Italy, the Netherlands, Sweden, United Kingdom, and USA.

Task Leader (Scientific): Professor Martin Junginger, Copernicus Institute of Sustainable Development, Utrecht University, the Netherlands

Task Leader (Industry): Mr Peter-Paul Schouwenberg, RWE Generation, the Netherlands

Secretary: Ms Thuy Mai-Moulin, Copernicus Institute of Sustainable Development, Utrecht University, The Netherlands

Operating Agent: Ir Kees Kwant, RVO, The Netherlands

For further details on Task 40, please refer to Appendices 2, 4, 5 and 6; the Task website (http://task40.ieabioenergy.com/) and the IEA Bioenergy website (www.ieabioenergy.com) under 'Our Work: Tasks'.

Progress in R&D

Task Meetings and Workshops

The Task organised two Task meetings in 2017: Task 40 meetings were held in Copenhagen in May and in London in October respectively. The meeting programme, study reports and updates are provided at the dedicated page for Task 40 members under Task 40 website http://task40.ieabioenergy.com/.

Future Meetings and Workshops

On 12-13th March 2018, Task 40 will organise an internal meeting in Brussels, Belgium. At the end-of-triennium IEA Bioenergy conference, Task 40 will have another Task meeting in San Francisco in early November 2018. On the 7th November, IEA Bioenergy will organise a conference with the involvements of all committed Tasks. Task 40 is proposed to lead sections 1 and 3 (with contributions from other Task members of 38 and 43) on Biomass mobilisation & sustainability governance. In addition, Task 40 members are –as part of the inert-task project on sustainable bioenergy supply chains – organising workshops at two conferences in April and May 2018, both in Copenhagen. We are also currently still exploring the option to organise a short session to inform members of the European parliament about the work of Task 40 on biomass sustainability.

Work Programme and Outputs

As outlined in the 2013-2015 work programme, the core objective of the Task is: 'to support the development of sustainable, international bioenergy markets and international trade, recognising the diversity in resources and biomass applications'. The work programme in the 2016-2018 period consists of the following five topics:

1. Mobilisation of sustainable biomass resources for the international market across different regions in the world.
2. Analysis of the future market demand for biomass from the broader biobased economy perspective.
3. Sustainability and certification.
4. Support of business model development for biomass supply and value chains.
5. Assisting the development and deployment of advanced analysis tools to improve the understanding of potential future market developments, implications and impacts of policies.

Regarding the budget, Task 40 has received a higher budget than originally anticipated (as a result of a higher number of countries participating in the Task). The current budget is distributed to carry out the on-going and proposed studies. The 2017 budget closure has a surplus of about $186,000. However, a large part of this budget will be earmarked for the Inter-tasks Sustainability project in 2018.

In 2017, the Task has participated in two IEA Bioenergy webinars and published two reports. The webinars *The European Wood Pellet For Small-Scaling Heating* and *The Hotspots of the Global Wood Pellet Industry and Trade 2017* have reached a broad audience and received positive feedbacks from stakeholders attending the events. The two published reports are *Socio-economic assessment of forestry production for a developing pellet sector: The case of Santa Catarina in Brazil* and The *Global Wood Pellet Industry and Trade Study 2017*. All reports and webinar presentations are available for free download from the Task 40 website http://task40.ieabioenergy.com/.

Report: Socio-economic assessment of forestry production for a developing pellet sector: The case of Santa Catarina in Brazil.

Improvement of socio-economic conditions is a relevant goal for the further development of biomass and bioenergy production and trade. The production of woody biomass depends mostly on forestry related sectors. This report assesses the forestry sector in a part of Brazil, which has grown strongly and shows positive socioeconomic developments, explained by the close relationship between the forestry industry and the local communities. Selected criteria, index and indicators to assess the socio-economic impacts were applied in a selected region in Santa Catarina, Brazil. Data was gathered from industry and government sources and combined with primary data gathered from in-depth interviews and visits to the region. The results show that in Santa Catarina, there is availability of resources from the forestry production, but the pellet production sector is yet only developing and mainly for regional

use. From a socio-economic point of view, the research has shown that the wood and forest sector plays a crucial role in the Lages region, through jobs and income creation, by contributing to local GDP, and other multiplier effects on the local economy.

Report: Global Wood Pellet Industry and Trade study 2017

The *Global Wood Pellet Industry and Trade study 2017* provides a comprehensive overview of wood pellet markets in over 30 countries, providing information on regulatory frameworks, production capacities, consumption and price trends, trade, logistics and country specific standardisation aspects. The global wood pellet market has increased dramatically since 2011, with an average increase rate of 14% per year. New countries have entered the market for both pellet production (such as those from South-East Europe) and pellet consumption (such as East Asia). Also the global wood pellet trade increased. Intercontinental flows are dominated by the trade relation between the U.S. and the UK, while the non-industrial use is still mainly an intra-European business.

On-going and New Topics (2017-2018)

The projects listed below are all currently ongoing and will be finalised over the course of 2017 or in early 2018.

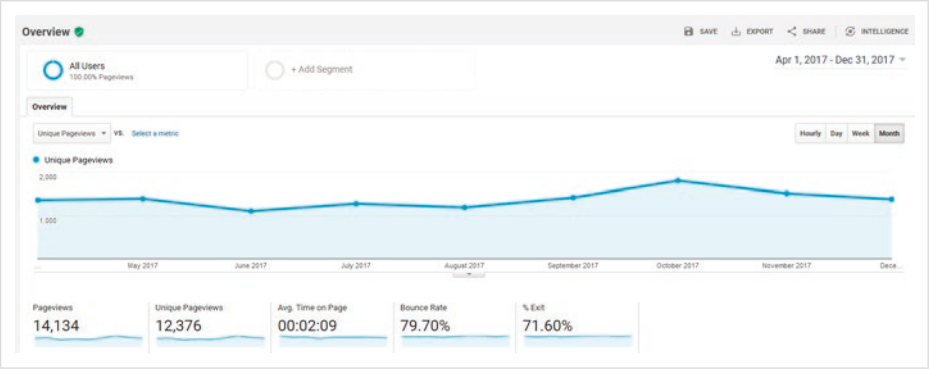
- ***Socio-economic assessment of the US supply chains of imported biomass (pellets) to the EU:*** The EU objectives to reduce emissions under the Renewable Energy Directive (RED) (EC, 2009) and the objectives of pushing forward the green economy in the EU have indicated that biomass exports for electricity, heat and biomaterials is expected to increase in the next 20 years. There are only a few studies conducted to better understand the socio-economic implications of biomass production and use for specific supply chains feeding the European market and, in particular, assessing the impacts on smallholders or on communities. To tackle this knowledge gap, this report proposed to conduct a detailed assessment of socio-economic impacts of the biomass production and conversion supply chain with the EU biomass market target. Two case studies have been developed: one for Brazil, a potential supplier of solid biomass, and the other for the US, which is the largest exporter to the EU. The Brazilian case study has already been published and the US case study will be soon finalised. A framework to conduct the study had been developed and an assessment of the socio-economic impacts based on previous work was conducted by the researchers.
- ***Transboundary flows of biomass waste streams:*** Martin Junginger, Daniela Thrän, Olle Olsson, Jussi Heinimö and the MSc student Pranav Dadhich have written the report investigating how much solid (biomass) waste feedstock is being transported for energy purposes around Europe in the years of 2010-2015, and the underlying drivers, incentives and implications. Currently the report is being further developed and a future outlook is considered. Also the current country-specific sections need to be further reviewed. The final report is planned to be published in mid 2018.

- *Global biomass trade for energy:* Svetlana Proskurina has led an effort to update global biomass trade statistics, which has resulted in two scientific publications in the journal BioFPR (accepted for publication in 2018) with Task 40 co-authors Martin Junginger and Jussi Heinimö. The two papers deal with 1) statistical and methodological considerations and 2) production and trade streams of wood pellets, liquid biofuels, industrial roundwood and emerging energy biomass.

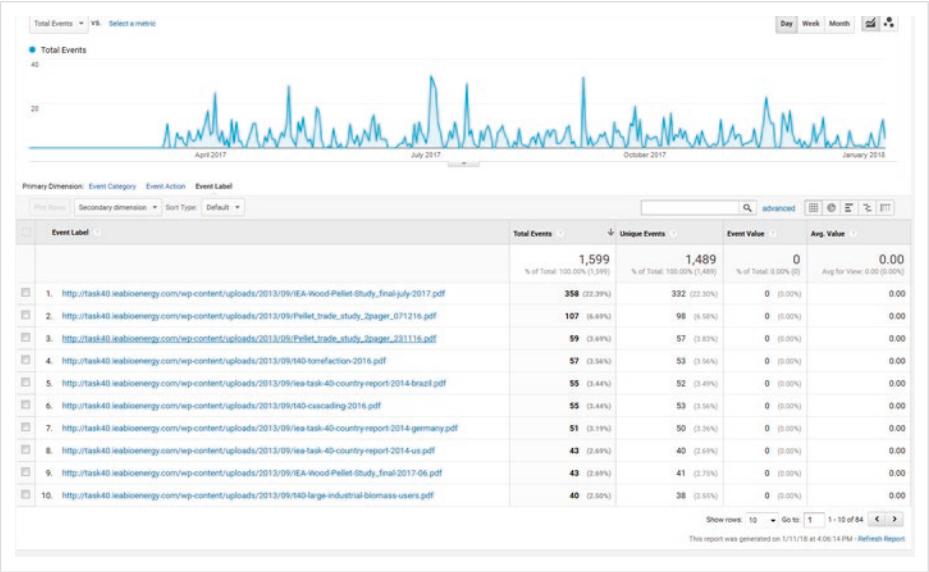
Task 40 members are also preparing a final proposal for a study on the marginal potential for long-term sustainable/viable wood pellet supply chains. This study will be carried out over the course of 2018.

Website

The website http://task40.ieabioenergy.com/ has been officially launched since September 2016 and it is now under the management of IEA Bioenergy organisation. The trademark bioenergytrade.org is planned to be retained in the upcoming 10 year period. The Task website is a key tool for dissemination of information. In 2017, the average number of unique visitors was about 1,400 per month, similar to the number of visitors in the previous years.



Regarding the top downloaded 10 documents, the updated **Global Wood Pellet Industry and Trade Study 2017** is ranked the top report of the Task 40 readers. The top 10 downloads in 2017 (until 31 December) are presented below and it can be concluded that Task 40 readers are interested by Task studies on biomass trade and technological development for processing biomass.



Collaboration with Other Tasks/Networking

Collaboration with both IEA Bioenergy Tasks and external partners is important, therefore the Task has been continuing this effort in 2017. The Intertask Sustainability project has been running since January 2016 with various IEA Bioenergy Tasks including Task 40 members. Under the lead of Task 40, this InterTasks project has brought together and synthesises part of the work done by the individual Tasks. Preliminary results of the InterTasks were presented in an international workshop in Gothenburg, Sweden in May 2017. Final results of the Intertask will be presented in an international conference in San Francisco in November 2018 and several other conferences. Also, a high number of scientific articles have already been published as project outcomes.

Deliverables

Deliverables in 2017 included two webinars, two main reports, one newsletter (circulation to 1500 subscribers), minutes from two Task meetings, two progress reports and audited accounts to the ExCo. These are detailed in Appendix 4.

TASK 41: Bioenergy Systems Analysis

Overview of the Task

The objective of the Task is to supply various categories of decision makers with scientifically sound and politically unbiased analyses needed for strategic decisions related to research or policy issues. The target groups are particularly decision makers in Ministries, national or local administrations, deploying agencies, etc. Depending on the character of the projects some deliverables are also expected to be of direct interest to industry stakeholders. Decision makers, both public and private, have to consider many aspects, so the Task needs to cover technical, economic, and environmental data in its work. The Task's activities build upon existing data, information sources, and conclusions. It does not intend to produce new primary scientific data.

The Task differs from the other Tasks in that it does not have networking as one of its prime objectives, nor do the Task's activities have continuous and repeating components, e.g., biannual meetings, country updates, etc. The work programme has a pronounced project emphasis with each project having very specific and closely defined objectives. Because of its special character in terms of participation, financing and cross-cutting orientation, the Task aims to be a valuable resource and instrument to the ExCo serving the ExCo with highly qualified resources to carry out projects, involving several parties (e.g., other Tasks and organisations) as requested by the ExCo. Due to the close contact with the other Tasks, Task 41 is intended to develop into a platform for joint Task work and a catalyst for proposals from the Tasks to the ExCo.

A project leader directs and manages the work of each project. For new projects an appropriate project leader is appointed by the project participants acting through the Executive Committee. The ExCo Member from each participating country acts as the national Team Leader and is responsible for coordinating national input to the projects undertaken.

For further details on Task 41, please refer to Appendices 2, 4 and 5; and the IEA Bioenergy website www.ieabioenergy.com under 'our Work: Tasks'.

Work Programme

The work programme is comprised of a series of projects. Each project has its own budget, work description, timeframe, and deliverables and is approved by the participants. The focus is on the needs of the participants by way of project outputs. Four projects were active in 2017 as follows:

Project 5: Bio-CCS and Bio-CCUS in Climate Change Mitigation

This two-year special project has been set up in order to fully define concepts of Bio-CCS and Bio-CCU, and to define their realistic significance in the medium and long term. Two workshops were held in 2016 and one was held in 2017 (http://task41project5.ieabioenergy.com/iea-publications/). One final workshop will be held in 2018 prior to project completion with a final report.

Participating countries: The European Commission, Finland, The Netherlands and Norway

Status: Expected completion in 1st quarter of 2018

Project 6*:* Bioenergy in balancing the grid and providing storage options

This project aimed to identify those areas in the grid system where bioenergy in balancing the grid and providing storage options could play a strategic role, and to promote the commercialisation of a diverse set of such bioenergy applications and processes. In addition, it sought to identify and disseminate sound business models for practical, cost-effective and environmentally friendly ways to facilitate the transformation of the electricity grid based to a large extent on bioenergy technologies.

Participating countries: The European Commission and Finland

Status: The project has been completed with the publication of a final report in February 2017 – see http://www.ieabioenergy.com/publications/bioenergys-role-in-balancing-the-electricity-grid-and-providing-storage-options-an-eu-perspective/

Project 7*:* Bioenergy RES Hybrids

This one-year project (http://task41project7.ieabioenergy.com/iea-publications/) looked at some of the ways that bioenergy could be integrated with other renewable energy sources to achieve one or more of flexible generation, flexible storage of variable renewable energy (VRE) and increased overall efficiency of biomass use. The project developed a series of key findings for domestic applications, utility scale and district heating and cooling networks, industry and farm scale applications.

Participating countries: Austria, the European Commission, Finland and Germany

Status: The project has been completed with the publication of a final report in April 2017 – see http://www.ieabioenergy.com/publications/integrated-bioenergy-hybrids-flexible-renewable-energy-solutions/

Project 8: Bioenergy Roadmap 2017

This one-year project involved the development of a roadmap on Bioenergy of the IEA Secretariat and the IEA Bioenergy Technology Collaboration Programme. The aim was to produce a single roadmap encompassing bioenergy for transport, heat and power. This would allow a holistic approach taking account of the fact that some of the key issues around feedstock availability and sustainability were relevant for all sectors.

Participating countries: European Commission and The Netherlands

Status: The project has been completed with the publication of a final report in November 2017 – see http://www.ieabioenergy.com/publications/technology-roadmap-delivering-sustainable-bioenergy/

TASK 42: Biorefining in a Future BioEconomy

www.iea-bioenergy.task42-biorefineries.com

Overview of the Task

Biorefining in the Circular Economy & BioEconomy

Biorefining, the sustainable processing of biomass into a range of marketable biobased products and bioenergy/biofuels, is an innovative and efficient approach to use available biomass resources for the synergistic co-production of power, heat and biofuels alongside food and feed ingredients, pharmaceuticals, chemicals, materials, minerals and short-cyclic CO_2.

The Circular Economy is defined as an economy that is restorative and regenerative by design, and which aims to keep products, components and materials at their highest utility and value at all times, distinguishing between technical and biological-cycles [Ellen MacArthur Foundation]. The Circular Economy mainly focuses on the efficient use of finite resources and ensures that these resources are reused as long as possible. Biorefining is one of the key enabling strategies of the Circular Economy, closing loops of raw biomass materials (re-use of agro-, process- and post-consumer residues), minerals, water and carbon. Therefore, biorefining is the optimal strategy for large-scale sustainable use of biomass in the BioEconomy. It will result in cost-competitive co-production of food/feed ingredients, biobased products and bioenergy combined with optimal socio-economic and environmental impacts (efficient use of resources, reduced GHG emissions, etc.).

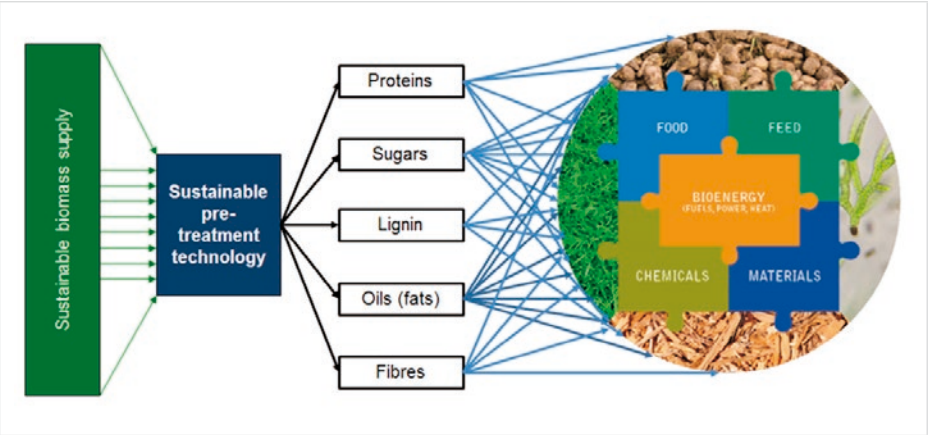


Figure 1. Bioenergy and biorefining being the lubricating oil of the Bio(based)Economy[5] as part of the overall Circular Economy [IEA Bioenergy Task42].

Biorefineries – current status and expected developments

Biorefining is not a fully new approach. Thousands of years ago the production of vegetable oils, beer and wine already required pre-treatment, separation and conversion steps; whereas paper production started around 100 AD. Industrial conventional biorefineries are currently still mainly found in the food and paper sectors.

Within recently constructed biorefineries, bioenergy/biofuel based facilities are more common. In these, heat, power and biofuels are the main products, and both agro and process residues are used to produce additional biobased products. In product based biorefineries, higher-value food and feed ingredients, pharmaceuticals, chemicals, fibrous materials (e.g. pulp, paper) and/or fertilisers are the main products, with low-quality agro and process residues used for the production of bioenergy and less commonly, biofuels. Product based biorefineries are mainly found in the food, feed and dairy, and pulp and paper industries at the current time.

Assessing the number of biorefinery facilities currently in operation globally is challenging. However, over 100 commercial, demonstration and pilot facilities have been identified in the participating countries (www.task42.ieabioenergy.com); whereas in 2017 over 220 facilities have been identified Europe-wide by Nova Institut (GER) and the European Biobased Industries Consortium (more information, see: www.biconsortium.eu).

5 BioEconomy (BE): An economy that encompasses the production of renewable biological resources and their conversion into food, feed, fibres, materials, chemicals, fuels, energy and minerals through efficient and innovative technologies [European BioEconomy Alliance]. The Biobased Economy (BbE) is the BE without the food/feed sectors.

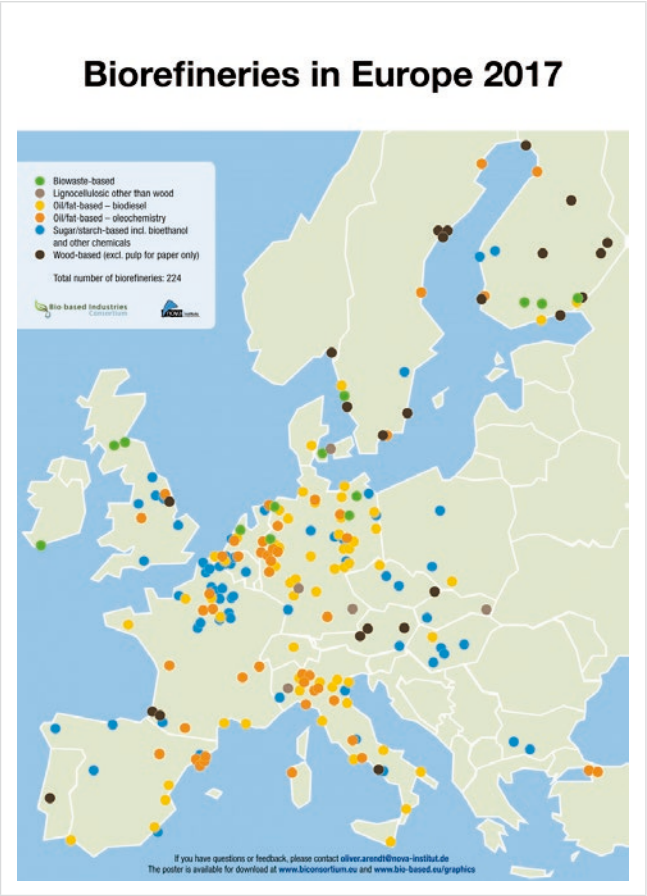


Figure 2. Biorefineries in Europe 2017 [Nova Institute/BIC, 2017].

It is expected that within the next 10-20 years the use of biomass for non-food/feed applications will shift from an energy to a more product-based approach. However, over the longer-term part of the biomass resources is still expected to be used for the production of advanced biofuels for transport (heavy duty road transport, aviation and shipping).

In the short-term (up to 2025) advanced biorefineries may be introduced in a variety of market sectors, mainly by means of upgrading of existing infrastructures, reducing both initial investment costs and the time-to-market. Bioenergy will play both an initiating and central role for the market deployment of these advanced biorefineries:

- Certified sustainable biocommodities that are now being developed and mobilised for energy applications in the mid/longer-term will also be available as raw materials for the biorefinery facilities ensuring sustainable biomass supply.

- Industrial bio-transportation fuel production facilities and digestion facilities can be further upgraded to integrated biorefineries co-producing fuels and added-value biobased products to optimise their overall sustainability, i.e. increase their financial market competitiveness.
- Low-quality value chain residues, i.e. residues that cannot be reused for added-value applications in an economically attractive way, like agro-residues, process residues and post-consumer residues, will be used for bioenergy production.

A portfolio of new biorefining concepts – i.e. whole crop biorefineries, lignocellulosic feedstock biorefineries, oleo-chemical biorefineries, green biorefineries, thermochemical biorefineries, micro and macro algae (marine) biorefineries and next generation hydrocarbon biorefineries – is currently being developed. These concepts are expected to be implemented into the market in the medium-term (2025-2030). However, the current economic conditions (low oil price, credit crisis, recessions in part of the world) might cause severe delays in their market deployment.

A very important non-technical barrier for the market deployment of product-based biorefineries is the availability of sufficient amounts of sustainable biomass resources. Product-based biorefineries can accelerate their market deployment by using both the certification expertise and logistical infrastructures that are currently being developed and set-up for the use of sustainable biobased commodities for energy purposes.

Towards 2050, the portfolio of product based biorefinery concepts could expand further. Lignocellulosic feedstock, herbaceous (green), oleo-chemical and marine (microalgae and seaweeds) biorefineries may enter the market. However, expansion will require further technology development as product-based biorefinery facilities are generally less technically mature than bioenergy/biofuel alternatives. In addition, current policy support is more favourable towards bioenergy and biofuels than the production of biobased products. As such, facilitating the market development of product-based biorefineries is likely to require more widespread policy frameworks to support biobased products.

However, since such materials are generally higher-value products than bioenergy and biofuels, expanding markets for biobased products will be a key factor in product-driven refinery expansion. Initiatives to support industry development include: a Biorefineries Roadmap in Germany in 2012, a Strategic Biomass Vision 2030 in the Netherlands, and ongoing funding for innovative biorefinery projects from the US Department of Energy (DOE). Deployment in Europe should be boosted by the Bio-Based Industries Joint Undertaking, a partnership between the European Union and the private sector to invest USD 4.1 billion in innovative technologies and biorefineries to produce biobased products from biomass wastes and residues. In addition, the European Commission's Circular Economy package includes biomass and biobased products as a priority sector and outlines the promotion of support to innovation in the BioEconomy.

Bioenergy markets will play a central role in facilitating the growth of product based biorefineries through the development of sustainability certification processes and biomass fuel and feedstock supply chains. In addition, biofuel and biogas plants offer potential for upgraded and integrated biorefineries co-producing fuels and added-value biobased products, with such facilities benefiting from diversified product streams and increased market competitiveness. Furthermore, even in the context of wider deployment of product based biorefineries, lower-value biomass feedstock, such as agricultural and post-consumer residues that are less suitable for economic biobased product manufacture are likely to remain destined for bioenergy markets.

Aim of IEA Bioenergy Task 42 – Biorefining in a future BioEconomy

The aim is to facilitate the commercialisation and market deployment of environmentally sound, socially acceptable, and cost-competitive biorefinery systems and technologies, and to advise policy and industrial decision makers accordingly. Task42 provides an international platform for collaboration and information exchange between industry, SMEs, GOs, NGOs, RTOs and universities concerning biorefinery research, development, demonstration and policy analysis. This includes the development of networks, dissemination of information, and provision of science-based technology analysis, as well as support and advice to policy makers, involvement of industry, and encouragement of membership by countries with a strong biorefinery infrastructure and appropriate policies. Gaps and barriers to deployment will be addressed to successfully promote sustainable biorefinery systems market implementation.

Challenges to be tackled

- Develop industry legitimacy, including social acceptance and a level-playing field, for sustainable biomass use.
- Global sustainable biomass sourcing and development of an international trading market, incl. the development of biocommodities.
- Internalisation of externalities (CO_2-price).
- Multi-sectorial stakeholder involvement in the deployment of sustainable value chains, incl. industrial symbiosis of full sustainable biomass use for Food and Non-food, and improved communication (still separate languages food/non-food and cultivation/processing).
- Technology development and biorefinery scale-up using best practices, i.e. for lignocellulosic-based biorefineries, herbaceous and aquatic biomass based biorefineries, protein-based biorefineries, food/non-food flexible biorefineries, mobile/decentralised biorefineries, integral Bio Industrial Complexes, etc.
- Unlock available expertise and industrial infrastructure energy/fuel, agro/food, material and chemical manufacturing sectors.
- Standardisation/regulation of biobased products (BBPs).
- Develop the necessary human capital by training students and other stakeholders to become the biorefinery experts of tomorrow

Task data

The Task Leader directs and manages the work programme. A National Team Leader from each country is responsible for coordinating the national participation in the Task.

Participating countries: Australia, Austria, Canada, Denmark, Germany, Ireland, Italy, The Netherlands, and the USA.

Task Leader: Dr Ing René van Ree, Wageningen Food and Bio-based Research, The Netherlands.

Assistant Task Leader: Dr Bert Annevelink, Wageningen Food and Bio-based Research, The Netherlands.

Operating Agent: Ir Kees Kwant, NL Enterprise Agency, Ministry of Economic Affairs, the Netherlands.

For further details on Task 42, please refer to Appendices 2, 4, 5 and 6; the Task website (www.task42.ieabioenergy.com), and the IEA Bioenergy website (www.ieabioenergy.com) under 'Our Work: Tasks'.

Task Meetings & Workshops

22nd Task 42 Progress Meeting – Gothenburg, Sweden

On the 15th of May 2017 the Task 42 NTLs met in Gothenburg, Sweden, for their 22nd Progress Meeting. All country reports and other presentations of the Task 42 Progress Meeting can be found on the Task 42 website.

Figure 3. NTLs at work @ Task 42 Progress Meeting in Gothenburg, Sweden

Workshop "The role of industrial biorefineries in al low-carbon economy" – Gothenburg, Sweden

This workshop was organised on the 16th of May by the Technology Collaboration Programmes IEA Bioenergy Task 42 and IEA IETS, and hosted by Chalmers University of Technology and the Swedish Energy Agency. The workshop covered both strategic biorefinery developments and how to overcome deployment barriers. All workshop introducing slide-decks are available for downloading at the website of Task 42.

Figure 4. Joint IEA Bioenergy Task 42/IETS workshop on Industrial Biorefineries in Gothenburg, Sweden

The results of the Workshop were reported on by the Technical Coordinator of IEA Bioenergy in cooperation with IEA IETS, and the coordinator of Task 42, and the final report is available at the Task 42 website. The major messages resulting from this workshop are:

1. IEA scenario calculations have shown that efficient and sustainable use of biomass will be the key driver to reach 2050-2060 GHG-emission reduction targets, and the uptake of biorefineries at industrial level will be required to achieve this.
2. Co-production of biobased products and bioenergy by industrial symbioses can have the highest impact on both meeting the climatic goals and economic growth.
3. Both governmental facilitation, communication and education will be needed to support large-scale market deployment.

Figure 5. Summary results workshop "The role of industrial biorefineries in a low-carbon economy" available for downloading at www.task42.ieabioenergy.com

Workshop "The role of bioenergy in the Circular Economy (CE) (incl. the BioEconomy)

Task 42 organised this workshop, which was held on 27 September 2017 in Brussels, Belgium.

Figure 6. Representatives international organisations at work @ workshop.

Task 42 invited IEA Bioenergy, FAO, OECD, EERA Bioenergy, ETIP Bioenergy, IRENA, JRC, and DOE to inform each other on: running and planned activities in the field mentioned, to analyse cooperation opportunities to be able to use available (financial) resources as efficiently as possible, and to come-up with results that will have broad support, to define one/more joint activities to be performed in the coming year(s), and to organise a joint dissemination event to communicate our views/results to a wider public (side event international conference).

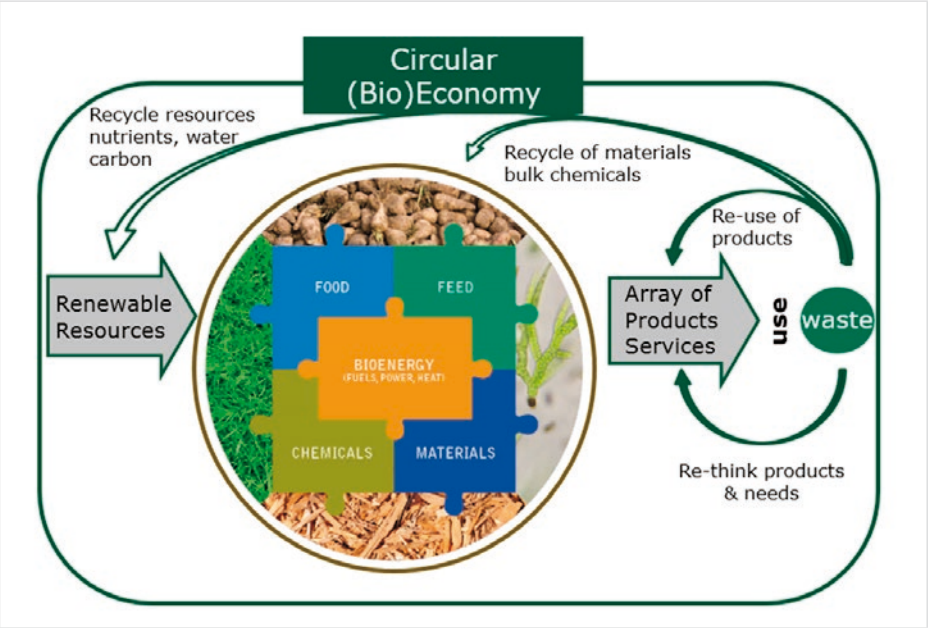


Figure 7. Role bioenergy in Circular (Bio)Economy [IEA Bioenergy Task 42, 2017].

23rd Task 42 Progress Meeting – Vienna, Austria

This Task 42 Progress Meeting, 23-26 October 2017, consisted of both an Austrian Stakeholder Workshop, the Task 42 Progress Meeting and an Excursion. The slides used in this workshop are available for downloading from the Task 42 website; the summarising report is currently being prepared by the Austrian NTL, and will be placed also on the website as soon as available.

Figure 8. Austrian Stakeholder Workshop in progress.

The Task 42 Progress Meeting took place at the site of the Austrian NTL tbw Research GesmbH in Vienna. Austria.

Figure 9. Participants Task 42 Meeting (left to right): Tobias Stern (AT), Bart Bonsall (IR), Henning Jorgensen (DEN), Michael Mandl (AT), Eric Soucy (CAN), René van Ree (NL), Franziska Hesser (AT), Geoff Bell (AUS), Heinz Stichnothe (GER), Borka Kostova (US), Julia Wenger (AT), Bert Annevelink (NL).

For the excursion, the Task 42 representatives visited the running Algae Photo-Bioreactor Demo Plant of ECODUNA-AG.

Figure 10. Visit Task 42 NTLs to Algae Demo Plant ECODUNA-AG.

Planned Meetings/Workshops 2018

- 24th Task 42 Progress Meeting, 5-8 February 2018, Montreal, Canada.
- Thematic Stakeholder Workshop on Role Bioenergy/Biorefining in a Circular Economy, May 2018, Copenhagen, Denmark
- Contribution to Biorefinery Summer School "Zero-waste Biorefineries", Wageningen, the Netherlands, early September 2018
- 25th Task 42 Progress Meeting, 5-9 November 2018, San Francisco, US.

2016-2018 Work Programme & Major Achievements

The work **programme 2016 – 2018** is based on four Activity Areas (AAs) with composing activities, viz.:

AA1) Biorefinery Systems – Analysis and assessment of biorefining in the whole value chain.

- Biorefinery expert system [D1]
- Biorefinery fact sheets [D2]
- Upgrading industrial infrastructures to integrated biorefineries [D3]

AA2) Product Quality – Reporting on related biobased products/bioenergy standardisation, certification and policy activities at national, European and global levels.

- International developments in biomass standardisation/certification [D4]
- Role of Bioenergy and Biorefining in a Circular Economy [D5]
- Sustainable supply chains (JTP) [D6]

AA3) Evolving BioEconomy – Analysing and advising on perspectives of biorefining in a Circular BioEconomy

- Monitoring of the Evolving BioEconomy in co-operation with EC DG JRC [D7]
- Biorefinery Success Stories [D8]

AA4) Communication, Dissemination and Training – Knowledge exchange by stakeholder consultation, reporting and lecturing

- Biorefinery Country Reporting [D9]
- Report Biobased Chemicals [D10]
- Report Proteins for Food/Feed and Industrial Applications [D11]
- Report Biobased Fibrous Materials [D12]
- Task 42 dissemination items (brochure, banner, website) [D13-15]
- Task 42 Progress Meetings [D16]
- Task 42 Newsletters [D17]
- Training Activities [D18]
- Papers/lectures International Events [D19]
- Thematic Stakeholder Workshops (TSWs) [D20]

Biorefinery Systems – Analysis and assessment of biorefining in the whole value chain

The Biorefinery Expert System [D1] is currently being developed by the University of Graz (AT) with the input of all Task 42 NTLs. A full draft version of the system is currently in operation, and will be used in 2017 to deliver some case-study based Biorefinery Fact Sheets [D2]. Both a report describing the system and the factsheets will be put on the Task 42 website for further dissemination in 2018. The Canadian NTL (CanmetENERGY, Natural Resources Canada) has developed a TEE-assessment tool at a national level, that can be used for the assessment of biorefineries in the pulp and paper section (more information: eric.soucy@canada.ca). Concerning upgrading of industrial infrastructures to integrated biorefineries [D3], due to time and budget constraints, in this triennium the activity will be limited to the Gothenburg workshop co-organised with IEA IETS. This subject will be further picked-up in the 2019 – 2021 work programme, probably in close collaboration with IEA IETS.

Product Quality – Reporting on related biobased products/bioenergy standardisation, certification and policy activities at national, European and global levels

The international developments in biomass standardisation and certification are monitored in this triennium by our German NTL. The results are reported in slide-decks that are made available at the Task 42 website. During 2018 the information in the slide-decks of 2016-2018 will be assessed and reported in a short summarising report.

Concerning the assessment of the role of bioenergy and biorefining in a Circular Economy [D5] the workshop in Brussels in September 2017 was organised, where representatives of IEA Bioenergy, FAO, OECD, EERA Bioenergy, ETIP Bioenergy, IRENA, JRC, and DOE were invited to present their views and activities in this field (slides see Task 42 website). A further event is expected to be organised linked to EUBCE2018 in Copenhagen (Denmark) to further inform each other on running activities, and to identify activities to be performed together.

Further, Task 42 (German NTL) participates as an observer in the Joint Tasks Project on Sustainable Supply Chains [D6], bringing in biobased products related data, wherever needed.

Evolving BioEconomy – Analysing and advising on perspectives of biorefining in a Circular BioEconomy

Together with EC DG JRC and the EU BBI JTU, our Italian NTL (ENEA) has set-up and distributed a questionnaire to monitor the evolving BioEconomy worldwide. Reactions are currently being assessed by these parties. Based on the replies, ENEA will analyse the current deployment of biorefineries within this frame work, and will come-up with a summarising report [D7], that will be made available at the Task 42 website, in the 1st half of 2018.

No activities dealing with Biorefinery Success Stories [D8] took place in 2017.

Communication, Dissemination and Training – Knowledge exchange by stakeholder consultation, reporting and lecturing

Updated extensive Country Reports [D9] were produced by Australia, Germany and the US, and are available for downloading from the Task 42 website. The others will come-up with updated ones in 2018.

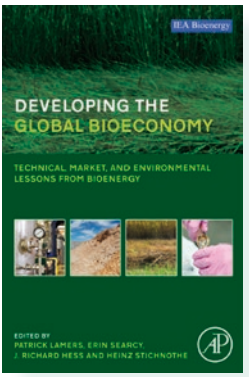
Concerning Task 42 Reports, the report on Proteins for Food/Feed and Industrial Applications [D11] was delivered in 2016, the report on Biobased Fibrous Materials [D12] is ready in draft and will be made available in March 2018, and the report on Biobased Chemicals [D10] (update) will be prepared and published in 2018.

Other Task-related information (brochures, leaflets, newsletters, papers etc.) are available at the Task 42 website: www.task42.ieabioenergy.com.

Collaboration with Other Tasks/Networking

Within this 2016-2018 triennium the following collaborations were foreseen:

- Biorefinery expert system development: EC DG JRC; no cooperation yet
- Biorefinery factsheets: T34 (liquefaction), Task 37 (biogas), Task 39 (biofuels), ongoing
- Role of Bioenergy in Circular Economy: Task 36 (solid waste management); EERA Bioenergy, ETIP Bioenergy etc., ongoing
- BioEconomy Monitoring: FAO, OECD, EC DG JRC, ongoing
- Sustainable supply chains: Task 40 coordinated JTP, ongoing
- Biorefinery Success Stories: Task 40 coordinated JTP, no cooperation yet
- Biorefinery Country Reporting: IEA Bioenergy/Energy 2020+, ongoing
- Thematic Stakeholder Workshops: Industrial Biorefineries (IEA-IETS), finalised



Earlier this triennium, a joint analysis brought together expertise from three IEA Bioenergy Tasks, namely Task 34 on Pyrolysis, Task 40 on International Trade and Markets, and Task 42 on Biorefineries. The underlying hypothesis of the work was that BioEconomy Market Developments potentially can benefit from lessons learned and developments observed in modern bioenergy markets. The question was not only how the BioEconomy can be developed, but also how it can be developed sustainably in terms of economic and environmental concerns. The results of this analysis resulted in the book "Developing the Global BioEconomy". Both the conclusions and book ordering details can be found at the IEA Task 42 website.

TASK 43: Biomass Feedstocks for Energy Markets

Overview of the Task

The work of the Task in the current triennium addresses issues critical to mobilising sustainable bioenergy supply chains, including all aspects of feedstock production, its markets and environmental, social and economic impacts. The objective is to promote sound bioenergy development that is driven by well-informed decisions by land owners, businesses, governments and others. This is achieved by collecting, analysing, and sharing technical and non-technical information related to biomass feedstock supply and providing relevant actors with timely and topical analyses, syntheses and information.

The Task has a global scope and includes commercial, near-commercial and promising feedstock production systems in agriculture and forestry. The primary focus is on land use and land management of biomass production systems. The Task work builds upon the work of the previous triennium and seeks new opportunities for collaboration with other Tasks as well as organisations outside IEA Bioenergy. The Task also interacts with other research networks and programmes that have workplans in the same areas.

Participating countries (as in Dec 2017): Australia, Belgium, Canada, Croatia, Denmark, European Commission, Finland, Germany, Ireland, the Netherlands, Norway, Sweden, and the USA

Task Leader: Associate Professor Ioannis Dimitriou, Swedish University of Agricultural Sciences, Sweden

Work Package leaders: Göran Berndes, Chalmers University of Technology; Mark Brown, University of the Sunshine Coast; Hans Langeveld, Bioenergy Research; Tat Smith, University of Toronto

Task Secretary: Assistant Professor Sally Krigstin, University of Toronto, Canada

Operating Agent: Dr Åsa Forsum, Swedish Energy Agency, Sweden

The Task leader, together with the Work Package (WP) leaders, manages the work of the Task. A Steering Committee (SC), consisting of the Task Leader, WP leaders and the National Team Leaders (NTLs), is responsible for reviewing progress and making overall priorities. Each NTL forms a national team of experts that support the NTL in making national contributions to the collaboration. Other associated experts are also involved.

For further details on Task 43, please refer to Appendices 2, 4, 5 and 6; the Task website http://task43.ieabioenergy.com/ and the IEA Bioenergy website www.ieabioenergy.com.

Task Meetings and Workshops

A number of business/planning meetings and workshops were held in 2017.

i) Joint seminar between IEA Bioenergy Task 43 with Grebe project (Interreg-EU), Joensuu, Finland. The title was "From resource to sustainable business", more information at: https://www.lyyti.fi/p/resource_to_sustainable. A Task 43 business meeting attached to these activities occurred as well as a policy workshop and an excursion (February 2017)

ii) Conference call on planning activities related to LULUCF accounting and forest reference levels, participants from Denmark, Finland, Sweden and the US (February 2017)

iii) Webinar "Mobilizing Sustainable Bioenergy Supply Chains", Ontario Ministry of Agriculture, Food and Rural Affairs (March 217)

iv) Workshop "Sustainability of bioenergy supply chains". Presentation and discussion of interim results of the IEA Bioenergy inter-task project on Measuring, governing and gaining support for sustainable bioenergy supply chains, Gothenburg Sweden (May 2017)

v) Project work meeting Inter-Task project: Measuring, governing and gaining support for sustainable bioenergy supply chains, Gothenburg Sweden. Progress meeting of 01, 02 and 03 of the intertask. Summary available upon request from the coordinator (May 2017)

vi) Workshop: European Biomass Conference and Exhibition, Stockholm, Sweden. Side event: The Nordic Forest Model – A Sustainable Way to Take the Lead Towards a Fossil Free Europe. Side event at EUBCE, presentations available at Task 43 website (June 2017)

vii) Workshop Bioenergy, water and SDG implementation: Experiences and linkages (GBEP-IEA Bioenergy workshop at World Water Week – Stockholm, Sweden). Examples where bioenergy feedstock systems promote SDG goals (August 2017)

viii) Webinar "Bioenergy, water and SDG implementation: Experiences and linkages". Follow-up of the successful workshop at the World Water Week (October 2017)

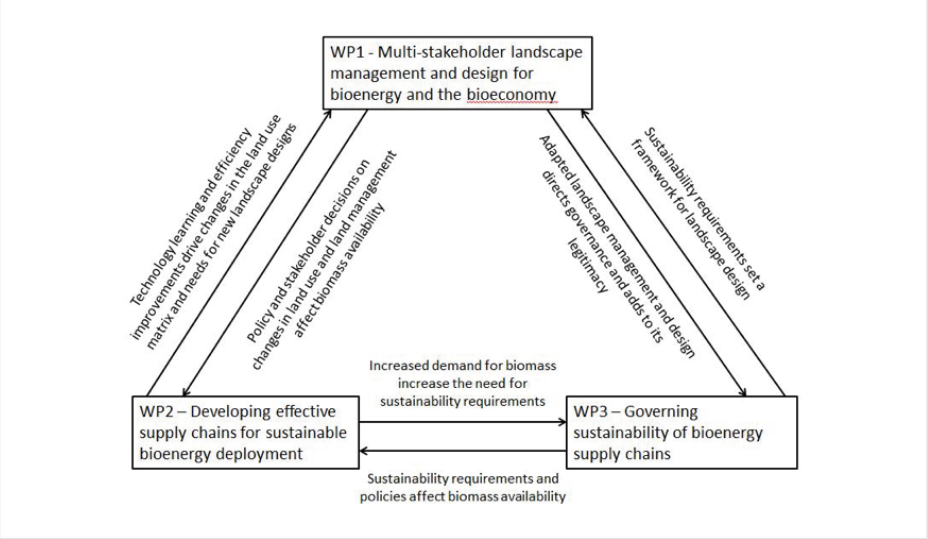
ix) Workshop "Attractive Systems for Bioenergy Feedstock Production in Sustainably Managed Landscapes" 20th November 2017. Sydney Australia, November 2017, http://task43.ieabioenergy.com/publications/5090/

Work Programme

The objective of the Task work is to promote sound bioenergy development that is driven by well-informed decisions by land owners, businesses, governments and others. This will be achieved by collecting, analysing, and sharing technical and non-technical information related to biomass feedstock supply and providing relevant actors with timely and topical analyses, syntheses and information. The work of the Task addresses issues critical to mobilising sustainable bioenergy supply chains, including all aspects of feedstock production, its markets and environmental, social and economic impacts.

Studies integrating several disciplines are conducted to analyse trade-offs, compatibility and synergies between food, fibre and energy production systems and the bio-economy. The Work Programme is organised in three WPs that are each organised in a set of Task Activities. Research priorities include Landscape management and design for bioenergy and the bio-economy (WP1); Developing effective supply chains for sustainable bioenergy deployment (WP2); Governance sustainability of bioenergy supply chains (WP3). The Task also participates in three strategic inter-Task projects run in the 2016-2018 triennium: i) Measuring, governing and gaining support for sustainable bioenergy supply chains; ii) Fuel pretreatment of biomass residues in the supply chain for thermal conversion; iii) Bioenergy Success Stories.

The three WPs represent the main elements to achieve the general Task objectives. Specific focus areas and associated work and activities have been outlined within each WP. Topics addressed are critical for deployment of sustainable biomass supply chains and many are relevant for more than one WP as exemplified in the following figure:



WP1 aims at supporting landscape management and design for bioenergy and the bio-economy, by expanding the knowledge base required for sustainable expansion of biomass production systems that also contribute positively to biodiversity and the generation of other ecosystem services. The work takes a landscape level approach to deployment of biomass production for bioenergy and integration of this objective with ownership and societal objectives for existing land use and associated systems. The WP activities address the below overarching questions, which are relevant for both agricultural and forestry systems and reflect that agriculture and forestry activities often co-exist and shape the landscape together.

Which are the most suitable areas for production and/or extraction of various biomass feedstocks? How can biomass feedstock production systems be located, designed and managed to increase resource use efficiency, avoid/mitigate negative and promote positive environmental, economic, and social effects? How can outcomes be optimised to meet the goals of individual stakeholders and society as a whole, including environmental, economic, and social goals? How can analysis and assessment inform participatory processes engaging land owners, policy makers, and other stakeholders in further developing and re-defining goals and plans for landscape management and designs?

A number of feedstock systems and landscapes are analysed and compared with each other and with relevant reference systems, e.g., cultivation of conventional food/feed crops and forest management to produce saw timber and pulpwood. The feedstock alternatives, their location in the landscape, and the needed management systems vary in how they perform relative to different stakeholder objectives (e.g., biomass yields, economy, nutrient use efficiency, energy efficiency, water quality, soil quality, biodiversity and GHG balances). Comparison with stakeholders' preferences, existing guidelines and regulations will help clarify benefits and trade-offs related to choices and alternatives.

The aim of WP2 is to identify opportunities, strategies and practices for improved supply chains and supply chain technology to support large-scale bioenergy deployment. WP2 synthesises and advances state-of-the-art knowledge on biomass supply chains to increase understanding, development and deployment of effective, efficient and sustainable biomass production, harvest, and delivery options. The roles of technologies and of logistics and other management aspects are analysed in varying regulatory and policy contexts. Particular attention is given to integration and interaction between biomass supply chains and the operating and regulatory environment in which they are set, and how that impacts the efficient, sustainable production and use of the biomass resource. The WP is organised around four main activities: Biomass resource assessment and system mapping; technology learning and systems mapping; integration of natural resources and energy systems; and integration of biomass supply chains with existing forest and agricultural supply chains.

The aim of WP3 is to identify how public or private regulatory systems governing the sustainability of land use and bioenergy supply chains can be improved in terms of abilities to monitor, assess and promote the achievement of economic, social, and environmental goals while

considering the perspectives of land owners, biomass users, and the society as a whole. WP3 examines the interactions among sustainability governance, bioenergy supply chain deployment and climate change. WP3 uses field research, modelling, reviews, syntheses of scientific knowledge, assessments of existing and emerging governance systems, and surveys to determine the views and experiences of different stakeholder groups with sustainability governance. The work intends to inform development of governance from local to international levels, and focuses on the following activities: Improving legitimacy, including effectiveness and efficiency, of governance developed to address sustainability of biomass and bioenergy at different scales; advancing governance mechanisms and science-based assessment of GHG balances and climate effects of LULUCF activities associated with biomass and bioenergy systems.

The work within the different WPs is interrelated and conducted in close co-operation with the WPs; findings in activities of one WP affect the baselines of other activities and therefore close collaboration is a prerequisite to successfully tackle the great number of open questions that the Task has identified and aims to answer.

Website

The Task website (http://task43.ieabioenergy.com/) has been updated in line with changes of the IEA Bioenergy website. Extensive information concerning the Task 43 work is available and updated constantly.

Collaboration with Other Tasks/Networking

As mentioned above, Task 43 is involved in three Inter-task projects: i) Measuring, governing and gaining support for sustainable bioenergy supply chains (Leader: Martin Junginger, Task 40), Bioenergy success stories (Leader: Uwe Fritsche, Task 40); Fuel pretreatment of biomass residues in the supply chain for thermal conversion (Leader: Jaap Koppejan, Task 32). Concerning the inter-Task project "Measuring ..." Göran Berndes (Task 43) and Annette Cowie (Task 38) coordinate the work of Objective 1 while Tat Smith and Inge Stupak (both Task 43) coordinate the work of Objective 2. Several Task 43 members (including Biljana Kulisic and Ioannis Dimitriou) are involved in the work of Objective 3. In the "Pretreatment" intertask, there will be involvement of Task 43 collaborators in two sub-case studies: Wolter Elbersen in ag-residues leaching and potential, and Antti Asikainen and Évelyne Thiffault in forest residues.

There has been extensive collaboration with GBEP-AG6 on Bioenergy and Water and Task 43; one workshop and one webinar in collaboration with GBEP-AG6 have taken place in 2017 and further activities in 2018 are planned. Göran Berndes (WP1 leader) serves as chair of AG6 and several other Task 43 members are also engaged in AG6.

The collaboration of Task 43 with FAO is developing in several levels: the Bioenergy and Food Security (BEFS RA) division at FAO has been invited and participated in

our workshops aiming at closer collaboration e.g. on sustainability assessment issues, and discussions in order to co-organise a workshop with FAO in the third or fourth quarter of 2018 have been taken place during 2017 (with Olivier Dubois).

Task 43 has been collaborating with several networks worldwide who are engaged in the same topics and has co-organised several events in 2017 (see list above) which resulted in several publications (see list below). Collaboration with the Biofuelnet Canada community has occurred during the workshop with Grebe, and the ambition is to continue with this co-operation in the future. The same is valid for Task 43's co-operation with USDA-FS, Oak Ridge National Laboratory and other National Labs and their collaborating organisations, with several common activities planned in the coming years that address topics that are central for Task 43 and collaboration plans are discussed. An example is Task 43's collaboration with the Woody Crops network and the co-organisation of the International Short Rotation Woody Crops Conference 2018. Discussions in 2017 have resulted in the organisation of a joint conference in July 22-26 2018 in Rhinelander, WI, USA between Short Rotation Woody Crops Operations Working Group, the Poplar and Willow Council of Canada, the IUFRO Working Party 2.08.04 (Physiology and Genetics of Poplars and Willows), the IUFRO Working Party 1.03.00 (Short Rotation Forestry), the IEA Task 43 (Biomass Feedstocks for Energy Markets) and the IPC Environmental and Ecosystem Services Working Party (http://www.woodycrops.org/).

Networks such as CAR-ES (CeRntre of Advanced Research on Environmental Services from Nordic Forest Ecosystems), which brings together Nordic and Baltic forest researchers with the aim to provide scientific knowledge on the impacts of forest management, and the SNS "Effects of bioenergy production from forests and agriculture on ecosystem services in Nordic and Baltic landscapes" bring Task 43 researchers (Bentsen, Berndes, Dimitriou, Stupak, and others) with several research and research projects in the area. Discussions in 2017 have resulted in the organisation of a Joint IEA Bioenergy Task 43, SNS-NKJ and CAR-ES conference in governing, documenting and measuring sustainability of bioenergy and biomaterials supply chains from forest and agricultural landscapes which will take place from the 17-19 April 2018 at the University of Copenhagen.

The collaboration between Task 38 and Task 43 members is continuous in terms of common work within reports (example "Forest biomass, carbon neutrality and climate change mitigation" that has been published by the European Forest"), in the intertask projects but also in Task 43 activities such as the iLUC activity involving members of Task 38 (Annette Cowie; Miguel Brandao). Additionally, concrete collaboration has been initiated with Task 40 via the Task 43 activity "Exploring novel regional and landscape-based approaches to govern sustainability of bioenergy and biomaterials supply chains" starting in autumn 2017 involving Rocio Diaz-Chavez from Task 40.

APPENDIX 1: TASK PARTICIPATION IN 2017

TASK	AUS	AUT	BEL	BRA	CAN	CRO	DEN	FIN	FRA	GER	IRE	ITL	JAP	KOR	NEL	NZE	NOR	SA	SWE	SWI	UK	USA	EC	Total
32		•	•		•		•			•	•	•	•		⊗		•	•	•	•				**13**
33		•					•			•		•			•		•		•	•		⊗		**9**
34					•			•		•					•	•			•			⊗		**7**
36									•	•		•							⊗					**4**
37	•	•		•			•	•	•	•	⊗			•	•		•		•	•	•			**14**
38	⊗							•	•	•									•			•		**6**
39	•	•		•	⊗		•			•			•	•	•	•		•	•			•	•	**14**
40		•	•				•	•		•		•			⊗				•		•	•		**10**
42	•	•			•		•			•	•	•			⊗							•		**9**
43	•		•		•	•	•	•		•	•				•		•		⊗			•	•	**13**
Total	**5**	**6**	**3**	**2**	**5**	**1**	**7**	**5**	**3**	**10**	**4**	**5**	**2**	**2**	**8**	**2**	**4**	**2**	**9**	**3**	**2**	**7**	**2**	**99**

⊗ = Operating Agents • = Participant

APPENDIX 2: BUDGET IN 2017 – SUMMARY TABLES

Budget for 2017 by Member Country (US$)

Contracting Party	ExCo funds	Task funds	Total
Australia	11,700	77,500	89,200
Austria	12,700	91,500	104,200
Belgium	9,700	45,000	54,700
Brazil	8,700	29,000	37,700
Canada	11,700	80,500	92,200
Croatia	7,700	15,000	22,700
Denmark	13,700	106,500	120,200
Finland	11,700	78,000	89,700
France	9,700	45,400	55,100
Germany	16,700	155,900	172,600
Ireland	10,700	61,500	72,200
Italy	11,700	77,900	89,600
Japan	8,700	30,000	38,700
Korea	8,700	29,000	37,700
Netherlands	14,700	124,500	139,200
New Zealand	8,700	33,000	41,700
Norway	10,700	59,000	69,700
South Africa	8,700	30,000	38,700
Sweden	15,700	138,400	154,100
Switzerland	9,700	44,000	53,700
UK	8,700	29,000	37,700
USA	13,700	111,500	125,200
European Commission	8,700	30,000	38,700
Total	**253,100**	**1,522,100**	**1,775,200**

BUDGET IN 2017 – SUMMARY TABLES

Budget for 2017 by Task (US$)

Task	Number of participants	Annual contribution per participant	Total Task funds
Task 32: Biomass Combustion and Co-firing	13	15,000	195,000
Task 33: Gasification of Biomass and Waste	9	15,000	135,000
Task 34: Direct Thermochemical Liquefaction	7	18,000	126,000
Task 36: Integrating Energy Recovery into Solid Waste Management Systems	4	15,400	61,600
Task 37: Energy from Biogas	14	14,000	196,000
Task 38: Climate Change Effects of Biomass and Bioenergy Systems	6	16,000	96,000
Task 39: Commercialising Conventional and Advanced Liquid Biofuels from Biomass	14	15,000	210,000
Task 40: Sustainable biomass markets and international bioenergy trade to support the biobased economy	10	15,000	150,000
Task 41: Bioenergy Systems Analysis	5	0	0
Task 42: Biorefining in a future BioEconomy	9	17,500	157,500
Task 43: Biomass Feedstocks for Energy Markets	13	15,000	195,000
Total			**1,522,100**

APPENDIX 3: CONTRACTING PARTIES

Bioenergy Australia (Forum) Ltd

The Republic of Austria

The Government of Belgium

The National Department of Energy Development of the Ministry of Mines and Energy (Brazil)

Natural Resources Canada

The Energy Institute "Hrvoje Pozar" (Croatia)

The Ministry of Transport and Energy, Danish Energy Authority

Commission of the European Union

Tekes, Finnish Funding Agency for Technology and Innovation

L'Agence de l'Environnement et de la Maîtrise de l'Énergie (ADEME) (France)

Federal Ministry of Food and Agriculture (Germany)

The Sustainable Energy Authority of Ireland (SEAI)

Gestore dei Servizi Energetici – GSE (Italy)

The New Energy and Industrial Technology Development Organization (NEDO) (Japan)

Ministry of Knowledge Economy, the Republic of Korea

NL Enterprise Agency (The Netherlands)

The New Zealand Forest Research Institute Limited

The Research Council of Norway

South African National Energy Development Institute (SANEDI)

Swedish Energy Agency

Swiss Federal Office of Energy

Department of Business, Energy and Industrial Styrategy (United Kingdom)

The United States Department of Energy

APPENDIX 4: REPORTS FROM THE TASKS

The Executive Committee

Final Minutes of the ExCo79 meeting, Gothenburg, Sweden, May 2017.

Final Minutes of the ExCo80 meeting, Baden, Switzerland, October 2017.

IEA Bioenergy News February 2017

IEA Bioenergy News Volume 29(1), June 2017

IEA Bioenergy News September 2017

IEA Bioenergy News Volume 29(2), December 2017

IEA Bioenergy Update. Number 60. In press.

IEA Bioenergy Update. Number 61. In press.

IEA Bioenergy Update. Number 62. In press.

Anon. Bioenergy for Sustainable Development, January 2017. Paper produced jointly between IEA Bioenergy, FAO and IRENA.

Anon. IEA Work Programme 2016-2018. IEA Bioenergy ExCo:2017:01.

Anon. IEA Bioenergy Annual Report 2016. IEA Bioenergy ExCo:2017:03.

Anon. Drop-in biofuels for international marine and aviation markets. Summary and Conclusions from the IEA Bioenergy ExCo78 Workshop. IEA. Bioenergy ExCo:2017:04

Anon. The role of industrial biorefineries in a low-carbon economy. Summary and Conclusions from the IEA Bioenergy ExCo79 Workshop. IEA. Bioenergy ExCo:2017:07

Anon. Sustainability of Bioenergy Supply Chains Workshop. Summary from an inter-Task workshop 18-19 May 2017, Gothenburg, Sweden. IEA. Bioenergy ExCo:2017:08

All publications listed are available on the IEA Bioenergy website: www.ieabioenergy.com

TASK 32

Minutes of the Task meeting in Stockholm, Sweden, June 2017.

Minutes of the Task meeting in Ottawa, Canada, September 2017.

Thomas Nussbaumer, Needs to reduce particle emissions from biomass combustion – Conclusions from the IEA Bioenergy Task 32 session at 20th ETH Conference on Combustion Generated Nanoparticles in Zurich, Switzerland, ISBN 3-908705-32-0, IEA Bioenergy Task 32, 14 June 2016

Progress report for ExCo79, Göteborg, May 2017

Progress report for ExCo80, Baden, Nov 2017

Koppejan, J. Report from the Workshop 'Practical test methods for small scale furnaces, 19 Jan 2017

- **M. Wöhler, S. Pelz,** HFR Rottenburg, Germany, The Firewood Method
- **Hans Hartmann**, TFZ Straubing, Germany, The Pellet Method
- **Gabriel Reichert**, Bioenergy 2020+ GmbH, Austria, Scientific highlights of BeReal
- **Christoph Schmidl**, Bioenergy 2020+ GmbH, Austria, Labelling concept
- **Lisa Rector**, NESCAUM, United States of America, Current developments of US testing protocols
- **Michael Sattler**, Ökozentrum Langenbruck, Switzerland, The EN-PME method
- **Elisa Carlon and Markus Schwarz**, Bioenergy 2020+ GmbH, Austria, Load cycle test for biomass boilers
- **Lukas Sulzbacher**, Josephinum Research, Austria, Emissions of small-scale pellet boilers

Pellet production and utilisation in the utility and domestic market, 18 Sept 2017

- **William Strauss**, FutureMetrics – How wood pellets can be part of Canada's decarbonization strategy
- **Sandy Fleming**, Capital Power – Economic and policy conditions to incent Canadian biomass conversions
- **Fioana Matthews**, Hawkins Right – The global outlook for wood pellet markets
- **Hugues Imbeault-Tétreault**, CIRAIG, GHG accounting frameworks for the analysis of the climate mitigation potential from wood biomass in Canada
- **Carsten Hulus**, SBP, Demonstrating sustainability through certification
- **Preben Messerschmidt**, Ramboll, Conversion from coal to wood pellets

Yves Ryckmans, Tractebel, Experience with biomass firing for large scale power

Rob Mager, Ontario Power Generation, OPG's biomass journey

Jamie Stephen, Torchlight Bioresources, Biomass Power Generation Support – Policy Options for Canada and its Provinces

Butt Phillips, WorkSafeBC, WorksafeBC – A different approach to compliance

Scott Bax, Pinnacle Renewable Energy Inc., A paradigm shift in safety – Pinnacle's owning safety journey

John Ackerly, Alliance for Green Heat, Heating North American homes with wood pellets

Seth Walker, FutureMetrics, Review of North American pellet heating markets

Please visit the Task website: task32.ieabioenergy.com

TASK 33

Please visit the Task website: http://task33.ieabioenergy.com/

TASK 34

Please visit the Task website: http://task34.ieabioenergy.com/

TASK 36

- Minutes of the Task meeting in Paris, France, Jan 2017.
- Presentations/proceedings from the Workshop on circular economy in Paris, France Jan 2017.
- Progress report for ExCo79, Gothenburg, May 2017
- Annual report Task 36
- Minutes of the Task meeting in Stockholm, Sweden June 2017.
- Progress report for ExCo80, Basel, Oct 2017.
- Proceedings of workshop on Alternative thermal treatment methods for feedstock recycling, Karlsruhe, Dec 2017
- Minutes of the Task meeting in Karlsruhe, Dec 2017.

Please visit the Task website: http://task36.ieabioenergy.com/

TASK 37

- Methane Emissions Report December 2017
- Two page summary Methane Emissions Report December 2017
- Three case studies:
  - DEN EELDER FARM: Small farm scale mono-digestion of dairy slurry, March 2017
  - GREEN GAS HUB: Provision of biogas by farmers by pipe to a Green Gas Hub with a centralised upgrading process, April 2017
  - BIOMETHANE DEMONSTRATION: Innovation in urban waste treatment and in biomethane vehicle fuel production in Brazil, November 2017

- IEA Task 37 Country Report Summaries 2016
- Upgrading plant list 2016
- Minutes from the Task meeting in Vlijmen, The Netherlands, April 2017;
- Minutes from the Task meeting in Esbjerg, Denmark, September 2017
- Progress report for ExCo79, Gotenberg, Sweden, May 2017
- Progress report for ExCo80, Baden, Switzerland, October 2017
- Presentations from *Grid injection of and innovations in biomethane Workshop* Vlijmen, The Netherlands, April 6th 2017 http://www.iea-biogas.net/workshops.html
  - Jerry Murphy (Task 37 leader)
  - Jörg Gigler (manager of the topsector Gas)
  - Gerard van Pijkeren (Chairman of New Energy Group of Gasunie)
  - Pieter Mans (Alliander and Chairman Expert Group New Gases of the Gridoperators)
  - Jan Liebetrau (DBFZ, and German representative Task 37)
  - Niels den Heijer (Pentair Process Technologies)
  - Boris Colsen (manager Colsen bv)

- Presentations from *Biogas Externalities Workhop,* Esbjerg, Denmark, September 14th 2017 http://www.iea-biogas.net/workshops.html
  - Jerry D Murphy, Task Leader – IEA Task 37: IEA Bioenergy Task 37: Goals and work programme
  - Kurt Hjort Gregersen, AGROTECH, Denmark: Biogas from corporate economy to socio-economy: Externalities not included

- Henning P. Jørgensen, SDU Esbjerg, Denmark: Local societies and the potential economic impacts of investments in biogas plants
- Karetta Timonen, LUKE Finland: Village level green economy indicators in Lapland
- Jakob Lorenzen, DFFB, Denmark: Danish Biogas Centre: Role, objectives and activities within the Danish biogas sector

- Newsletters: 11 issues in 2017

Please visit the Task website: http://www.task37.ieabioenergy.com

TASK 38

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TASK 39

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Please visit the Task website: http://task39.ieabioenergy.com/

TASK 40

Task documents

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Please visit the Task website: http://task40.ieabioenergy.com/

TASK 41

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Mandl, M.G., 2016. Green Biorefining: Grass for Generating Products and Bioenergy. Presentation at Irish Stakeholder Meeting combined with Task42 Progress Meeting, Dublin, Ireland, 19 April 2016.

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Please visit the Task website www.task42.ieabioenergy.com.

TASK 43

Task 43 Technical Reports

There have been several reports delivered from our Task during 2017. Note that the following list is in chronological order and includes only reports produced within our Task work that were published in 2017. There are several other reports that are at the moment under review process and will be published in our website soon.

i) Report "Mobilization of Agricultural Residues for Bioenergy and Higher Value Bio-Products: Resources, Barriers and Sustainability. IEA Bioenergy Task43 TR2017:01". Available at http://task43.ieabioenergy.com/publications/mobilization-agricultural-residues-bioenergy-higher-value-bio-products-resources-barriers-sustainability-iea-bioenergy-task43-tr201701/

ii) Report "Albedo Effects of Biomass Production: A Review. IEA Bioenergy EXCO:2017:02". Available at: http://task43.ieabioenergy.com/publications/httptask43-ieabioenergy-comwp-contentuploads201709tr2017-02-pdfalbedo-effects-biomass-production-review-iea-bioenergy-exco201702/

iii) Report "Climate Impact Assessment of Forest Bioenergy Affected by Decomposition Modelling-Comparison of the Q and YASSO Models". IEA Bioenergy EXCO:TR2017:05. Available at http://task43.ieabioenergy.com/publications/climate-impact-assessment-forest-bioenergy-affected-decomposition-modelling-comparison-q-yasso-models-iea-bioenergy-excotr201705/

iv) Report "Stump Harvesting – Climate and Environment Impact". IEA Bioenergy TR2017-02. Available at: http://task43.ieabioenergy.com/publications/stump-harvesting-climate-environment-impact-iea-bioenergy-tr2017-02/

v) Survey in Support of Planning of Work in WP1 in the 2017-2018 Period – Results Report TR2017-03. Available at http://task43.ieabioenergy.com/publications/survey-support-planning-work-wp1-2017-2018-period-results-report/

vi) Peer-review paper: Dale, V.H., Kline, K.L., Parish, E.S., Cowie, A., Emory, R., Malmsheimer, R.W., Slade, R., Smith, C.T., Wigley, T.B., Bentsen, N.S., Berndes, G., Bernier, P., Brandão, M., Chum, H., Diaz-Chavez, R., Egnell, G., Gustavsson, L., Schweinle, J., Stupak, I., Trianosky, P., Walter, A., Whittaker, C., Brown, M., Chescheir, G., Dimitriou, I., Donnison, C., Goss Eng, A., Hoyt, K.P., Jenkins, J.C., Johnson, K., Levesque, C.A., Lockhart, V., Negri, M.C., Nettles, J.E., Wellisch, M., 2017. Status and prospects for renewable energy using wood pellets from the southeastern United States. GCB Bioenergy 9(8), 1296–1305.

Please visit the Task website: http://task43.ieabioenergy.com/.

APPENDIX 5: KEY PARTICIPANTS IN EACH TASK

TASK 32 – Biomass Combustion and Co-firing

Operating Agent: Kees Kwant, NL Enterprise Agency, Ministry of Economic Affairs, The Netherlands. For contacts see Appendix 7.

Task Leader: Jaap Koppejan, Procede Biomass BV, the Netherlands. For contacts see Appendix 6.

The Task is organised with 'National Teams' in the participating countries.
The contact person (National Team Leader) in each country is listed below:

Country	National Team Leader	Institution
Austria	Christoph Schmidl	Bioenergy 2020+
Belgium	Pierre-Louis Bombeck	Valbiom
Canada	Sebnem Madrali	Natural Resources Canada
Denmark	Morten Tony Hansen	Ea Energy Analyses
Germany	Hans Hartmann	Technologie- und Forderzentrum
Ireland	William Smith	University College of Dublin
Italy	Roberta Roberto	ENEA Research Center of Saluggia
Japan	Nobuyuki Tahara	New Energy and Industrial Technology Development Organization (NEDO)
The Netherlands	Jaap Koppejan	Procede Biomass BV
	Marcel Cremers	DNV GL
	Kees Kwant	RVO
Norway	Øyvind Skreiberg	SINTEF
South Africa	Yokesh Singh	ESKOM
Sweden	Claes Tullin	SP Technical Research Institute of Sweden
Switzerland	Thomas Nussbaumer	Verenum

TASK 33 – Gasification of Biomass and Waste

Operating Agent: Jim Spaeth, US Department of Energy, USA. For contacts see Appendix 7.

Task Leader: Kevin Whitty, University of Utah, USA. For contacts see Appendix 6.

The Task is organised with national teams in the participating countries.
The contact person (National Team Leader) in each country is listed below.

Country	National Team Leader	Institution
Austria	Jitka Hrbek	Vienna University of Technology
Denmark	Morten Tony Hansen	Ea Energianalyse a/s
Germany	Thomas Kolb	KIT
Italy	Donatella Barisano	ENEA
The Netherlands	Berend Vreugdenhil	ECN
Norway	Judit Sandquist	SINTEF
Sweden	Lars Waldheim	Waldheim Consulting
Switzerland	Martin Rüegsegger	ETECA
USA	Kevin Whitty	University of Utah

TASK 34 – Direct Thermochemical Liquefaction

Operating Agent: Jim Spaeth, US Department of Energy, USA. For contacts see Appendix 7.

Task Leader: Alan Zacher, PNNL, USA. For contacts see Appendix 6.

The Task is organised with 'National Teams Leaders' in the participating countries. The contact person (National Team Leader) in each country is listed below:

Country	National Team Leader	Institution
Canada	Fernando Preto	CanmetENERGY, Natural Resources Canada
Finland	Kristin Onarheim	VTT (Technical Research Centre of Finland Ltd.)
	Anja Oasmaa	VTT (Technical Research Centre of Finland Ltd.)
Germany	Nicolaus Dahmen	Thünen Institute for Wood Research
Netherlands	Bert van de Beld	BTG (Biomass Technology Group)
New Zealand	Ferran de Miguel Mercader	Scion
Sweden	Magnus Marklund	SP ETC (Energy Technology Centre)
USA	Alan Zacher	PNNL (Pacific Northwest National Laboratory)

TASK 36 – Integrating Energy Recovery into Solid Waste Management Systems

Operating Agent: Åsa Forsum, Swedish Energy Agency (SWEA), Sweden. For contacts see Appendix 7.

Task Leader: Inge Johansson, RISE Research Institutes of Sweden, Sweden. For contacts see Appendix 6.

The Task is organised with 'National Teams' in the participating countries. The contact person (National Team Leader) in each country is listed below:

Country	National Team Leader	Team Leader Institution
France	Elisabeth Poncelet	ADEME
Germany	Dieter Stapf	KIT
Italy	Giovanni Ciceri	RSE
Sweden	Inge Johansson	RISE

TASK 37 – Energy from Biogas

Operating Agent: Matthew Clancy, Sustainable Energy Authority of Ireland, Dublin, Ireland. For contacts see Appendix 7.

Task Leader: Prof Jerry D Murphy, MaREI Centre, Environmental Research Institute, University College Cork, Ireland. For contacts see Appendix 6.

The Task is organised with 'National Teams' in the participating countries.
The contact person (National Team Leader) in each country is listed below:

Country	National Team Leader	Institution
Australia	Bernadette McCabe	University of Southern Queensland
Austria	Bernhard Drosg	BOKU University, IFA-Tulln
	Gunther Bochmann	BOKU University, IFA-Tulln
Brazil	Paulo Afonso Schmidt	Itaipu Binacional, Foz do Iguaçu
	Marcelo Alves de Sousa	Itaipu Binacional, Foz do Iguaçu
	Rodrigo Regis de Almeida Galvao	CIBiogas Foz do Iguaçu
Denmark	Teodorita Al Seadi	BIOSANTECH
Finland	Saija Rasi	Natural Resources Institute Finland (Luke)
France	Olivier Théobald	ADEME
	Guillaume Bastide	ADEME
Germany	Jan Liebretrau	DBFZ, Leipzig, Germany
Ireland	Jerry D Murphy	MaREI centre, University College Cork
Korea	Soon Chul Park	Korea Institute of Energy Research
Netherlands	Mathieu Dumont	Netherlands Enterprise Agency
Norway	Tormod Brieid	Norwegian Institute for Bioeconomy Research (NIBIO)
Sweden	Anton Fagerstrom	Energiforsk
Switzerland	Urs Baier	ZHAW Zürcher Hochschule für Angewandte Wissenschaften
United Kingdom	Clare Lukehurst	Probiogas UK
	Charles Banks	University of Southampton

TASK 38 – Climate Change Effects of Biomass and Bioenergy Systems

Operating Agent: Mark Brown, Bioenergy Australia Manager.
For contacts see Appendix 7.

Task Leader: Annette Cowie, NSW Department of Primary Industries, Australia.
For contacts see Appendix 6.

Task Manager: Miguel Brandão, Royal Institute of Technology, Stockholm, Sweden

The Task is organised with 'National Teams' in the participating countries.
The contact person (National Team Leader) in each country is listed below:

Country	National Team Leader	Institution
Australia	Annette Cowie	NSW Department of Primary Industries
Finland	Kati Koponen	VTT Technical Research Centre of Finland
France	Alice Gueudet	Ademe Service Bioressources
	Miriam Buitrago	
Germany	Sebastian Rüter	Thünen Institute of Wood Research
Sweden	Leif Gustavsson	Linnaeus University
USA	Alison Goss Eng	US Department of Energy
	Kristen Johnson	

TASK 39 – Commercialising Conventional and Advanced Liquid Biofuels from Biomass

Operating Agent: Alex McLeod, Natural Resources Canada, Canada.
For contacts see Appendix 7.

Task Leader: Jim McMillan, NREL, USA. For contacts see Appendix 6.

Associate Task Leader: Jack Saddler, University of British Columbia, Canada.

The Task is organised by 'National Teams' from participating countries. The contact person (National Team Leader) and other representatives from each country are listed below:

Country	National Team Leader	Institution
Australia	Steve Rogers	Licella
Austria	Dina Bacovsky	Bioenergy 2020+
Brazil	Antonio Maria Bonomi	CTBE
Canada	Jack Saddler	University of British Columbia
Denmark	Michael Persson	Danish Bioenergy Association
	Claus Felby	University of Copenhagen
	Henning Jørgensen	Technical University of Denmark
European Commission	Luisa Marelli	JRC
	Jacopo Giuntoli	
Germany	Franziska Mueller-Langer	DBFZ
	Nicolaus Dahmen	DBFZ
Japan	Shiro Saka	Kyoto University
	Satoshi Aramaki	NEDO
The Netherlands	Timo Gerlagh	NL Agency
	Johan van Doessum	DSM

New Zealand	Ian Suckling	Scion
South Africa	Emile van Zyl	University of Stellenbosch
South Korea	Jin Suk Lee	Korean Institute of Energy Research
	Kyu Young Kang	Dongguk University
	Seonghan Park	Pusan National University
Sweden	Tomas Ekbom	Swedish Bioenergy Association
USA	Jim McMillan	NREL

TASK 40 – Sustainable biomass markets and international bioenergy trade to support the biobased economy

Operating Agent:	Kees Kwant, NL RVO, the Netherlands.
Task Leader (Scientific):	Martin Junginger, Copernicus Institute of Sustainable Development, Utrecht University, the Netherlands.
Task Leader (Industry):	Peter-Paul Schouwenberg, RWE Generation, the Netherlands.
Task assistant (Secretary):	Thuy Mai-Moulin, Copernicus Institute of Sustainable Development, Utrecht University, the Netherlands.

The Task is organised with 'National Teams' in the participating countries. The contact persons (National Team Leaders) as of December 2017 in each country are listed below:

Country	National Team Leader	Institution
Austria	Lukas Kranzl Michael Wild	Vienna University of Technology Wild und Partner
Belgium	Ruben Guisson	VITO – Flemish Institute for Technological Research
Denmark	Wolfgang Stelte	Danish Technological Institute
	Anders Evald	HOFOR
Finland	Tapio Ranta	Lappeenranta Technical University
	Jussi Heinimö	Miktech
Germany	Uwe Fritsche	IINAS
	Daniela Thrän	Deutsches Biomasse Forschungs Zentrum
Italy	Luca Benedetti	Gestore Servizi Energetici (GSE)
The Netherlands	Martin Junginger	Copernicus Institute, Utrecht University
	Peter-Paul Schouwenberg	RWE Generation
Sweden	Lena Bruce	Sveaskog
UK	Rocio Diaz-Chavez	Imperial College
	Laura Cragg	Drax
USA	Richard Hess	Idaho National Laboratory

TASK 42– Biorefining in a future BioEconomy

Operating Agent: Kees Kwant, NL Enterprise Agency, Ministry of Economic Affairs, The Netherlands. For contacts see Appendix 7.

Task Leader: René van Ree, Wageningen UR – Food and Bio-based Research, The Netherlands. For contacts see Appendix 6.

Assistant Task Leader: Ed de Jong, Avantium Technologies B.V., The Netherlands and Bert Annevelink, Wageningen Food and Bio-based Research, The Netherlands. For contacts see Appendix 6.

Secretariat: Wageningen UR, +31-317481165, secretariaat.bbp@wur.nl

The Task is organised with 'National Teams' in the participating countries.
The contact person (National Team Leader) in each country is listed below:

Country	National Team Leader	Institution
Australia	Geoff Bell	Microbiogen Pty Ltd
Austria	Michael Mandl	tbw research GesmbH
Canada	Eric Soucy	CammetENERGY, Natural Resources Canada
Denmark	Henning Jorgensen	University of Copenhagen
Germany	Heinz Stichnothe	Thunen-Institute of Agricultural Technology
Italy	Isabella de Bari	ENEA C.R.TRISAIA
Ireland	Bart Bonsall	Technology Centre for Biorefining and Bioenergy
Netherlands (coordinator)	René van Ree	Wageningen UR – Food and Biobased Research
	Ed de Jong	Avantium B.V.
	Bert Annevelink	Wageningen UR – Food and Biobased Research
USA	Borislava Kostova	U.S. Department of Energy

TASK 43 – Biomass Feedstocks for Energy Markets

Operating Agent:	Åsa Forsum Swedish Energy Agency (SWEA), Sweden. For contacts see Appendix 7
Task Leader:	Ioannis Dimitriou, Swedish University of Agricultural Sciences, Sweden. For contacts see Appendix 6.
Work Package Leaders:	Göran Berndes (Sweden) Mark Brown (Australia) Hans Langeveld (The Netherlands) Tat Smith (Canada)
National Team Leaders:	Mark Brown (Australia) Livia Spezzani (Belgium) Tat Smith (Canada) Biljana Kulišič (Croatia) Inge Stupak (Denmark) Jean-Francois Dallemand (EC) Antti Asikainen (Finland) Jörg Schweinle (Germany) Ger Devlin (Ireland) Wolter Elbersen (Netherlands) Bruce Talbot (Norway) Gustaf Egnell (Sweden) Toral Patel-Weynand (USA)

APPENDIX 6: OPERATING AGENTS AND TASK LEADERS

Operating Agent Task 32: The Netherlands

(duration 1 January 2016-31 December 2018)

OA: Kees Kwant

TL Jaap Koppejan
Procede Biomass BV
PO Box 328
Enschede. 7500 AH
THE NETHERLANDS

Phone: +31 53 7112 500/502
Fax: +31 53 7112 599
Email: jaapkoppejan@procede.nl

Operating Agent Task 33: USA

(duration 1 January 2016-31 December 2018)

OA: Jim Spaeth

TL Kevin Whitty
The University of Utah
50 S. Central Campus Dr., Room 3290
Joseph F. Merrill Engineering Building
Salt Lake City, UT 84112
USA

Phone: 801-585-9388
Fax: 801-585-9291
Email: kevin.whitty@utah.edu

Reinhard Rauch (Associate Task Leader)
Karlsruher Institut für Technologie
Engler-Bunte-Institut, Bereich Chemische Energieträger – Brennstofftechnologie
Engler-Bunte-Ring 3, Geb. 40.02, R005
D-76131 Karlsruhe
GERMANY

Phone: + 49 721 608 42960
Email: reinhard.rauch@kit.edu

Jitka Hrbek (Task Secretary)
Institute of Chemical Engineering
Vienna University of Technology
Getreidemarkt 9/166
A-1060 Vienna
AUSTRIA

Phone: +43 664 88 537 003
Fax: +43 1 58801 15999
Email: Jitka.hrbek@tuwien.ac.at

Operating Agent Task 34: USA

(duration 1 January 2016-31 December 2018)

OA: Jim Spaeth
TL Alan Zacher
Pacific Northwest National Laboratory
902 Battelle Boulevard
PO Box 999, MSIN P8-60
Richland, Washington 99352
USA
Phone: +1 509 372 4545
Email: Alan.Zacher@pnnl.gov

Operating Agent Task 36: Sweden

(duration 1 January 2016-31 December 2018)

OA: Åsa Forsum
TL Inge Johansson
RISE Research Institutes of Sweden
Box 857, SE-501 15 Borås
SWEDEN
Phone: +46 (0)10 516 58 64
Fax: +46 (0)33 13 19 79
Email: Inge.Johansson@ri.se

Operating Agent Task 37: Ireland

(duration 1 January 2016-31 December 2018)

OA: Matthew Clancy
TL Jerry Murphy
Environmental Research Institute
School of Engineering
University College Cork
Cork
IRELAND
Phone: +353-(0)21 490 2286
Email: Jerry.Murphy@ucc.ie

Operating Agent Task 38: Australia

(duration 1 January 2016-31 December 2018)

OA: Mark Brown
TL Annette Cowie
School of Environmental and Rural Science
NSW Deptartment of Primary Industries
Beef Industry Centre, Trevenna Road
University of New England
ARMIDALE, NSW 2351
AUSTRALIA
Phone: +61 2 6770 1842
Email: annette.cowie@dpi.nsw.gov.au

Operating Agent Task 39: Canada

(duration 1 January 2016-31 December 2018)

OA: Alex MacLeod

TL Jim McMillan
NREL
15013 Denver West Parkway
Golden, CO 80401
USA
Phone: +1 (303) 384-6861
Email: jim.mcmillan@nrel.gov

Jack Saddler (Associate Task Leader)
Professor of Forest Products Biotechnology/ Bioenergy
Faculty of Forestry
University of British Columbia
4th Floor, Forest Sciences Centre
4042 – 2424 Main Mall
Vancouver, B.C. V6T 1Z4
CANADA
Phone: +1 604 822 9741
Email: saddler@ubc.ca

Operating Agent of Task 40: The Netherlands

(duration 1 January 2016-31 December 2018)

OA: Kees Kwant

TL Martin Junginger (Scientific)
Energy & Resources, Faculty of Geosciences,
Copernicus Institute of Sustainable Development,
Van Unnik gebouw
Heidelberglaan 2,
3584 CS Utrecht
THE NETHERLANDS
Phone: +31-30-2537613
Email: h.m.junginger@uu.nl

TL Peter-Paul Schouwenberg (Industry)
Manager Biomass
Nidera Handelscompagnie B.V.
P.O. Box 676
ROTTERDAM 3000 AR
THE NETHERLANDS
Phone: +31 10 430 1911
Fax: +31 10 413 9769
Email: peter-paul.schouwenberg@essent.nl

Thuy Mai-Moulin
Energy & Resources,
Faculty of Geosciences,
Copernicus Institute of Sustainable Development,
Van Unnik gebouw
Heidelberglaan 2 (K906),
3584 CS Utrecht
THE NETHERLANDS

Phone: +31 30 253 7610
Email: T.P.T.Mai-Moulin@uu.nl

Operating Agent Task 42: The Netherlands

(duration 1 January 2016-31 December 2018)

OA: Kees Kwant
TL René van Ree
Theme Leader Bioenergy & Biofuels
Wageningen University and Research Centre (WUR)
Food and Bio-based Research
P.O. Box 17
Wageningen, 6700 AA
THE NETHERLANDS

Phone: +31 317 480 710
Fax: +31 317 475 347
Email: rene.vanree@wur.nl

Ed de Jong (Assistant Task Leader)
Avantium Technologies BV
Zekeringstraat 29
Amsterdam, 1014 BV
The Netherlands

Phone: +31 020 586 80 80
Fax: +31 020 586 80 85
Email: ed.dejong@avantium.com

Operating Agent Task 43: Sweden

(duration 1 January 2016-31 December 2018)

OA: Åsa Forsum
TL Ioannis Dimitriou
Swedish University of Agricultural Sciences
Department of Crop Production Ecology
PO Box 7043, SE-756 51, UPPSALA
SWEDEN

Phone: +46 18 672553
Email: Jannis.Dimitriou@slu.se

APPENDIX 7: EXCO MEMBERS AND ALTERNATES

	Member	Alternate Member
AUSTRALIA	Professor Mark Brown Director of the Forest Industries Research Group Forest Industries Research Group (ML16) Locked Bag 4 University of the Sunshine Coast Maroochydore DC, QLD 4558 Phone: +61 (0) 488 123 155 Fax: +61 7 5456 5544 Email: mbrown2@usc.edu.au	Mrs Shahana McKenzie Chief Executive Officer Bioenergy Australia P.O. Box 127 Civic Square ACT 2608 Phone: +61 0 439 555 764 Email: shahana@bioenergyaustralia.org.au
AUSTRIA	Dr Theodor Zillner Federal Ministry for Transport, Innovation and Technology Radetzkystrasse 2 1030 WIEN Phone: +43 1 711 62 652925 Email: theodor.zillner@bmvit.gv.at	Dr Manfred Wörgetter Bioenergy2020+ GmbH Standort Wieselburg Gewerbepark Haag 3 3250 WIESELBURG Phone: +43 7416 52238 30 Email: manfred.woergetter@bioenergy2020.eu
BELGIUM	Dr Yves Schenkel CRAW Rue de Liroux, 9 Gembloux, B-5030 Phone: +32 81 62 65 56 Fax: +32 81 61 57 47 Email: schenkel@cra.wallonie.be	Mr. Ruben Guisson Project manager biobased economy VITO NV Boeretang 200 MOL, BE-2400 Phone: +32 14 33 58 49 Fax: +32 14 32 11 85 Email: ruben.guisson@vito.be
BRAZIL	Mr Miguel Ivan Lacerda de Oliveira Director, Biofuels Department Ministry of Mines and Energy Esplanada dos Ministérios, Bloco U, 9° Andar 70 065-900 – BRASILIA – DF Phone: +55 61 2032 5509 Fax: +55 61 2032 5626 Email: miguel.oliveira@mme.gov.br	To be announced
CANADA	Dr Alex MacLeod Senior Science & Technology Adviser Office of Energy Research & Development Natural Resources Canada 580 Booth Street, 14th Floor OTTAWA, Ontario K1A 0E4 Phone: +1 613 286 1459 Fax: +1 613 995 6146 Email: alex.macleod@canada.ca	Mr Jeff Karau Project Officer Forest Science Division Natural Resources Canada 580 Booth Street, Ottawa, Ontario K1A 0E4 Phone: +1 613 947 8997 Fax: +1 613 947 9035 Email: jkarau@rncan.gc.ca
CROATIA	Dr Branka Jelavic Head Dept for Renewable Resources Energy Institute 'Hrvoje Pozar' Savska 163 P.B. 141 Zagreb, 10001 Phone: +385 1 632 6117 Fax: +385 1 604 0599 Email: bjelavic@eihp.hr	Mr. Tugomir Majdak State Secretary Ministry of Agriculture Ulica grada Vukovara 78 10000 Zagreb Phone: +385 1 6106 111 Fax: +385 1 6109 200 Email: tugomir.majdak@mps.hr

	Member	Alternate Member
DENMARK	Dr Ane Katharina Paarup Meyer Programme Manager – Energy R&D Danish Energy Agency – Centre for Energy Administration Niels Bohrs Vej 8D 6700 Esbjerg Phone: + 45 33 92 7917 Email: akpm@ens.dk	Mrs Bodil Harder Programme Manager Energy R&D The Danish Energy Agency Ministry of Climate & Energy Amaliegade 44 DK-1256 Copenhagen K Phone: +45 33 92 6797 Email: bha@ens.dk
FINLAND	Dr. Tuula Savola Tekes, Finnish Funding Agency for Technology and Innovation Energy and Environment Industries PO Box 69 Kyllikinportti 2, Lansi-Pasila HELSINKI, FIN-00101 Phone: +358 2950 55667 Email: tuula.savola@tekes.fi	Dr. Antti Arasto VTT TECHNICAL RESEARCH CENTRE OF FINLAND Biologinkuja 5, Espoo P.O. Box 1000 FI-02044 VTT Phone: +358 20 722 4016 Email: antti.arasto@vtt.fi
FRANCE	Mde Emilie Machefaux Cheffe de service adjointe Service Forêt, Alimentation et Bioéconomie 20 avenue du Grésillé – BP 90406 F – 49004 ANGERS Cedex 01 Phone: +33 2 41 20 43 27 Fax: +33 2 41 20 43 02 Email: emilie.machefaux@ademe.fr	Ms Elisabeth Poncelet Direction Economie Circulaire et Déchet, Service Mobilisation et Valorisation des Déchets ADEME 20 avenue du Grésillé – BP 90406 F – 49004 ANGERS Cedex 01 Phone: +33 2 41 20 42 57 Email: elisabeth.poncelet@ademe.fr
GERMANY	Mr Birger Kerckow Fachagentur Nachwachsende Rohstoffe e.V. (FNR) Hofplatz 1 GÜLZOW-PRÜZEN, 18276 Phone: +49 3843 693 0125 Fax: +49 3843 693 0102 Email: B.Kerckow@fnr.de	Dr Volker Niendieker Federal Ministry of Food and Agriculture (BMEL) Wilhelmstraße 54 10117 Berlin Phone: +49 30 18 529-3140 Fax: +49 30 18 529 55-3140 Email: volker.niendieker@bmel.bund.de
IRELAND	Mr Matthew Clancy Programme Manager Bioenergy & CHP Sustainable Energy Authority of Ireland Wilton Park House Wilton Place Dublin 2 Phone: +353 1 808 2152 Fax: +353 1 808 2002 Email: matthew.clancy@seai.ie	Mr Denis Dineen Specialist: Bioenergy Programme Sustainable Energy Authority of Ireland Wilton Park House Wilton Place Dublin 2 Fax: +353 1 808 2002 Email: denis.dineen@seai.ie

	Member	Alternate Member
ITALY	Mr Luca Benedetti Gestore dei Servizi Energetici – GSE S.p.A. Viale Maresciallo Pilsudski, 92 00197 ROME Phone: +39 06 8011 4572 Fax: +39 06 8011 2040 Email: luca.benedetti@gse.it	Mr Vito Pignatelli ENEA Research Centre of Casaccia Via Anguillarese, 301 – 00123 – S.M. di Galeria, ROME Phone: +39 06 3048 4506 Fax: +39 06 3048 6514 Email: vito.pignatelli@casaccia.enea.it
JAPAN	Mr Seiji Morishima Director, New Energy Development Dept. NEDO Muza Kawasaki Central Tower 18F 1310 Ohmiyacho, Saiwai-ku, Kawasaki, Kanagawa 212-8554 Phone: +81 44 520 5271 Fax: +81 44 520 5275 Email: morishimasij@nedo.go.jp	Mr Kenji Itakura Director General, New Energy Technology Department NEDO Muza Kawasaki Central Tower 18F 1310 Ohmiyacho, Saiwai-ku, Kawasaki, KANAGAWA 212-8554 Phone: +81 44 520 5271 Fax: +81 44 520 5275 Email: itakuraknj@nedo.go.jp
Korea	Dr Seungchan CHANG Team Leader. DSM Policy Division Korea Energy Agency (KEA) 388, Poeundaero, Suji-gu, Yongin-si Gyeonggi-do 16842 Phone: +82 31 260-4191 Email: schang@energy.or.kr	Professor Don-Hee Park Chonnam National University Rm5B-216 77-Yongbongro Gwangju 500-757 Phone: +82-62-530-1841 Email: parkdon55@hanmail.net
NETHERLANDS	Ir Kees Kwant Ministry of Economy, Agriculture and Innovation NL Agency Division: NL Energy and Climate Change PO Box 8242, UTRECHT, 3503 RE Phone: +31 88 602 2458 Email: kees.kwant@agentschapnl.nl	Mr Patrick Todd Directie Energie en Duurzaamheid Directoraat-Generaal Energie, Telecom en Mededinging Ministerie van Economische Zaken Postbus 20401 Den Haag, 2500 EK Phone: + 31 6 460 66053 Email: p.g.todd@minez.nl
NEW ZEALAND	Dr Paul Bennett Scion Private Bag 3020 Rotorua Phone: +64 7 343 5601 Fax: +64 7 348 0952 Email: paul.bennett@scionresearch.com	Dr Elspeth MacRae Scion Private Bag 3020 Rotorua Phone: +64 7 343 5824 Fax: +64 7 343 5528 Email: elspeth.macrae@scionresearch.com
NORWAY	Mr Trond Vaernes The Research Council of Norway Department for Energy Research Postboks 564 1327 Lysaker Phone: +47 22 03 70 00 Email: trv@rcn.no	Mr Øyvind Leistad Enova SF Professor Brochsgt Gate 2 7030 Trondheim Phone: + 47 73 19 04 61 Fax: + 47 99 51 80 08 Email: oyvind.leistad@enova.no

	Member	Alternate Member
SOUTH AFRICA	Dr Thembakazi Mali SANEDI (Pty) Ltd Senior Manager: Clean Energy Solutions PO Box 786141 Sandton, 2146 Johannesburg Phone: +27 010 201 4782 Fax: +27 010 201 4932 Email: thembakazim@saneri.org.za	To be announced
SWEDEN	Dr Åsa Forsum Swedish Energy Agency P.O. Box 310 Eskilstuna, SE-631 04 Phone: +46 16 544 2255 Fax: + 46 16 544 2261 Email: asa.forsum@energimyndigheten.se	Dr Göran Berndes Department of Energy and Environment, Physical Resource Theory Chalmers University of Technology Göteborg, SE-412 96 SWEDEN Phone: +46 31 772 3148 Fax: +46 31 772 3150 Email: goran.berndes@chalmers.se
SWITZERLAND	Dr Sandra Hermle Swiss Federal Office of Energy (SFOE) Energy Research, Biomass and Combustion Bern, CH – 3003 Phone: +41 31 325 8922 Fax: +41 31 323 2500 Email: sandra.hermle@bfe.admin.ch	Dr Matthieu Buchs Renewable energy specialist, Biomass Federal Department of the Environment Transport, Energy and Communications Swiss Federal Office of Energy SFOE Mühlestrasse 4, 3063 Ittigen, postal address: 3003 Bern Tel: +41 58 462 56 40 Fax: +41 58 462 25 00 Email: matthieu.buchs@bfe.admin.ch
UNITED KINGDOM	Mr Peter Coleman Head of Bioenergy & Land Use Science Department for Business, Energy & Industrial Strategy Science & Innovation for Energy & Climate Directorate 1 Victoria Street London, SW1H 0ET Phone: +44 (0)300 068 8270 Email: peter.coleman@beis.gov.uk	To be announced

	Member	Alternate Member
USA	Mr Jim Spaeth Bioenergy Technologies Office Advanced Development & Optimizationation, Program Manager Energy Efficiency and Renewable Energy U.S. Department of Energy 15013 Denver West Parkway Golden, CO 80401 Phone: +1 720 356 1784 Email: jim.spaeth@ee.doe.gov	Ms Corinne Drennan Pacific Northwest National Lab 902 Battelle Blvd P.O. Box 999, MSIN: K2-44 Richland, WA 99352 Email: corinne.drennan@pnnl.gov
EUROPEAN COMMISSION	Dr Kyriakos Maniatis DG Energy and Transport European Commission Rue de la Loi/Wetstraat 200 BRUSSELS, B-1049 BELGIUM Phone: +32 2 299 0293 Fax: +32 2 296 6261 Email: Kyriakos.Maniatis@ec.europa.eu	Ms Luisa Marelli European Commission-Joint Research Centre Directorate for Energy, Transport and Climate Sustainable Transport Unit – TP230 Via E. Fermi, 2749 I-21027 Ispra (VA) ITALY Phone: + 39 332 786332 Fax: + 39 332 785869 Email: luisa.marelli@ec.europa.eu

APPENDIX 8: SOME USEFUL ADDRESSES

ExCo Chairman 2017

Ir Kees Kwant
Senior Expert Bioenergy and Biobased Economy
Netherlands Enterprise Agency
Ministry of Economic Affairs
PO Box 8242,
UTRECHT, 3503 RE
NETHERLANDS

Phone: +31 88 602 2458
Email: kees.kwant@rvo.nl

ExCo Vice Chairman 2017

Mr Jim Spaeth
Bioenergy Technologies Office
Advanced Development & Optimizationation,
Program Manager
Energy Efficiency and Renewable Energy
U.S. Department of Energy
15013 Denver West Parkway
Golden, CO 804013
USA

Phone: +1 720 356 1784
Email: jim.spaeth@ee.doe.gov

IEA Liaison

Mr Hideki Kamitatara
Renewable Energy Division
International Energy Agency
9 Rue de la Fédération
75739 Paris Cedex 15
FRANCE

Phone: +33 1 40 57 65 62
Email: Hideki.KAMITATARA@iea.org

Contact details for the Secretary and Technical Coordinator are provided on the back cover of this report.

IEA Bioenergy

IEA BIOENERGY SECRETARIAT

Website:
www.ieabioenergy.com

Secretary:
Pearse Buckley
ODB Technologies Ltd
P.O. Box 12249
Dublin 9
IRELAND
Phone: +353 87 737 3652
Email: pbuckley@odbtbioenergy.com

Technical Coordinator:
Luc Pelkmans
CAPREA Sustainable Solutions
Tortelstraat 50
MOL, BE-2400
BELGIUM
Phone: +32 492 97 79 30
Email: luc.pelkmans@caprea.be

iea Energy Technology Network